

## LANDMARK DESCRIPTIONS

### Skull

**Landmark LM1. Jugal bar, caudalmost point** Caudalmost point of the jugal bar at its articulation with the quadrate (Fig. S1). This landmark marks the start of a series of semilandmarks along the ventrolateral margin of the jugal bar (SL1, below).

**Landmark LM2. Jugal bar, rostralmost point** Rostralmost point of the jugal bar at its articulation with the maxilla (Fig. S1). This landmark marks the end of a series of semilandmarks along the ventrolateral margin of the jugal bar (SL1, below).

**Landmark LM3. Maxilla, caudoventral point** The caudalmost point of the ventral (tomial) margin of the maxilla (Fig. S1). In most specimens, this landmark has approximately the same position as the ‘jugal bar, rostralmost point’ landmark (LM2), but in some species it is located further caudoventrally. This landmark marks the start of a series of semilandmarks along the ventrolateral (tomial) margin of the rostrum (SL2, below).

**Landmark LM4. Premaxilla, rostral tip** Rostralmost point on the tip of the premaxilla (Fig. S1). This landmark marks the end of a series of semilandmarks along the ventrolateral (tomial) margin of the rostrum (SL2, below), the start of a series of semilandmarks along the dorsal midline of the rostrum (SL3, below), and the end of a series of semilandmarks along the ventral expression of the median contact between the premaxillae (SL10, below).

**Landmark LM5. Craniofacial hinge** Median point of the craniofacial hinge, between the rostrum and braincase (Fig. S1). This landmark marks the end of a series of semilandmarks along the dorsal midline of the rostrum (SL3, below), and the start of a series of semilandmarks along the dorsal midline of the cranial vault (SL6, below)

**Landmark LM6. Orbital rim, caudoventral point** This landmark is placed on the tip of the postorbital process (Fig. S1) and marks the start point of a semilandmark series extending around the orbital rim (SL5, below). The orbital rim is open ventrally in most birds, but in some taxa it forms a closed circle (e.g. *Probosciger*). In these taxa, LM6 and LM7 are adjacent points on the contact of the postorbital process with the lacrimal on the ventral orbital rim.

**Landmark LM7. Orbital rim, ventrolateral point** This landmark is placed on the most caudoventrolateral point of the lacrimal bone (Fig. S1) and marks the end point of a semilandmark series extending around the orbital rim (SL5, below). As with LM6, in some taxa (e.g. *Probosciger*) the orbital rim forms a closed circle due to contact between an extended postorbital process and lacrimal bone. For such taxa, this landmark is placed slightly rostral and adjacent to LM6 on the postorbital-lacrimal contact.

**Landmark LM8. Processus zygomaticus of the squamosal** Apex of the zygomatic process of the squamosal (Fig. S1).

**Landmark LM9. Processus suprameaticus of the squamosal** Apex of the suprameatic process of the squamosal (Fig. S1).

**Landmark LM10. Processus orbitalis of the quadrate** Rostromedial projection of the orbital process of the quadrate (Fig. S1).

**Landmark LM11. Foramen magnum, dorsomedian point** The dorsomedian point on the rim of the foramen magnum (Fig. S2). This landmark marks the end of a series of semilandmarks along the midline of the cranial vault (SL6, below) and the start of a series of semilandmarks around the rim of the foramen magnum (SL7, below).

**Landmark LM12. Foramen magnum, ventromedian point** The ventromedian point of the rim of the foramen magnum, dorsal to the occipital condyle (Fig. S2). This landmark marks the end of a series of semilandmarks around the rim of the foramen magnum (SL7, below).

**Landmark LM13. Condylus occipitalis, rostroventral point** The rostroventral point of the occipital condyle (Fig. S2). This landmark marks the start of a series of semilandmarks along the midline of the ventral surface of the basicranium (SL8, below).

**Landmark LM14. Basioccipital-parabasisphenoid, rostralmost point** Rostralmost midline point on parabasisphenoid, near its articulation with the pterygoid (i.e. adjacent to LM15, the ‘palatine-ptyergoid contact’) (Fig. S2). This landmark marks the end of a series of semilandmarks along the midline of the ventral surface of the basicranium (SL8, below).

**Landmark LM15. Palatine–ptyergoid contact** The caudomedial point of the palatine at its articulation with the pterygoid (articulation ptyergopalatine) (Fig. S2). This landmark marks the start of a series of semilandmarks along the ventrolateral margin of the palatine (SL9, below).

**Landmark LM16. Palatine-maxilla contact** The rostrolateral point on the palatine at its articulation with the maxilla (Fig. S2). This landmark marks the end of a series of semilandmarks along the ventrolateral margin of the palatine (SL9, below).

**Landmark LM17. Premaxilla, caudomedial point** The caudomedial point on the ventral surface of the midline contact between the premaxillae (Fig. S2). This landmark marks the start of a series of semilandmarks along the ventral surface of the midline contact between the premaxillae (SL10, below).

**Landmark LM18. Condylus occipitalis** The middle, central projection and ventralmost point of the condylus occipitalis (Fig. S2).

**Landmark LM19. Pterygoid-parasphenoid contact, caudalmost point** The caudalmost point of the pterygoid articulation with the parasphenoid, on the medial surface of the pterygoid (Fig. S2).

**Landmark LM20. Pterygoid-parasphenoid contact, rostralmost point** The rostralmost point of the pterygoid articulation with the parasphenoid, on the lateral surface of the pterygoid (Fig. S2).

**Landmark LM21. Pterygoid-quadrato contact, caudoventral point** The ventral projection of the lateral end of the pterygoid at its articulation with the quadrato (Fig. S2).

**Landmark LM22. Quadrato lateral mandibular condyle** The ventralmost point on the lateral mandibular condyle of the quadrato (Fig. S2).

**Landmark LM23. Quadrato medial mandibular condyle** The ventralmost point on the medial mandibular condyle of the quadrato (Fig. S2).

**Semilandmark series SL1. Jugal bar** (Semilandmark) Open curve of semilandmarks along the jugal bar, starting at the caudoventral point (LM1) and ending at the rostralmost point (LM2), proceeding from caudal to rostral (Fig. S1).

**Semilandmark series SL2. Rostrum, ventrolateral (tomial) margin** Open curve of semilandmarks along the ventrolateral (tomial) margin of the rostrum, starting at the caudoventral point of the maxilla (LM3) and ending at the rostralmost point of the premaxilla (LM4), proceeding from caudal to rostral (Fig. S1).

**Semilandmark series SL3. Rostrum, dorsomedian margin** Open curve of semilandmarks along the dorsomedian margin of the rostrum, starting at the rostralmost point of the premaxilla (LM4) and ending at the median point of the craniofacial hinge (LM5), proceeding from rostral to caudal (Fig. S1).

**Semilandmark series SL4. Nasal aperture** Closed loop of semilandmarks around the nasal aperture, starting from the point of maximum curvature on the caudal end and ending just adjacent to that, proceeding clockwise as seen in right lateral view (Fig. S1).

**Semilandmark series SL5. Orbit rim** Open curve of semilandmarks along the orbit, starting from the caudoventral point of the orbital rim (LM6) and ending at its ventrolateral point (LM7), proceeding clockwise as seen in right lateral view (Fig. S1).

**Semilandmark series SL6. Cranial vault** Open curve of semilandmarks along the midline of the cranial vault, starting from the median point of the craniofacial hinge' (LM5) and ending at the foramen magnum (LM11), proceeding from rostral to caudal (Fig. S2) .

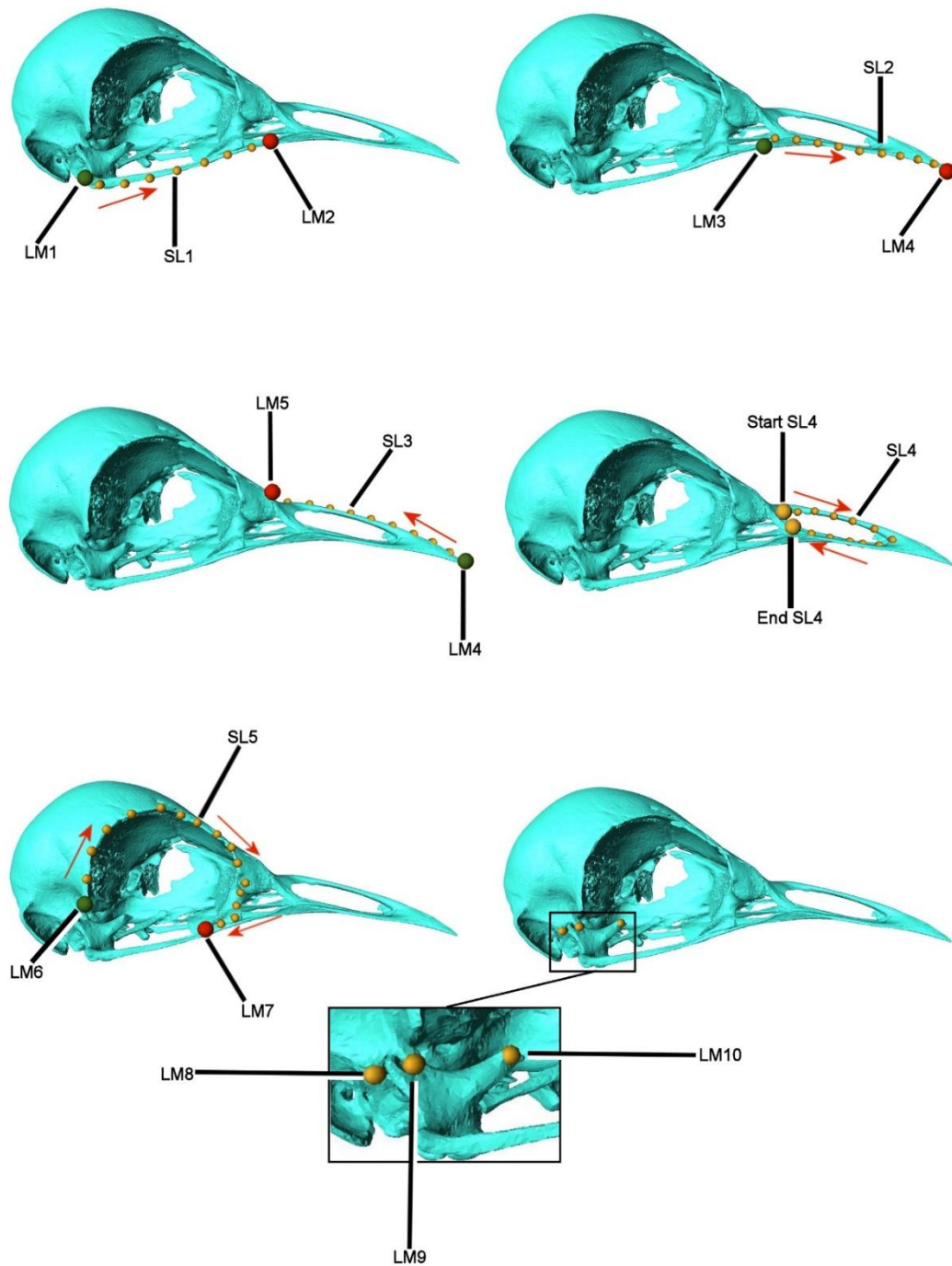
**Semilandmark series SL7. Foramen magnum** Open curve of semilandmarks along the rim of the foramen magnum, starting from its dorsomedian point (LM11) and ending at the at its ventromedian point (LM12), proceeding from dorsal to ventral (Fig. S2).

**Semilandmark series SL8. Basioccipital-parabasisphenoid** Open curve of semilandmarks along the ventral midline of the basioccipital and parabasisphenoid, starting from immediately ventral to the occipital condyle (LM13) and ending at the rostral end of the parasphenoid (LM14), proceeding from caudal to rostral (Fig. S2) .

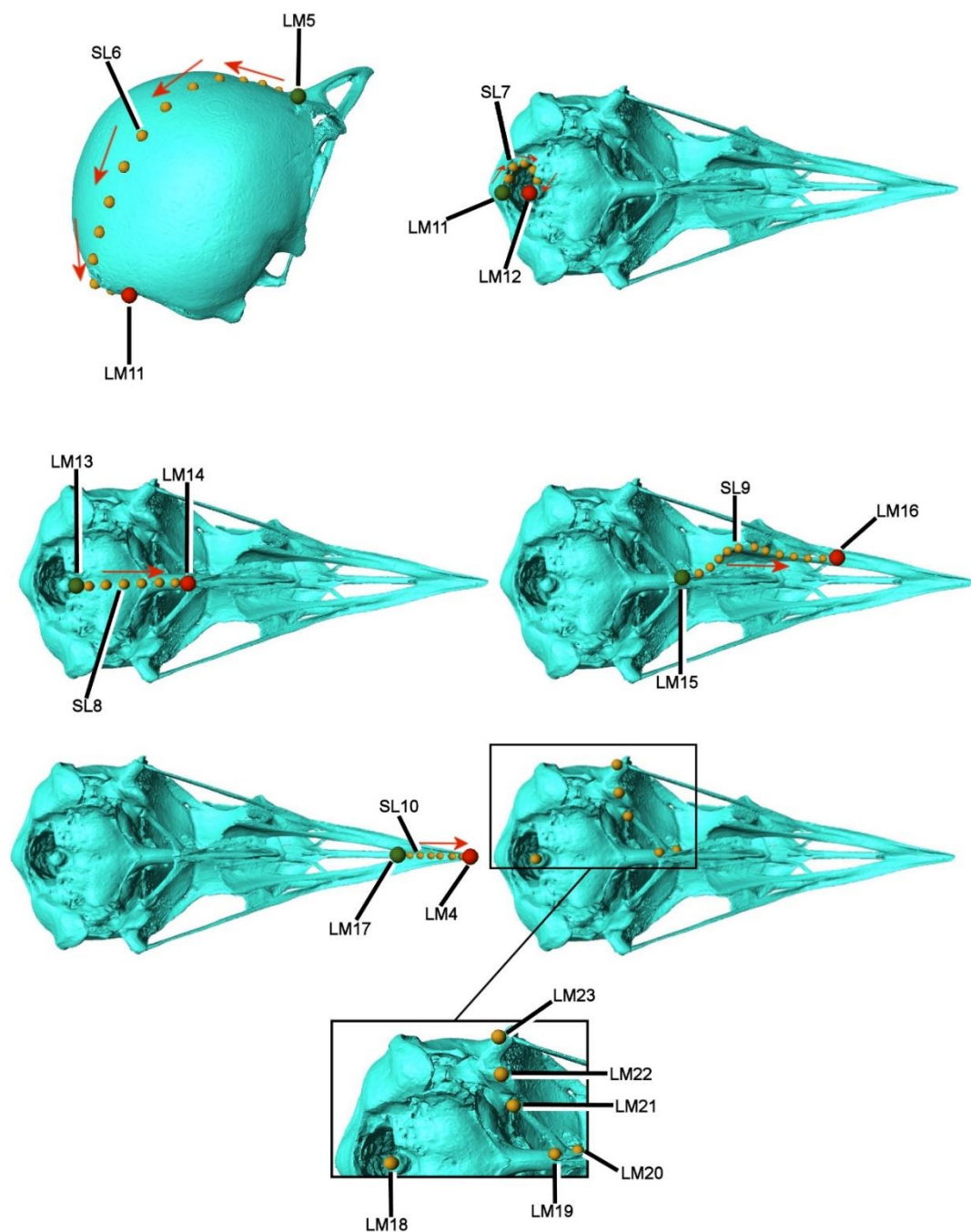
**Semilandmark series SL9. Palatine, ventrolateral margin** Open curve of semilandmarks along the ventrolateral margin of the palatine, starting at the palatine-

pterygoid contact (LM15) and ending at the palatine-maxilla contact (LM16), proceeding from caudal to rostral (Fig. S2).

**Semilandmark series SL10. Premaxillae, ventromedian contact** Open curve of semilandmarks along the ventral surface of the median contact between the premaxillae, starting from its caudal end (LM17) and ending its rostralmost point (LM4), proceeding from caudal to rostral (Fig. S2).



**Figure S1: Skull landmarks and semilandmarks.** Skull landmarks (LM1–LM10) and semilandmark series (SL1–SL5) shown on the skull of *Menura novaehollandiae* (FMNH 336751) in right lateral view. Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.



**Figure S2: Skull landmarks and semilandmarks.** Skull landmarks (LM5,11–LM23) and semilandmark series (SL6–SL10) shown on the skull of *Menura novaehollandiae* (FMNH 336751) in right caudolateral view (top left) and ventral view (other panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Mandible

**Landmark LM1. Mandibular symphysis, cranialmost point** Craniodorsal apex of the median symphysis between the dentaries, generally representing the cranialmost point of the mandible (Fig. S3). This landmark marks the start of a series of semilandmarks along the dorsal surface of the mandible (SL1, below).

**Landmark LM2. Mandible, contact of dorsal margin of the mandible with the glenoid** The point where the dorsal margin of the mandibles meets the rostral anterior rim of the articular cotyles of the glenoid (Fig. S3). This landmark marks the end of a series of semilandmarks along the dorsal surface of the mandible (SL1, below).

**Landmark LM3. Articular glenoid, craniolateral point** Craniolateral point of the articular glenoid adjacent to the cotyles (Fig. S3). This landmark marks the start of a series of semilandmarks along the caudodorsal rim of the articular glenoid (SL2, below).

**Landmark LM4. Articular glenoid, medial process** Apex of the medial process of the caudal part of the mandible (Fig. S3). This landmark marks the end of a series of semilandmarks along the caudodorsal rim of the articular glenoid (SL2, below).

**Landmark LM5. Mandibular symphysis, caudoventral point** Caudovernal point of the mandibular symphysis (Fig. S3). This landmark marks the start of a series of semilandmarks along the ventral surface of the mandible (SL3, below) and the end of a series of semilandmarks along the rostroventral surface of the symphysis (SL4, below).

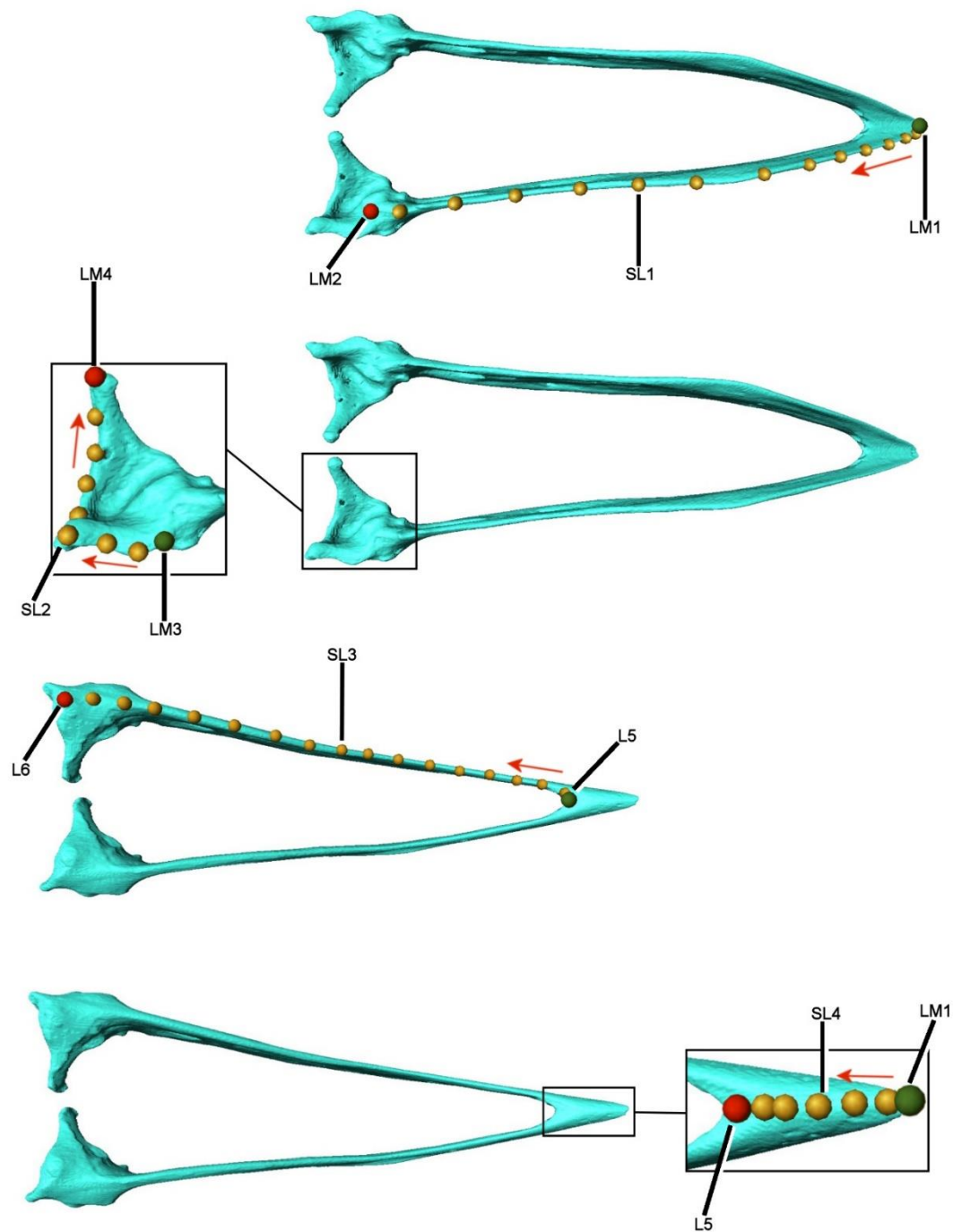
**Landmark LM6. Mandible, caudoventral point** The caudoventralmost point on the ventral surface of the mandible ventral to glenoid (Fig. S3). This landmark marks the end of a series of semilandmarks along the ventral surface of the mandible (SL3, below).

**Semilandmark series SL1. Dorsal crest of mandible** Open curve of semilandmarks along the dorsal surface of the mandible, starting at the cranialmost point of the mandible (LM1) and ending at the rostral margin of the articular glenoid (LM2), proceeding from cranial to caudal (Fig. S3).

**Semilandmark series SL2. Articular glenoid rim** Open curve of semilandmarks along the articular glenoid surface of the mandible, starting at its craniolateral point (LM3) and ending at the apex of the medial process (LM4), proceeding from rostralateral to caudomedial (Fig. S3).

**Semilandmark series SL3. Ventral surface of mandible** Open curve of semilandmarks along the ventral surface of the mandible, starting at the caudalmost point on the mandibular symphysis (LM5) and ending at the caudoventral point of the mandible (LM6), proceeding from cranial to caudal (Fig. S3).

**Semilandmark series SL4. Mandibular symphysis, rostroventral surface** Open curve of semilandmarks along the ventral surface of the mandibular symphysis, starting at its cranialmost point (LM1) and ending at its caudoventral point (LM5), proceeding from cranial to caudal (Fig. S3).



**Figure S3: Mandible landmarks and semilandmarks.** Mandible landmarks (LM1–LM6) and semilandmark series (SL1–SL4) shown on the mandible of *Menura novaehollandiae* (FMNH 336751) in dorsal view (upper panels) and ventral view (lower panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.



## Sternum

**Landmark LM1. Caudolateral process, caudolateral point** The caudolateral point on the caudolateral process of the sternum (Fig. S4). This landmark marks the start of a series of semilandmarks along the caudolateral process and lateral margin of the sternum (SL1, below).

**Landmark LM2. Sternal rib facets, caudalmost point** The caudalmost point of the sternal rib facets (Fig. S4). This landmark marks the end of a series of semilandmarks along the caudolateral process and lateral margin of the sternum (SL1, below).

**Landmark LM3. Sternal midline, caudoventral point** The caudalmost point on the midline of the ventral surface of the sternum (Fig. S4-5). This landmark marks the start of a series of semilandmarks along the midline of the ventral surface of the sternal keel (SL2, below) and the start of a series of semilandmarks along the midline of the dorsal surface of the sternum (SL5, below).

**Landmark LM4. Sternal midline, cranioventral point** The cranialmost point on the midline of the ventral surface of the sternum, on the midline of the rostral process (Fig. S4). This landmark marks the end of a series of semilandmarks along the ventral surface of the sternal keel (SL2, below).

**Landmark LM5. Sternal rib facets, cranialmost point** The cranialmost point of the sternal rib facets (Fig. S4). This landmark marks the start of a series of semilandmarks along the caudolateral margin of the craniolateral process of the sternum (SL3, below).

**Landmark LM6. Craniolateral process, craniolateral point** The craniolateral point on the craniolateral process of the sternum (Fig. S4-S5). This landmark marks the end of a series of semilandmarks along the caudolateral margin of the craniolateral process (SL3, below) and the start of a series of semilandmarks along the cranial margin of the craniolateral process (SL4, below).

**Landmark LM7. Craniolateral process, craniomedian point** The cranial point on the midline where the craniolateral process of the sternum fully merges with medial sulcus (Fig. S5). This landmark marks the end of a series of semilandmarks along the anterior margin of the craniolateral process (SL4, below) and the end of a series of semilandmarks along the midline on the dorsal surface of the sternum (SL5).

**Semilandmark series SL1. Caudolateral process** Open curve of semilandmarks along the caudolateral process, starting at the most caudolateral point of the caudolateral process (LM1) and ending at the caudalmost point of the caudal rib facets (LM2), proceeding from caudal to cranial (Fig. S4).

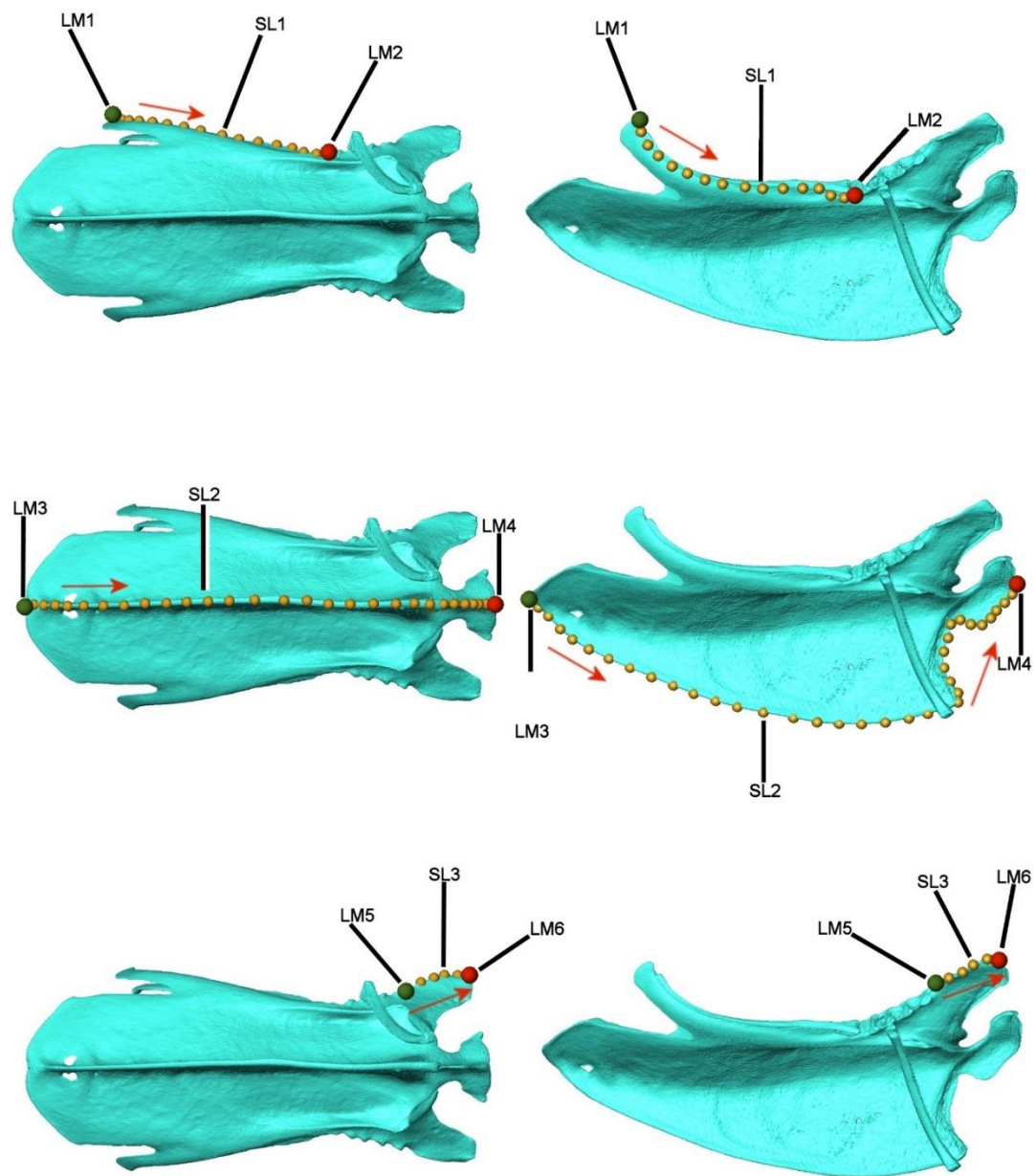
**Semilandmark series SL2. Sternal keel** Open curve of semilandmarks along the midline on the ventral surface of the sternal keel, starting at the caudoventral point of the sternum (LM3) and ending at its cranioventral point (LM4), proceeding from caudal to cranial (Fig. S4).

**Semilandmark series SL3. Craniolateral process, caudolateral margin** Open curve of semilandmarks along the caudolateral margin of the craniolateral process,

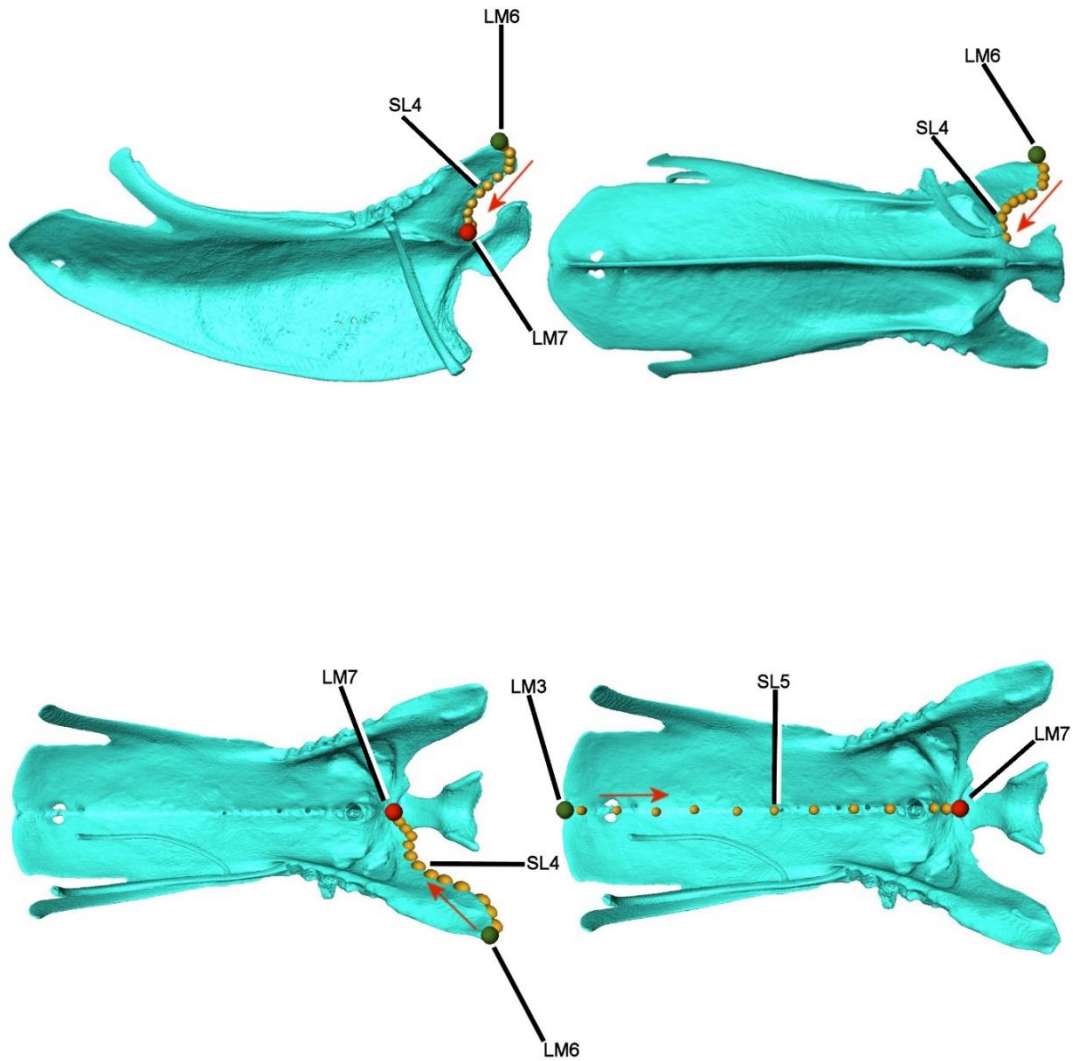
starting at the cranialmost point of the sternal rib facets (LM5) and ending at the craniolateral point of the craniolateral process (LM6), proceeding from caudal to cranial (Fig. S4).

**Semilandmark series SL4. Craniolateral process, cranial margin** Open curve of semilandmarks along the cranial margin of the craniolateral process, starting at the craniolateral point of the craniolateral process (LM6) and ending at midline where the craniolateral process meets the median sulcus (LM7), proceeding from lateral to medial (Fig. S5).

**Semilandmark series SL5. Sternum, midline of dorsal surface** Open curve of semilandmarks along the midline of the dorsal surface of the sternum, starting at the caudoventral point of the sternum (LM3) and ending at the contact of the craniolateral process with the median sulcus (LM7), proceeding from caudal to cranial (Fig. S5).



**Figure S4: Sternum landmarks and semilandmarks.** Sternum landmarks (LM1–LM6) and semilandmark series (SL1–SL3) shown on the sternum of *Menura novaehollandiae* (FMNH 336751) in ventral view (left-side panels) and right lateral view (right-side panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.



**Figure S5: Sternum landmarks and semilandmarks.** Sternum landmarks (LM3,6-7) and semilandmark series (SL4–SL5) shown on the sternum of *Menura novaehollandiae* (FMNH 336751) in right lateral view (top-left), ventral view (top-right) and dorsal view (lower panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Synsacrum

**Landmark LM1. Preacetabulare tubercle** The apex of the preacetabular tubercle (Fig. S6-7). This landmark marks the start of a series of semilandmarks along the cranioventral surface of the preacetabular process of the ilium (SL1, below) and the end of a series of semilandmarks along the ventral surface of the pubis (SL6, below).

**Landmark LM2. Preacetabular process of ilium, cranioventral point** Apex of the cranioventral projection on the preacetabular process (Fig. S6-7). This landmark marks the end of a series of semilandmarks along the cranioventral surface of the preacetabular process of the ilium (SL1, below) and the start of a series of semilandmarks along the dorsal margin of the iliac blade (S2, below).

**Landmark LM3. Caudal process of ilium** The caudalmost point of the caudal process of the ilium (Fig. S6-7). This landmark marks the end of a series of semilandmarks along the dorsal margin of the iliac blade (SL2, below) and the start of a series of semilandmarks along the caudal surface of the ilium and ischium (SL3, below).

**Landmark LM4. Ischium, caudoventral point** The caudoventral point of the ischium where it contacts the pubis (Fig. S6-7). This landmark marks the end of a series of semilandmarks along the caudal surface of the ilium and ischium (SL3, below) and the start of a series of semilandmarks along the ventrolateral surface of the ischium (SL4, below).

**Landmark LM5. Obturator foramen, craniodorsal point** The craniodorsal point of the obturator foramen, nominally on the contact of the pubis and ischium (Fig. S6-7). This landmark marks the end of a series of semilandmarks along the ventrolateral surface of the ischium (SL4, below) and the start of a series of semilandmarks along the dorsal surface of the pubis (SL5, below).

**Landmark LM6. Pubis, caudalmost point** The caudalmost point of the pubis at its point of maximum curvature (Fig. S6-7). This landmark marks the end of a series of semilandmarks along the caudodorsal surface of the pubis (SL5, below) and the start of a series of semilandmarks along the cranioventral surface of the pubis (SL6, below).

**Landmark LM7. Supratrochanteric process** The apex of the supratrochanteric process of the ilium (Fig. S7).

**Landmark LM8. Antitrochanter, caudoventral point** The caudoventral point of the antitrochanter where it contacts the acetabular rim (Fig. S7). This landmark marks the start of a series of semilandmarks along the rim of the antitrochanter (SL8, below).

**Landmark LM9. Antitrochanter, craniodorsal point** The craniodorsal point of the antitrochanter where it contacts the acetabular rim (Fig. S7). This landmark marks the end of a series of semilandmarks along the rim of the antitrochanter (SL8, below).

**Landmark LM10. Synsacrum dorsal midline, cranialmost point** The cranialmost point on the midline of the dorsal surface of the synsacrum (Fig. S7). This landmark marks the start of a series of semilandmarks along the dorsal surface (SL10, below).

**Landmark LM11. Synsacrum dorsal midline, caudalmost point** The caudalmost point on the midline of the dorsal surface of the synsacrum (Fig. S7). This landmark marks the end of a series of semilandmarks along the dorsal surface (SL10, below).

**Landmark LM12. Synsacrum ventral midline, cranialmost point** The cranialmost point on the midline of the ventral surface of the synsacrum (Fig. S7). This landmark marks the start of a series of semilandmarks along the ventral surface (SL11, below).

**Landmark LM13. Synsacrum ventral midline, caudalmost point** The caudalmost point on the midline of the ventral surface of the synsacrum (Fig. S7). This landmark marks the end of a series of semilandmarks along the ventral surface (SL11, below).

**Semilandmark series SL1. Preacetabular process, cranioventral surface** Open curve of semilandmarks along the ventral surface of the preacetabular process of the ilium, starting at the preacetabular tubercle (LM1) and ending at the cranioventral point of the preacetabular process (LM2), proceeding from caudal to cranial (Fig. S6).

**Semilandmark series SL2. Ilium, dorsal margin of blade** Open curve of semilandmarks along the dorsal margin of the iliac blade, starting at the cranioventral point of the preacetabular process (LM2) and ending at the caudalmost point of the caudal process of the ilium (LM3), proceeding from cranioventral to caudodorsal, following the rim of the fossa iliaca dorsalis via the processus supratrochantericus and along the crista dorsolateralis ilii (Fig. S6).

**Semilandmark series SL3. Ischium and ilium, caudal margin** Open curve of semilandmarks along the caudal surface of the ilium and ischium, starting at the caudalmost point of the caudal process of the ilium (LM3) and ending at the caudoventral point of the ischium where it contacts the pubis (LM4), proceeding from dorsal to ventral (Fig. S6).

**Semilandmark series SL4. Ischium, cranioventral margin** Open curve of semilandmarks along the cranioventral margin of the ischium, starting at the caudoventral point of the ischium where it contacts the pubis (LM4) and ending at the craniodorsal point of the obturator foramen (LM5), proceeding from caudal to cranial (Fig. S6).

**Semilandmark series SL5. Pubis, caudodorsal margin** Open curve of semilandmarks along the caudodorsal surface of the pubis, starting at the obturator foramen (LM5) and ending at the caudal apex of the pubis (LM6), proceeding from cranial to caudal (Fig. S6).

**Semilandmark series SL6. Pubis, cranioventral margin** Open curve of semilandmarks along the cranioventral margin of the pubis, starting at the caudal apex of the pubis (LM6) and ending at the preacetabular tubercle (LM1), proceeding from caudal to cranial (Fig. S6).

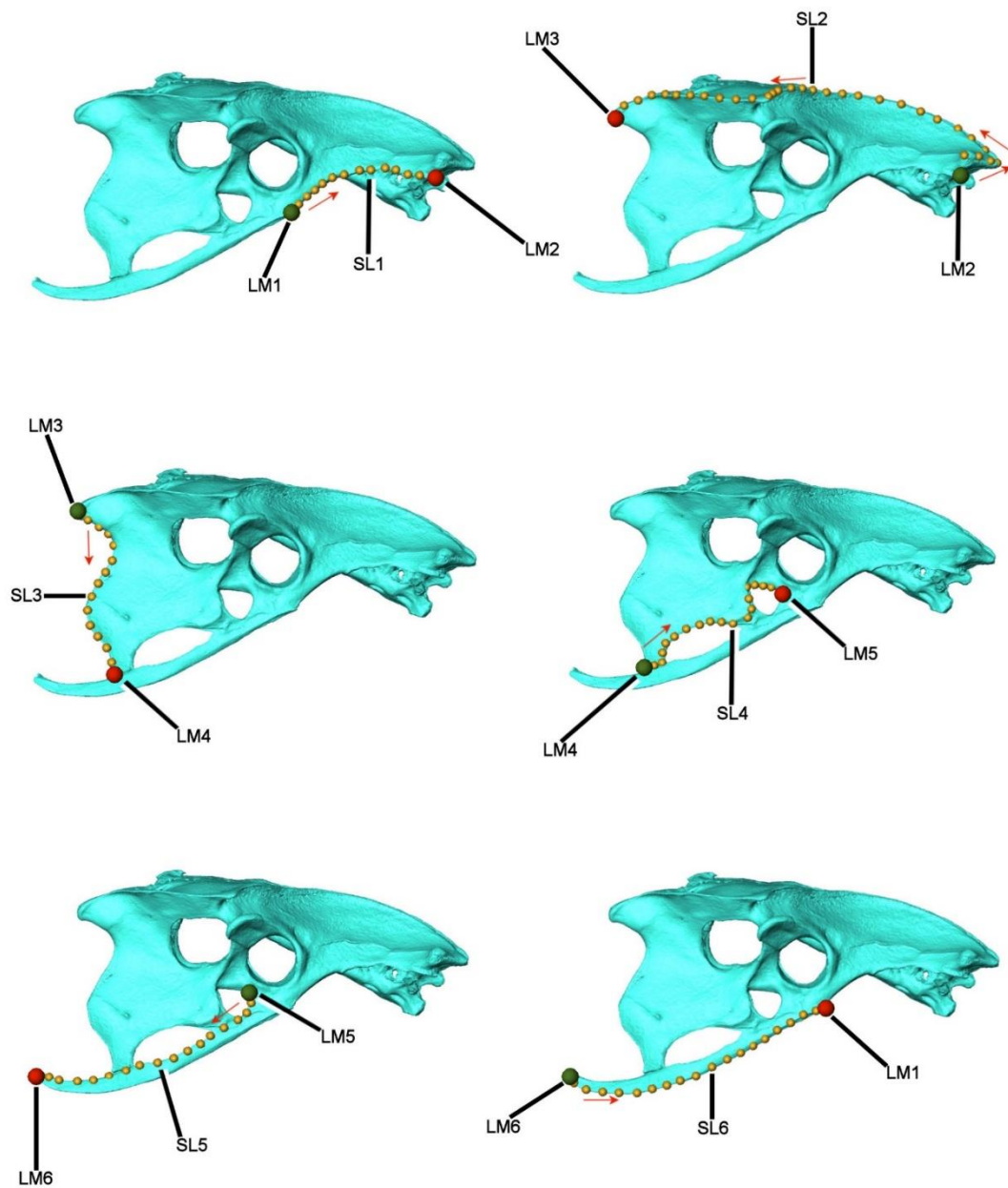
**Semilandmark series SL7. Ili-ischiadic foramen margin** Closed loop of semilandmarks along the ili-ischiadic foramen, starting at its cranialmost point adjacent to the antitrochanter, and ending just adjacent to it, proceeding anticlockwise as seen in right lateral view (Fig. S7).

**Semilandmark series SL8. Antitrochanter rim** Open curve of semilandmarks along the rim of the antitrochanter, starting at its caudoventral point where it contacts the acetabulum (LM8) and ending at its craniodorsal point (LM9), proceeding from caudal to cranial (Fig. S7).

**Semilandmark series SL9. Acetabular rim** Closed loop of semilandmarks along the rim of the acetabulum, starting at the caudoventral point of the antitrochanter (LM8) and ending just adjacent to it, proceeding clockwise as seen in right lateral view (Fig. S7).

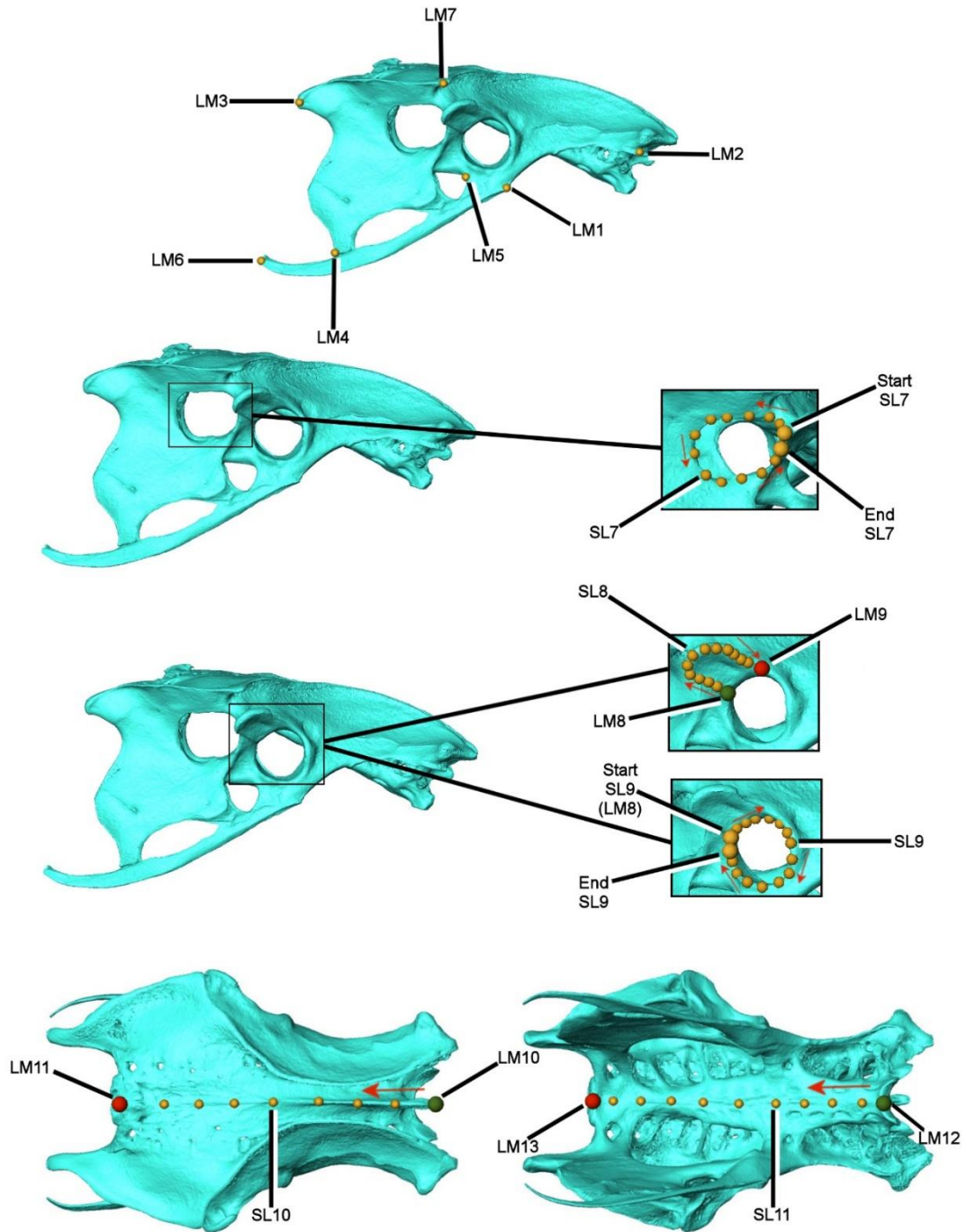
**Semilandmark series SL10. Dorsal surface midline** Open curve of semilandmarks along the midline of the dorsal synsacrum, starting at the cranialmost point of the synsacral dorsal midline (LM10) and ending at its caudalmost point (LM11), proceeding from cranial to caudal (Fig. S7).

**Semilandmark series SL11. Ventral surface midline** Open curve of semilandmarks along the midline of the ventral synsacrum, starting from the cranialmost point of the synsacral ventral midline (LM12) and ending at its caudalmost point (LM13), proceeding from cranial to caudal (Fig. S7).



**Figure S6: Synsacrum landmarks and semilandmarks.** Synsacrum landmarks (LM1–LM6) and semilandmark series (SL1–SL6) shown on the synsacrum of *Menura novaehollandiae* (FMNH 336751) in right lateral view. Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.





**Figure S7: Synsacrum landmarks and semilandmarks.** Synsacrum landmarks (LM1–LM16) and semilandmark series (SL7–SL11) shown on the synsacrum of *Menura novaehollandiae* (FMNH 336751) in dorsal view (bottom-left), ventral view (bottom-right) and right lateral view (all other panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Scapula

**Landmark LM1. Humeral articular surface, cranialmost point of contact with coracoid** Cranialmost point of the humeral articular surface on its contact with the coracoid (Fig. S8). This landmark marks the start of a series of semilandmarks along the rim of the humeral articular surface (SL1, below).

**Landmark LM2. Humeral articular surface, caudalmost point of contact with coracoid** Caudalmost point of the humeral articular surface on its contact with the coracoid (Fig. S8). This landmark marks the end of a series of semilandmarks along the humeral articular surface (SL1, below).

**Landmark LM3. Scapula blade apex, caudalmost point** The caudalmost point on the apex of the scapula blade (Fig. S8). This landmark marks the end of a series of semilandmarks along the ventral margin of the scapula blade (SL2, below) and the start of a series of semilandmarks along the dorsal margin of the scapula blade (SL3, below).

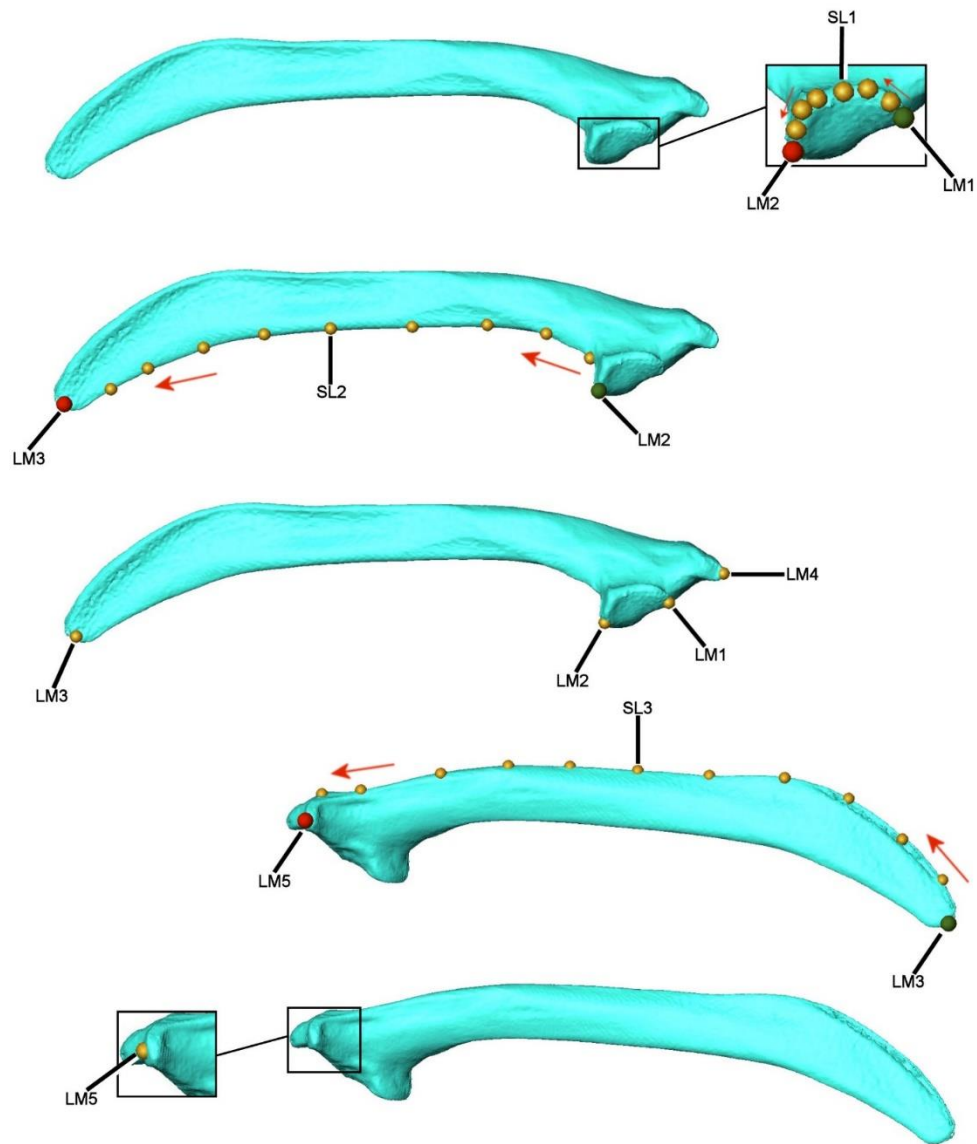
**Landmark LM4. Acromium** The apex of the acromium and cranialmost point on the dorsal surface of the scapula (Fig. S8). This landmark marks the end of a series of semilandmarks along the dorsal surface of the scapula blade (SL3, below).

**Landmark LM5. Coracoid tubercle** The apex of the coracoid tubercle (Fig. S8).

**Semilandmark series SL1. Humeral articular surface, external rim** Open curve of semilandmarks along the rim of the humeral articular surface, starting from the cranialmost point of its contact with the coracoid (LM1) and ending at the caudalmost point of its contact with the coracoid (LM2), proceeding from cranial to caudal (Fig. S8).

**Semilandmark series SL2. Scapula blade, ventral margin** Open curve of semilandmarks along the ventral margin of the scapula blade, starting at the caudalmost point of the contact between the humeral articular surface and the coracoid (LM2) and ending at the caudalmost point on the scapula blade (LM3), proceeding from cranial to caudal (Fig. S8).

**Semilandmark series SL3. Scapula blade, dorsal margin** Open curve of semilandmarks along the dorsal margin of the scapula blade, starting at the caudalmost point on the scapula blade (LM3) and ending at the acromium (LM4), proceeding from caudal to cranial (Fig. S8).



**Figure S8: Scapula landmarks and semilandmarks.** Scapula landmarks (LM1–LM5) and semilandmark series (SL1–SL3) shown on the right scapula of *Menura novaehollandiae* (FMNH 336751) in lateral view (upper panels) and medial view (lower panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Coracoid

**Landmark LM1. Sternal articular crest, lateralmost point** The lateralmost point on the sternal articulation (Fig. S9). This landmark marks the start of a series of semilandmarks along the lateral process (SL1, below).

**Landmark LM2. Lateral process, apex** The lateralmost point on the apex of the lateral process (Fig. S9). This landmark marks the end of a series of semilandmarks along the lateral process (SL1, below) and the start of a series of semilandmarks along the lateral margin of the coracoid (SL3, below).

**Landmark LM3. Sternal articular crest, medialmost point** The medialmost point on the sternal articulation (Fig. S9). This landmark marks the start of a series of semilandmarks along the medial margin of the coracoid (SL2, below).

**Landmark LM4. Procoracoid process** The apex, or cranialmost point, on the procoracoid process (Fig. S9). This landmark marks the end of a series of semilandmarks along the medial margin of the coracoid (SL2, below).

**Landmark LM5. Furcular articulation** The apex, or caudalmost point on the furcular articulation (Fig. S9).

**Landmark LM6. Acrocoracoid process** The apex or cranialmost projection of the acrocoracoid process (Fig. S9).

**Landmark LM7. Scapular articular surface, lateralmost point** The lateralmost point of the scapular articular surface (Fig. S9). This landmark marks the end of a series of semilandmarks along the lateral margin of the coracoid (SL3, below) and start of a series of semilandmarks along the external margin of the humeral articular surface (SL4, below).

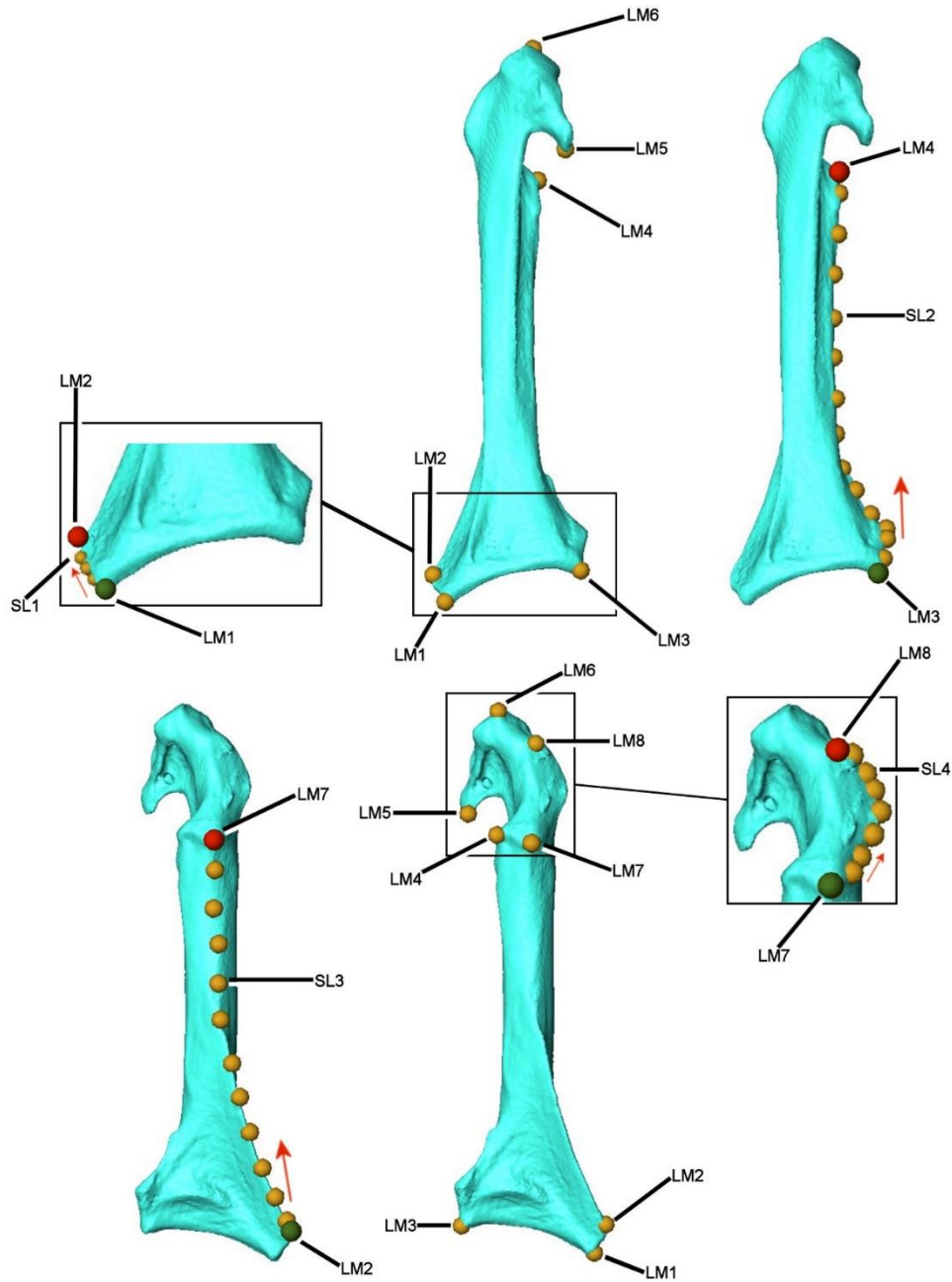
**Landmark LM8. Humeral articular surface, cranialmost point** The cranialmost point on the external margin of the humeral articulation (Fig. S9). This landmark marks the end of a series of semilandmarks along the external margin of the humeral articular surface (SL4, below).

**Semilandmark series SL1. Lateral process** Open curve of semilandmarks along the margin of the lateral process, starting at the lateralmost point of the sternal articular crest (LM1) and ending to the apex or lateralmost point of the lateral process (LM2), proceeding from caudal to cranial (Fig. S9).

**Semilandmark series SL2. Medial margin of coracoid** Open curve of semilandmarks along the medial margin of the coracoid, starting at the medialmost point of the sternal articular surface (LM3) and ending at the procoracoid process (LM4), proceeding from caudal to cranial (Fig. S9).

**Semilandmark series SL3. Lateral margin of coracoid** Open curve of semilandmarks along the lateral margin of the coracoid, starting at the apex of the lateral process (LM2) and ending at the lateralmost point of the scapular articular surface (LM7), proceeding from caudal to cranial (Fig. S9).

**Semilandmark series SL4. Humeral articular surface, external margin** Open curve of semilandmarks along external margin of the humeral articulation starting at the lateralmost point of the scapular articulation (LM7) and ending at the cranialmost point on the humeral articulation (LM8), proceeding from caudal to cranial (Fig. S9).



**Figure S9: Coracoid landmarks and semilandmarks.** Coracoid landmarks (LM1–LM8) and semilandmark series (SL1–SL4) shown on the coracoid of *Menura novaehollandiae* (FMNH 336751) in cranial view (upper panels) and caudal view (lower panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## **Humerus**

**Landmark LM1. Ventral condyle, proximalmost point** The proximalmost point of the major projection of the ventral condyle (Fig. S10). This landmark marks the start of a series of semilandmarks along the ventral condyle (SL1, below).

**Landmark LM2. Ventral condyle, distalmost point** The distalmost point of the ventral condyle where it meets the body of the humerus (Fig. S10). This landmark marks the end of a series of semilandmarks along the ventral condyle (SL1, below).

**Landmark LM3. Intercondylar groove, proximalmost point** The proximalmost point of the intercondylar groove (Fig. S10). This landmark marks the start of a series of semilandmarks along the intercondylar groove (SL2, below), the start of a series of semilandmarks around the proximal margin of the dorsal condyle (SL5, below), and the end of a series of semilandmarks around the proximal margin of the ventral condyle (SL4, below).

**Landmark LM4. Intercondylar groove, distalmost point** The distalmost point of the intercondylar groove (Fig. S10). This landmark marks the end of a series of semilandmarks along the intercondylar groove (SL2, below).

**Landmark LM5. Dorsal condyle, proximalmost point** The proximalmost point of the major projection of the dorsal condyle (Fig. S10). This landmark marks the start of a series of semilandmarks along the dorsal condyle (SL3, below).

**Landmark LM6. Dorsal condyle, distalmost point** The distalmost point of the dorsal condyle where it meets the body of the humerus (Fig. S10). This landmark marks the end of a series of semilandmarks along the dorsal condyle (SL3, below).

**Landmark LM7. Ventral condyle, ventral point** The ventralmost point of the ventral condyle (Fig. S10). This landmark marks the start of a series of semilandmarks along the proximal margin of the ventral condyle (SL4, below) and end of a series of semilandmarks along the dorsal margin of the flexor process (SL6, below).

**Landmark LM8. Dorsal condyle, dorsodistal point** The dorsodistal point of the dorsal condyle (Fig. S10). This landmark marks the end of a series of semilandmarks around the proximal margin of the dorsal condyle (SL5, below).

**Landmark LM9. Ventral epicondyle, apex** The apex or ventralmost point of the ventral epicondyle (Fig. S10).

**Landmark LM10. Tuberculum supracondylare, apex** The apex of the supracondylar tubercle (Fig. S10).

**Landmark LM11. Process supracondylare, proximalmost point** Proximalmost point of the supracondylar process (Fig. S10).

**Landmark LM12. Flexor process, proximalmost point** Proximalmost point of the dorsal margin of the flexor process (Fig. S10). This landmark marks the start of a series of semilandmarks along the dorsal margin of the flexor process (SL6, below).

**Landmark LM13. Bicipital crest, distalmost point** Distalmost point of the bicipital crest, where it meets the shaft of the humerus (Fig. S11). This landmark marks the start of a series of semilandmarks along the bicipital crest and distal margin of the ventral tubercle (SL7, below).

**Landmark LM14. Ventral tubercle, distodorsal point** The distodorsal point of the ventral tubercle at the end of the incisura capitis (Fig. S11). This landmark marks the end of a series of semilandmarks along the bicipital crest and distal margin of the ventral tubercle (SL7, below) and the start of a series of semilandmarks along the dorsal margin of the ventral tubercle along the incisura capitis (SL8, below).

**Landmark LM15. Incisura capitis, proximodorsal point** The proximalmost point of the incisura capitis (Fig. S11). This landmark marks the end of a series of semilandmarks along the dorsal margin of the ventral tubercle along the incisura capitis (SL8, below).

**Landmark LM16. Humeral head, ventralmost point** The ventralmost point of the humeral head (Fig. S11). This landmark marks the start of a series of semilandmarks along the proximal surface of the humerus (SL10, below) and the start of a series of semilandmarks around the caudal margin of the humeral head (SL9, below).

**Landmark LM17. Crista deltopectoralis, proximalmost point** The proximalmost point of the deltopectoral crest (Fig. S11). This landmark marks the start of a series of semilandmarks along the deltopectoral crest (SL11, below), the end of a series of semilandmarks along the proximal surface of the humeral head (SL10, below), and the end of a series of semilandmarks around the ventral margin of the humeral head (SL9, below).

**Landmark LM18. Ventral tubercle, caudalmost projection** The apex or caudalmost projection of the ventral tubercle (Fig. S11).

**Landmark LM19. Crista deltopectoralis, distalmost point** The distalmost point of the deltopectoral crest where it merges with the shaft (Fig. S11). This landmark marks the end of a series of semilandmarks along the deltopectoral crest (SL11, below).

**Semilandmark series SL1. Ventral condyle** Open curve of semilandmarks along the ventral condyle, starting at its proximalmost point (LM1) and ending at its distalmost point (LM2), proceeding from proximal to distal (Fig. S10).

**Semilandmark series SL2. Intercondylar groove** Open curve of semilandmarks along the intercondylar groove, starting at its proximalmost point (LM3) and ending at its distalmost point (LM4), proceeding from proximal to distal (Fig. S10).

**Semilandmark series SL3. Dorsal condyle** Open curve of semilandmarks along the dorsal condyle, starting at its proximalmost point (LM5) and ending at its distalmost point (LM6), proceeding from proximal to distal (Fig. S10).

**Semilandmark series SL4. Proximal margin of ventral condyle** Open curve of semilandmarks along the proximal margin of the ventral condyle starting at the ventralmost point of the ventral condyle (LM7) and ending at the proximalmost point of the intercondylar groove (LM3), proceeding from ventral to dorsal (Fig. S10).



**Semilandmark series SL5. Proximal margin of dorsal condyle** Open curve of semilandmarks along the proximal margin of the dorsal condyle, starting at the proximalmost point of the intercondylar groove (LM3) and ending at the dorsodistal point of the dorsal condyle (LM8), proceeding from ventral to dorsal (Fig. S10).

**Semilandmark series SL6. Ventral margin of flexor process** Open curve of semilandmarks along the ventral margin of the flexor process, starting at its proximalmost point (LM12) and ending at the ventralmost point of the ventral condyle (LM7), proceeding from proximal to distal (Fig. S10).

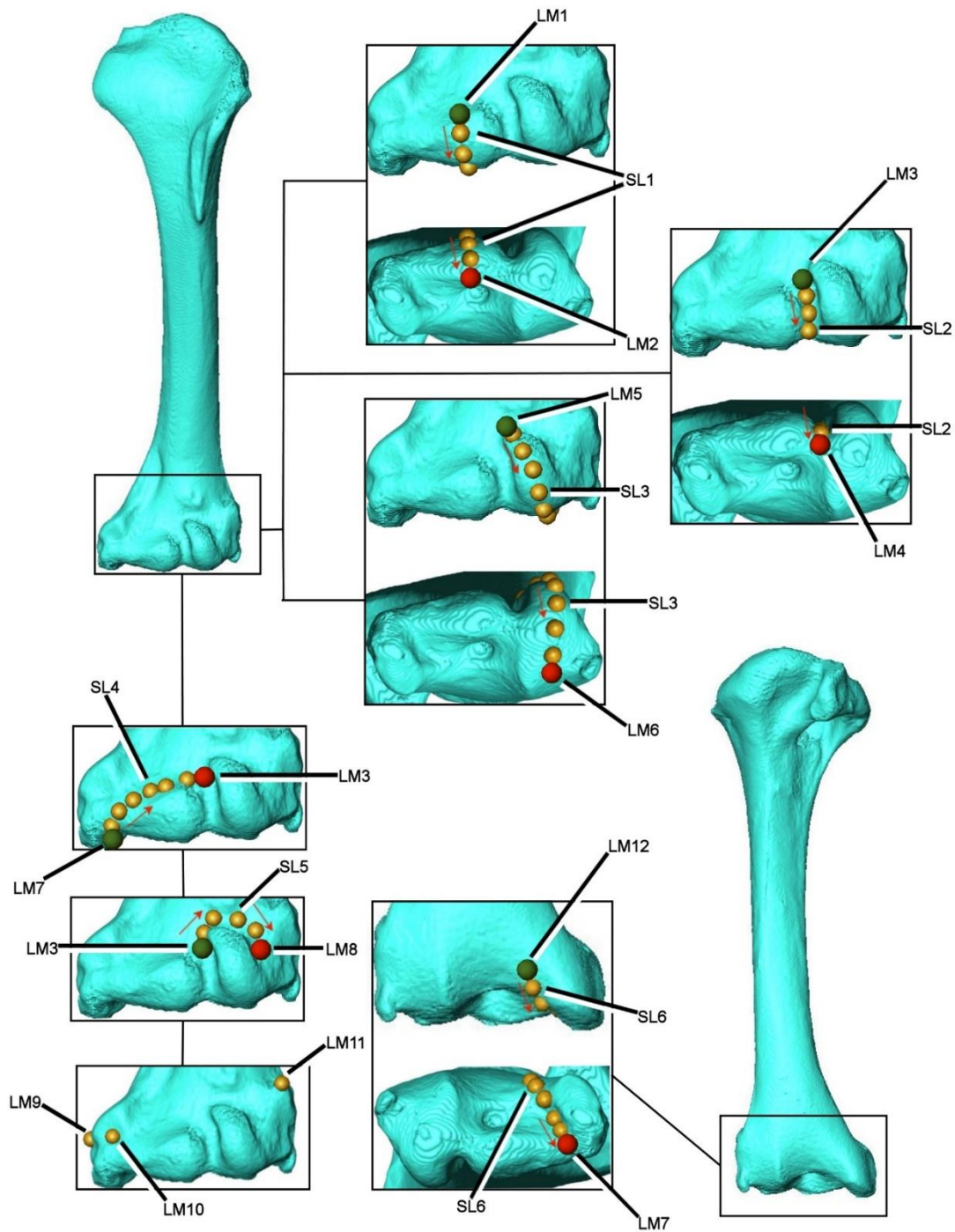
**Semilandmark series SL7. Bicipital crest and distal margin of ventral tubercle, dorsal-ventral axis** Open curve of semilandmarks along the bicipital crest and distal margin of the ventral tubercle, starting at the distalmost point of the bicipital crest (LM13) and ending at the distodorsal point of the ventral tubercle at the end of the incisura capitis (LM14), proceeding from ventral to dorsal (Fig. S11).

**Semilandmark series SL8. Bicipital crest, distal-proximal axis** Open curve of semilandmarks along dorsal margin of the ventral tubercle, along the incisura capitis, starting from the distodorsal point of the bicipital crest (LM14) and ending at the proximal end of the incisura capitis (LM15), proceeding from distal to proximal (Fig. S11).

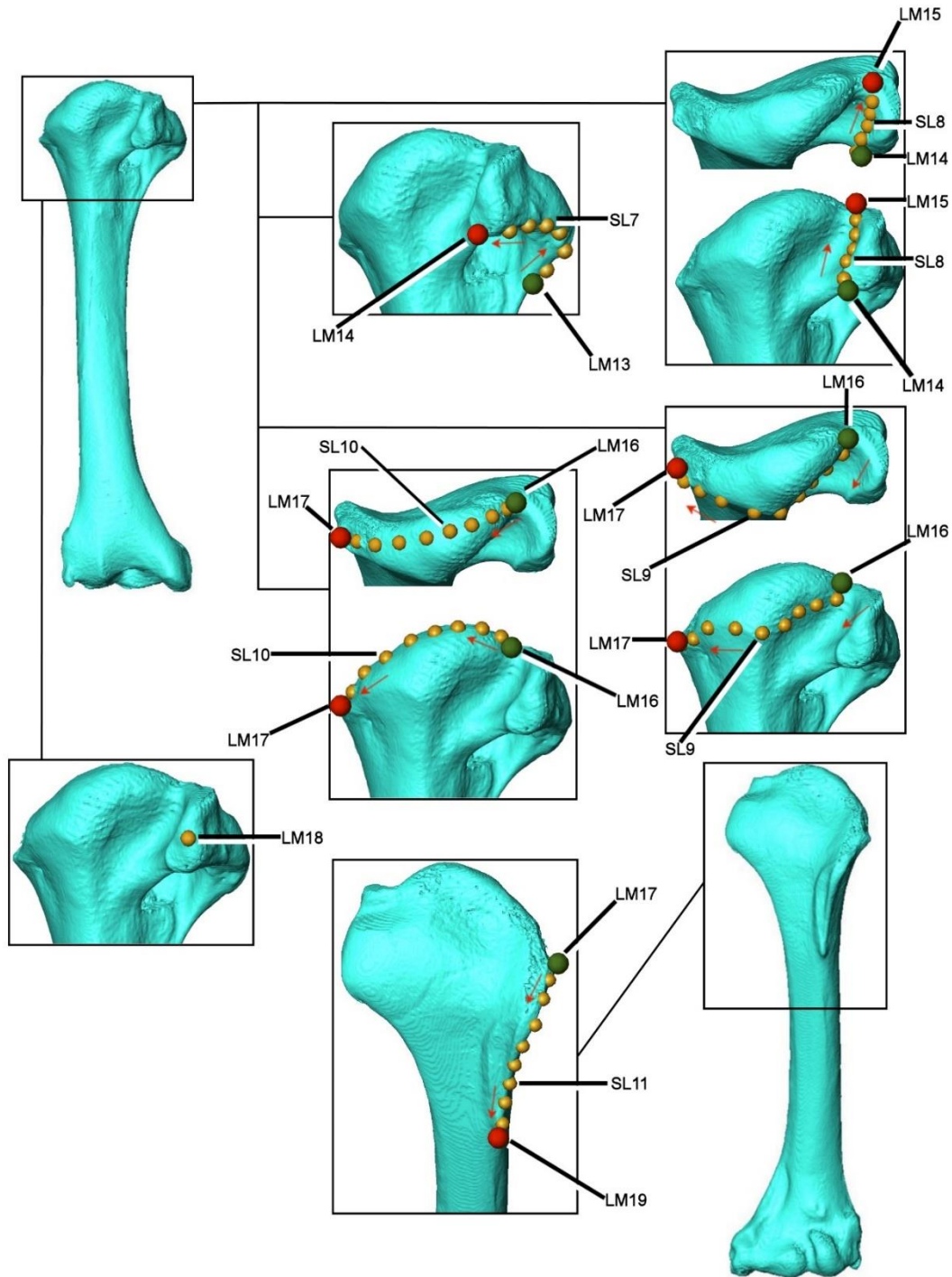
**Semilandmark series SL9. Humeral head, caudal margin** Open curve of semilandmarks along the ventral margin of the humeral head, starting at the ventralmost point of the head (LM16) and ending at the proximalmost point of the deltopectoral crest (LM17), proceeding from ventral to dorsal (Fig. S11).

**Semilandmark series SL10. Humeral head, proximal surface** Open curve of semilandmarks along the proximal surface of the humeral head, starting at the ventralmost point of the head (LM16) and ending at the proximalmost point of the deltopectoral crest (LM17), proceeding from ventral to dorsal (Fig. S11).

**Semilandmark series SL11. Crista deltopectoralis** Open curve of semilandmarks along the deltopectoral crest, starting at its proximalmost point (LM17) and ending at its distalmost point (LM19), proceeding from proximal to distal (Fig. S11).



**Figure S10: Humerus landmarks and semilandmarks.** Humerus landmarks (LM1–LM12) and semilandmark series (SL1–SL6) shown on the left humerus of *Menura novaehollandiae* (FMNH 336751) in cranial view (top-left and associated upper magnifications; lower magnifications are in distal view) and caudal view (bottom-right and associated upper magnification, lower magnification is in distal view). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.



**Figure S11: Humerus landmarks and semilandmarks.** Humerus landmarks (LM13–LM19) and semilandmark series (SL7–SL11) shown on the left humerus of *Menura novaehollandiae* (FMNH 336751) in caudal view (top-left and associated lower magnifications; upper magnifications are in proximal view) and cranial view (bottom-right and associated magnification). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Ulna

### **Landmark LM1. Dorsal cotyle, cranialmost point of contact with ventral cotyle**

The cranialmost point on the contact of the dorsal cotyle with the ventral cotyle (Fig. S12). This landmark marks the start of a series of semilandmarks around the margin of the dorsal cotyle (SL1, below).

### **Landmark LM2. Dorsal cotyle, caudalmost point of contact with crista**

**intercotylaris** The caudalmost point on the contact of the dorsal cotyle with the intercotylar crest (Fig. S12). This landmark marks the end of a series of semilandmarks around the margin of the dorsal cotyle (SL1, below).

**Landmark LM3. Olecranon, apex** The apex or greatest proximal projection of the olecranon (Fig. S12).

**Landmark LM4. Dorsal condyle, proximalmost point on caudal surface** The proximalmost point of the margin of the dorsal condyle on the caudal surface of the ulna (Fig. S12). This landmark marks the start of a series of semilandmarks around the caudodorsal margin of the dorsal condyle (SL3, below).

**Landmark LM5. Dorsal condyle, proximalmost point on cranial surface** The proximalmost point on the margin of the dorsal condyle on the cranial surface of the ulna (Fig. S12). This landmark marks the end of a series of semilandmarks around the caudodorsal margin of the dorsal condyle (SL3, below).

**Landmark LM6. Ventral condyle, caudalmost point** The apex or caudalmost point of the ventral condyle (Fig. S12).

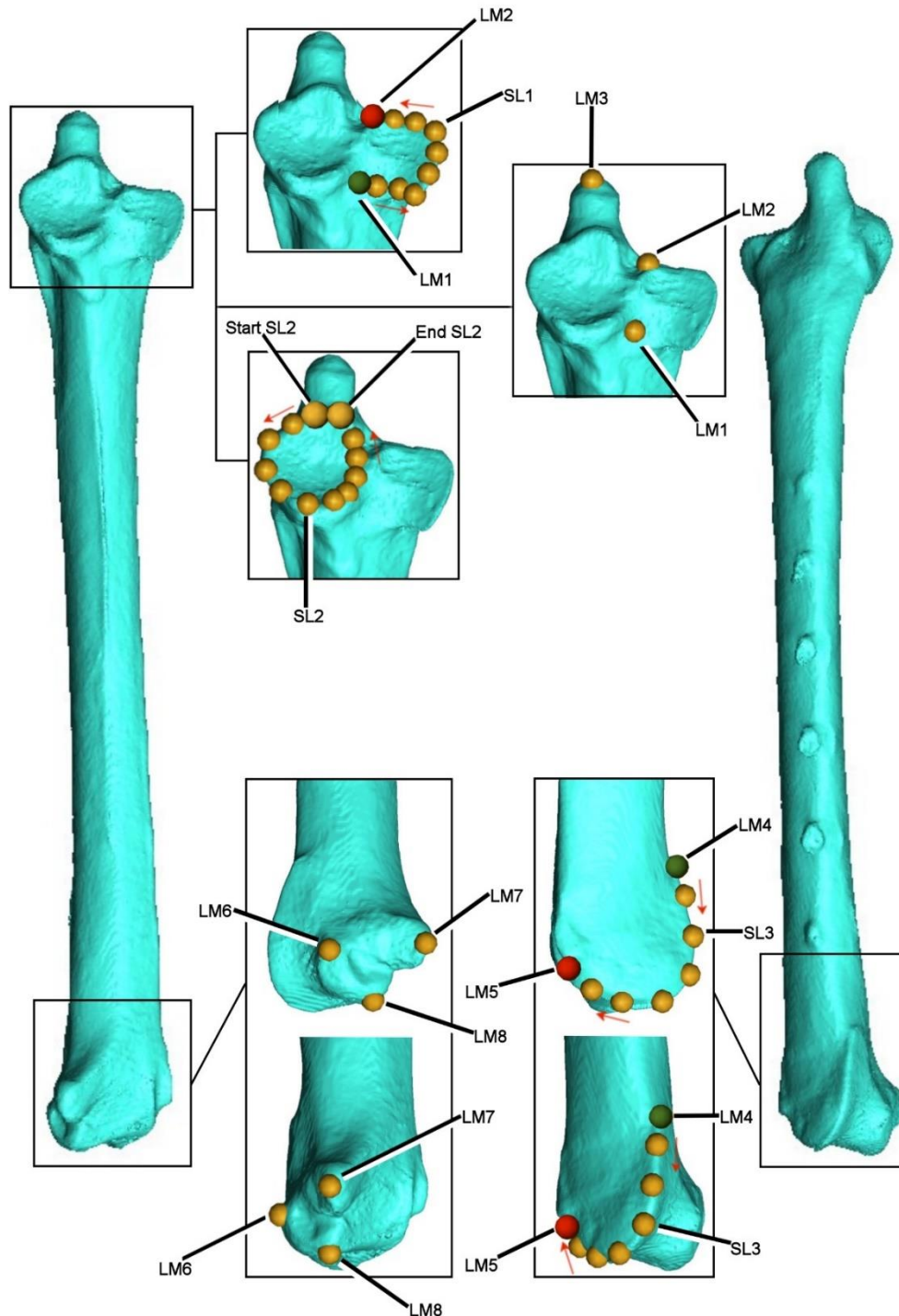
**Landmark LM7. Tuberculum carpale** (Fig. S12) The apex or ventral projection of the tuberculum carpale.

**Landmark LM8. Ventral condyle, cranialmost point** The cranialmost point of the ventral condyle (Fig. S12).

**Semilandmark series SL1. Margin of dorsal cotyle** Open curve of semilandmarks around the margin of the dorsal cotyle, its cranialmost point (LM1) and ending at the caudalmost point of its contact with the crista intercotylaris (LM2) (Fig. S12).

**Semilandmark series SL2. Ventral cotyle** Closed loop of semilandmarks along the ventral cotyle, starting from the proximal point in-line with the olecranon and ending just adjacent to it, proceeding anticlockwise as seen in left cranial view from dorsal to ventral and proximal to distal, then ventral to dorsal and distal to proximal (Fig. S12).

**Semilandmark series SL3. Dorsal condyle** Open curve of semilandmarks along the dorsal condyle, starting at the caudal proximalmost point (LM4) and ending at the cranial proximalmost point (LM5), proceeding from proximal to distal on the caudal surface, and distal to proximal on the cranial surface (Fig. S12).



**Figure S12: Ulna landmarks and semilandmarks.** Ulna landmarks (LM1–LM10) and semilandmark series (SL1–SL3) shown on the left ulna of *Menura novaehollandiae* (FMNH 336751) in cranial view (left and associated upper magnifications; left lower magnifications in cranioventral and cranial views) and caudal view (right and lower right magnifications in caudodorsal and caudal). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## **Radius**

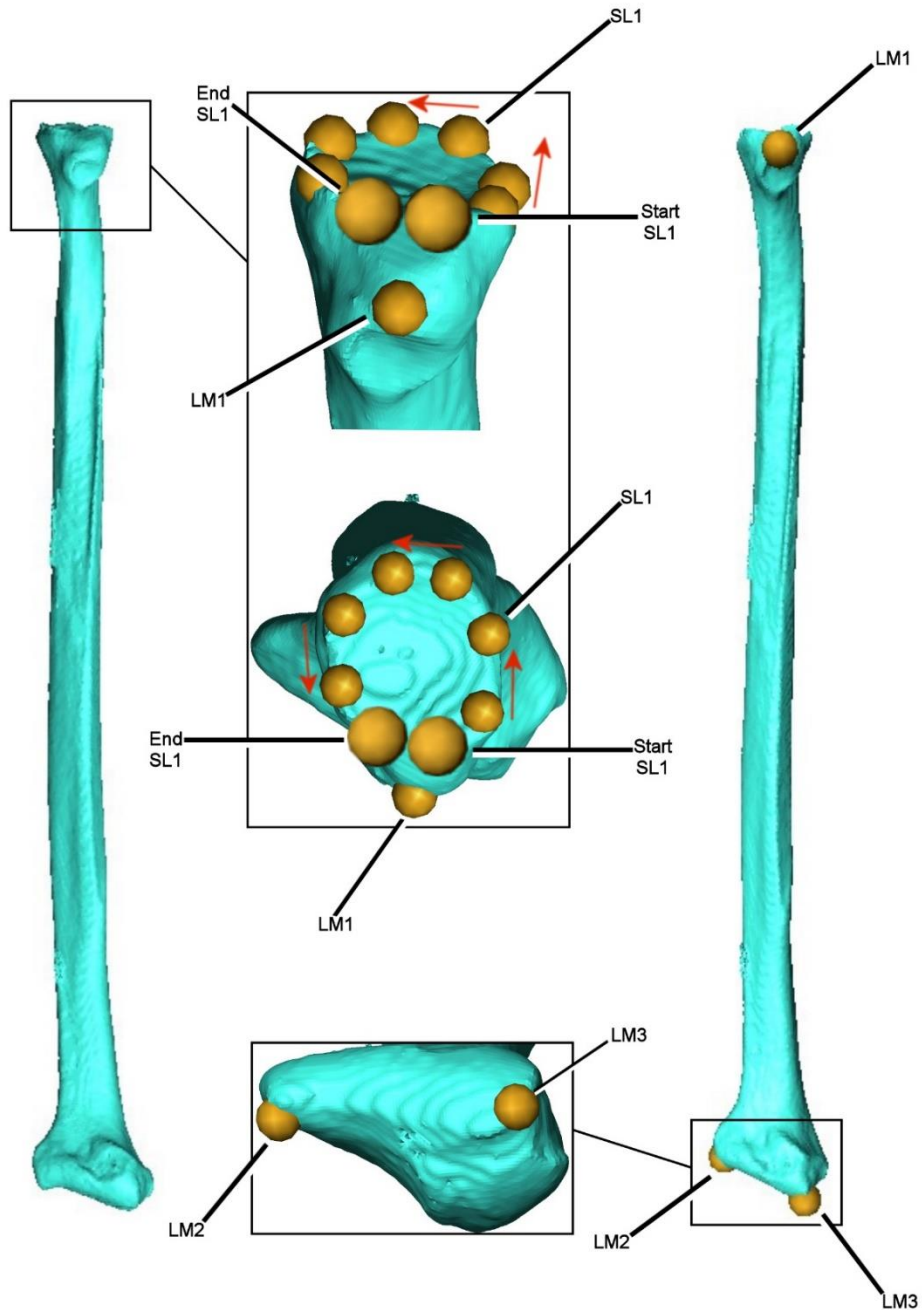
**Landmark LM1. Radial tuberosity** The proximal point of the radial tuberosity (Fig. S13).

**Landmark LM2. Ulnar articular surface** The apex or ventralmost point on the ulnar articular surface (Fig. S13).

**Landmark LM3. Carpus articular surface** The distalmost point on the articular surface for the carpus (Fig. S13).

**Semilandmark series SL1. Margin of the cotyla humeralis** Closed loop of semilandmarks around the margin of the humeral cotyle, starting from the its caudalmost point and ending just adjacent to it on the ventral side, proceeding anticlockwise as seen in left proximal view from ventral to dorsal and caudal to cranial, dorsal to ventral and cranial to caudal (Fig. S13).





**Figure S13: Radius landmarks and semilandmarks.** Radius landmarks (LM1–LM5) and semilandmark series (SL1) shown on the radius of *Menura novaehollandiae* (FMNH 336751) in caudal view (left, right and top magnification), proximal view (middle magnification) and distal view (bottom magnification). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## **Carpometacarpus**

**Landmark LM1. Trochlea carpalis, distalmost point on caudal surface of ventral margin** The distalmost point on the caudal surface of the ventral margin of the carpal trochlea (Fig. S14). This landmark marks the start of a series of semilandmarks around the margin of the carpal trochlea (SL1, below).

**Landmark LM2. Trochlea carpalis, distalmost point on caudal surface of dorsal margin** The distalmost point on the caudal surface of the dorsal margin of the carpal trochlea (Fig. S14). This landmark marks the end of a series of semilandmarks around the margin of the carpal trochlea (SL1, below).

**Landmark LM3. Processus pisiformis** The apex or cranioventral projection of the pisiform process (Fig. S14). This landmark marks the start of a series of semilandmarks along the caudoventral margin of the minor metacarpal (SL2, below).

**Landmark LM4. Digitalis minor, craniodistal apex of ventral surface** The craniodistal projection of the ventral surface of the minor digit (Fig. S14). This landmark marks the end of a series of semilandmarks along the caudoventral margin of the minor metacarpal (SL2, below).

**Landmark LM5. Proximal metacarpal synostosis** The proximalmost point on the proximal metacarpal synostosis on the ventral surface of the carpometacarpus (Fig. S14). This landmark marks the start of a series of semilandmarks along the ventral margin of the major metacarpal (SL3, below) and the end of a series of semilandmarks along the caudoventral margin of the minor metacarpal (SL4, below).

**Landmark LM6. Distal metacarpal synostosis** The proximalmost point on the distal metacarpal synostosis on the ventral surface of the carpometacarpus (Fig. S14). This landmark marks the start of a series of semilandmarks along the caudoventral margin of the minor metacarpal (SL4, below) and the end of a series of semilandmarks along the ventral margin of the major metacarpal (SL3, below).

**Landmark LM7. Processus extensorius** The apex or cranial projection of the extensor process (Fig. S15).

**Landmark LM8. Processus alularis** The apex or distal projection of the alular process (Fig. S15).

**Landmark LM9. Proximal metacarpal meeting point, dorsal surface** Proximalmost point of the groove between the major and minor metacarpus on the dorsal surface (Fig. S15). This landmark marks the start of a series of semilandmarks along the caudodorsal margin of the major metacarpal (SL5, below) and the end of a series of semilandmarks along the dorsal margin of the minor metacarpal (SL6, below).

**Landmark LM10. Sulcus interosseus** Proximalmost point of the interosseus sulcus on the dorsal surface (Fig. S15). This landmark marks the start of a series of semilandmarks along the dorsal margin of the minor metacarpal (SL6, below) and the end of a series of semilandmarks along the caudodorsal margin of the major metacarpal (SL5, below).



**Landmark LM11. Major digit articular surface, cranialmost point** The cranialmost point on the articular surface for the major digit (Fig. S15). This landmark marks the start of a series of semilandmarks along the dorsal margin of the articular surface (SL7, below) and the end of a series of semilandmarks along the ventral margin of the articular surface (SL9, below).

**Landmark LM12. Major digit articulation, caudodorsal point** The caudodorsal point of the articular surface for the major digit (Fig. S15). This landmark marks the start of a series of semilandmarks along the caudal margin of the articular surface (SL8, below) and the end of a series of semilandmarks along the dorsal margin of the articular surface (SL7, below).

**Landmark LM13. Major digit articulation, caudoventral point** The caudoventral point of the articular surface for the major digit (Fig. S15). This landmark marks the start of a series of semilandmarks along the ventral margin of the articular surface (SL9, below) and the end of a series of semilandmarks along the caudal margin of the articular surface (SL8, below).

**Semilandmark series SL1. Trochlea carpalis margin** Open curve of semilandmarks along the margin of the carpal trochlea, starting from the distalmost point caudoventrally (LM1) and ending at the distalmost point caudodorsally (LM2), proceeding from distal to proximal, around dorsally, and then from proximal to distal (Fig. S14).

**Semilandmark series SL2. Minor metacarpal, caudoventral margin** Open curve of semilandmarks along the caudoventral margin of the minor metacarpal, starting at the pisiform process (LM3) and ending at the craniodistal apex of the minor digit (LM4), proceeding from proximal to distal (Fig. S14).

**Semilandmark series SL3. Major metacarpal, ventral margin** Open curve of semilandmarks along the ventral surface of the major metacarpal, starting at the proximal metacarpal synostosis (LM5) and ending at the distal metacarpal synostosis (LM6), proceeding from proximal to distal (Fig. S14).

**Semilandmark series SL4. Minor metacarpal, cranioventral margin** Open curve of semilandmarks along the cranioventral surface of the minor metacarpal, starting at the distal metacarpal synostosis (LM6) and ending at the proximal metacarpal synostosis (LM5), proceeding from distal to proximal (Fig. S14).

**Semilandmark series SL5. Major metacarpal, caudodorsal margin** Open curve of semilandmarks along the caudodorsal margin of the major metacarpal, starting at the proximal metacarpal meeting point (LM9) and ending at the sulcus interosseus (LM10), proceeding from proximal to distal (Fig. S15).

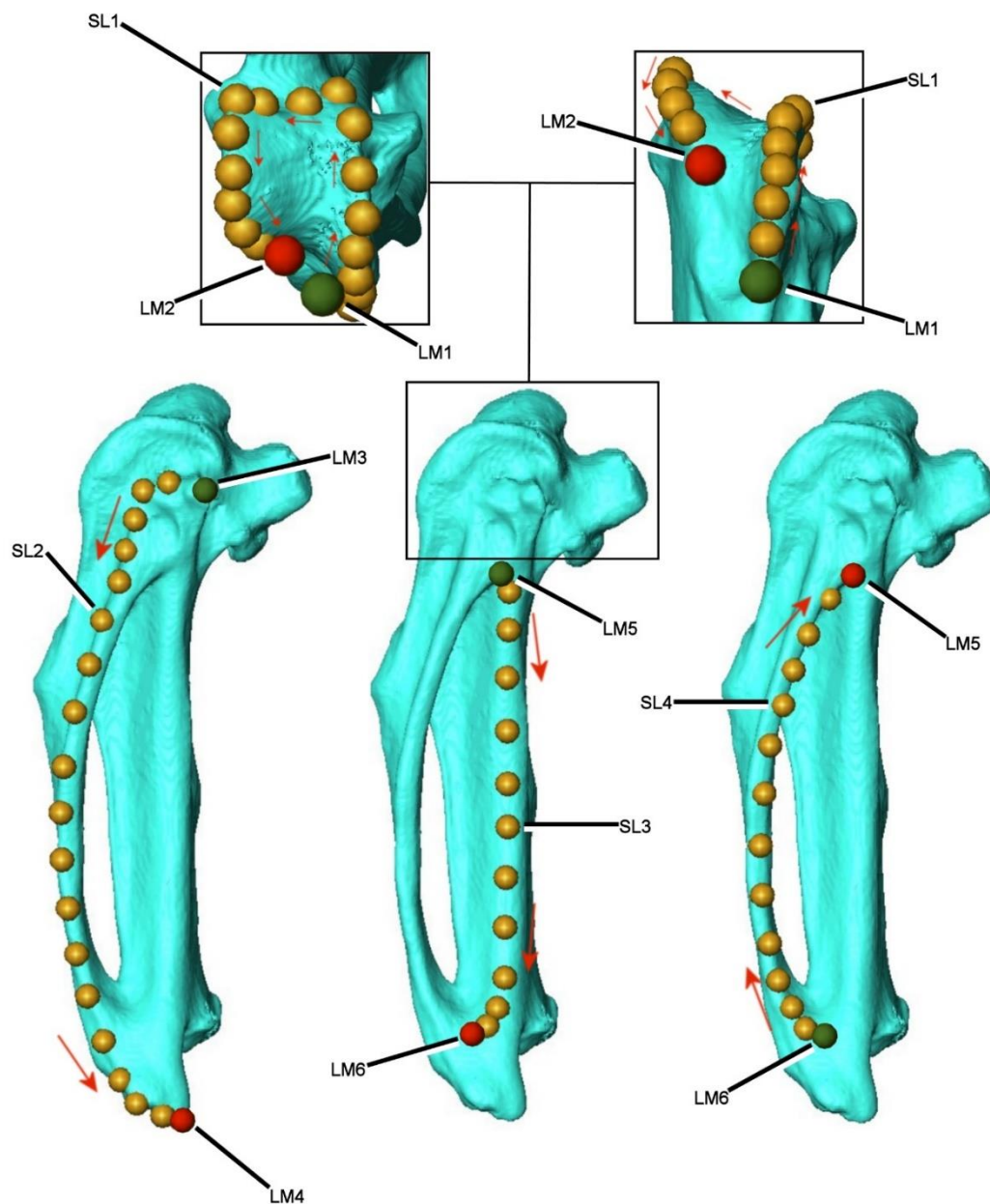
**Semilandmark series SL6. Minor metacarpal, dorsal surface** Open curve of semilandmarks along the dorsal surface of the minor metacarpal, starting at the sulcus interosseus (LM10) and ending at the proximal metacarpal meeting point (LM9), proceeding from distal to proximal (Fig. S15).

**Semilandmark series SL7. Major digit articular surface, dorsal margin** Open curve of semilandmarks along the dorsal surface of the major digit articulation,

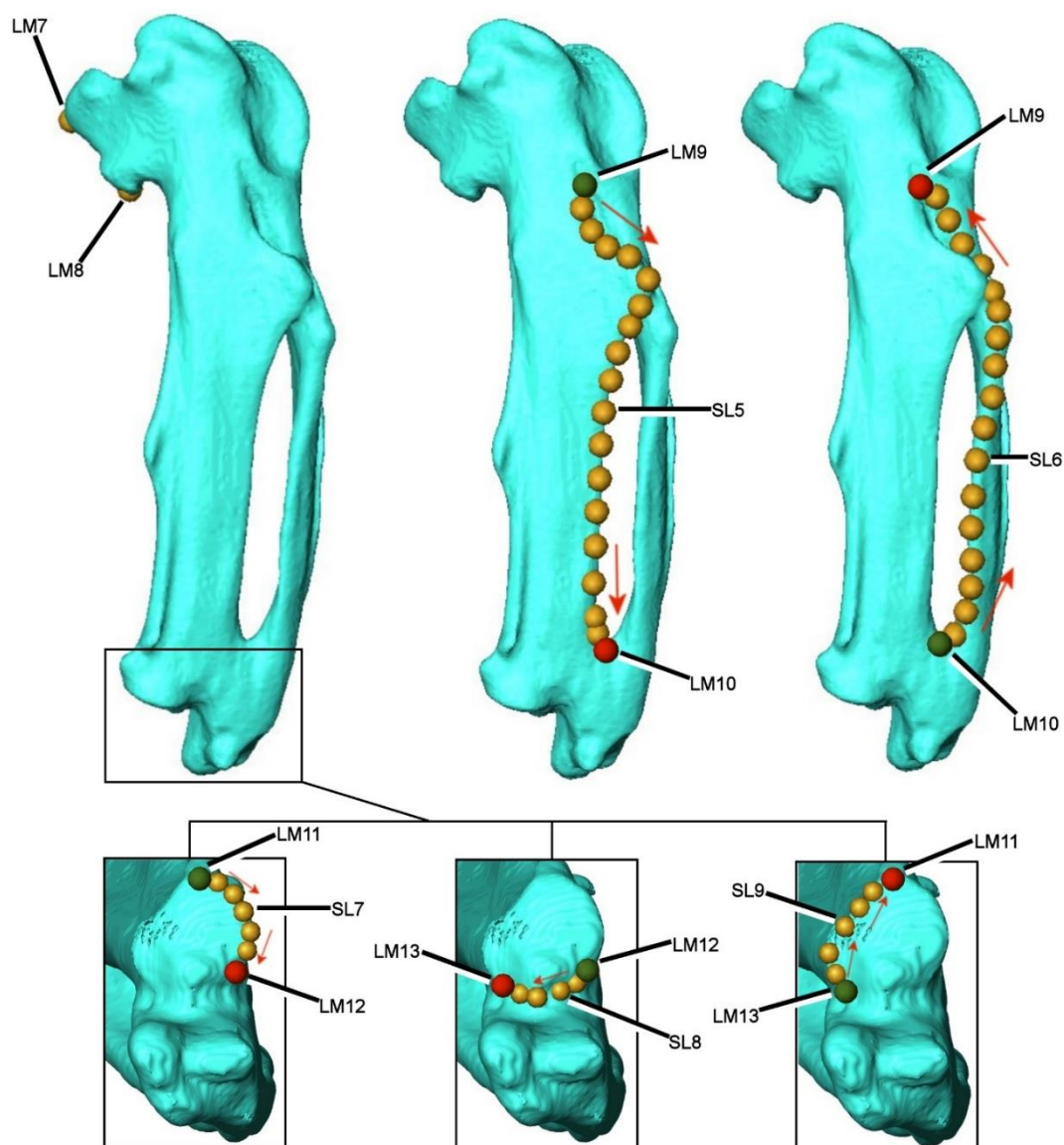
starting at the cranialmost point (LM11) and ending at the dorsocaudal point (LM12) (Fig. S15).

**Semilandmark series SL8. Major digit articular surface, caudal margin** Open curve of semilandmarks along the caudal surface of the major digit articulation, starting at the dorsocaudal point (LM12) and ending at the ventrocaudal point (LM13) (Fig. S15).

**Semilandmark series SL9. Major digit articular surface, ventral margin** Open curve of semilandmarks along the ventral surface of the major digit articulation, starting at the ventrocaudal point (LM13) and ending at the cranialmost point (LM11) (Fig. S15).



**Figure S14: Carpometacarpus landmarks and semilandmarks.** Carpometatarsus landmarks (LM1–LM6) and semilandmark series (SL1–SL4) shown on the left carpometacarpus of *Menura novaehollandiae* (FMNH 336751) in ventral view (lower panels), proximal view (top-left magnification) and caudal view (top-right magnification). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.



**Figure S15: Carpometacarpus landmarks and semilandmarks.** Carpometacarpus landmarks (LM7–LM13) and semilandmark series (SL5–SL9) shown on the left carpometacarpus of *Menura novaehollandiae* (FMNH 336751) in dorsal view (upper panels) and distal view (lower panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Femur

**Landmark LM1. Crista trochanteris, distalmost point** Distalmost point of the trochanteric crest on its craniolateral surface (Fig. S16). This landmark marks the start of a series of semilandmarks along the trochanteric crest (SL1, below).

**Landmark LM2. Crista trochanteris, caudalmost point** The caudalmost point on the proximal surface of the trochanteric crest (Fig. S16). This landmark marks the end of a series of semilandmarks along the trochanteric crest (SL1, below).

**Landmark LM3. Fovea capitis** The centre of the fovea capitis (Fig. S16).

**Landmark LM4. Epicondylus lateralis** Greatest projection or apex of the lateral epicondyle (Fig. S16).

**Landmark LM5. Medial condyle, proximolateral point on caudal surface** The proximolateral point on the medial condyle where it contacts the intercondylar sulcus (Fig. S16). This landmark marks the start of a series of semilandmarks along the lateral margin of the medial condyle along the intercondylar sulcus (SL3, below).

**Landmark LM6. Intercondylar sulcus, distolateral point** The distolateral point on the intercondylar sulcus where it contacts the lateral condyle (Fig. S16). This landmark marks the end of a series of semilandmarks along the medial condyle and intercondylar sulcus (SL3, below).

**Landmark LM7. Crista tibiofibularis, proximalmost point** The proximalmost point of the crista tibiofibularis on the caudal surface of the lateral condyle (Fig. S17). This landmark marks the start of a series of semilandmarks along the crista tibiofibularis and medial margin of the lateral condyle (SL4, below).

**Landmark LM8. Lateral condyle, proximalmost point of medial margin on cranial surface** The proximalmost point on the medial margin of the lateral condyle on the cranial surface of the femur (Fig. S17). This landmark marks the end of a series of semilandmarks along the crista tibiofibularis and medial margin of the lateral condyle (SL4, below).

**Landmark LM9. Intercondylar sulcus, proximolateral point** The proximolateral point of the intercondylar sulcus, where it contacts the lateral condyle (Fig. S17). This landmark marks the start of a series of semilandmarks along the lateral margin of the intercondylar sulcus (SL5, below).

**Landmark LM10. Lateral condyle cranial surface depression, proximalmost point** The proximalmost point of the depression adjacent to the lateral condyle on the cranial surface (Fig. S17). This landmark marks the end of a series of semilandmarks along the lateral condyle depression (SL5, below).

**Landmark LM11. Condylar ridge, lateralmost point on caudal surface** The lateralmost point of the ridge marking the dorsal margin of the condyles and ventral margin of the popliteal fossa (Fig. S17). This landmark marks the start of a series of semilandmarks along the condylar ridge and medial margin of the medial condyle (SL6, below).

**Landmark LM12. Medial condyle cranial surface, proximalmost point** The proximalmost point of the medial margin of the medial condyle on the cranial surface (Fig. S17). This landmark marks the end of a series of semilandmarks along the condylar ridge and medial margin of the medial condyle (SL6, below).

**Landmark LM13. Trochlea fibularis, proximocaudal point** The proximocaudal point on the trochlea fibularis (Fig. S17). This landmark marks the start of a series of semilandmarks along the caudal margin of the trochlea fibularis (SL7, below).

**Landmark LM14. Trochlea fibularis, distocaudal point** The distocaudal point on the trochlea fibularis (Fig. S17). This landmark marks the end of a series of semilandmarks along the caudal margin of the trochlea fibularis (SL7, below).

**Landmark LM15. Trochlea fibularis crista tibiofibularis depression, proximalmost point** The proximalmost point in the depression between the trochlea fibularis and crista tibiofibularis (Fig. S17). This landmark marks the start of a series of semilandmarks along the depression between the trochlea fibularis and crista tibiofibularis (SL8, below).

**Landmark LM16. Trochlea fibularis crista tibiofibularis depression, distalmost point** The distalmost point in the depression between the trochlea fibularis and crista tibiofibularis (Fig. S17). This landmark marks the end of a series of semilandmarks along the depression between the trochlea fibularis and crista tibiofibularis (SL8, below).

**Semilandmark series SL1. Crista trochanteris** Open curve of semilandmarks along the trochanteric crest, starting from its distalmost point (LM1) and ending at its caudalmost point (LM2), proceeding from craniodistal to proximocaudal (Fig. S16).

**Semilandmark series SL2. Femoral head margin** Closed loop of semilandmarks around the margin of the femoral head, starting from a point distal to the fovea capitis and ending just adjacent to that. Proceeding anticlockwise as seen in medial view of the left femur, initially from caudal to cranial (Fig. S16).

**Semilandmark series SL3. Lateral margin of medial condyle and intercondylar sulcus** Open curve of semilandmarks along the lateral margin of the medial condyle along the intercondylar sulcus, starting from the proximolateral point of the medial condyle (LM5) and ending at the distolateral point of the intercondylar sulcus where it contacts the lateral condyle (LM6). Proceeding from proximal to distal then medial to lateral along the cranial margin of the intercondylar sulcus (Fig. S16).

**Semilandmark series SL4. Crista tibiofibularis and medial margin of lateral condyle** Open curve of semilandmarks along the crista tibiofibularis and medial margin of the lateral condyle, starting from the proximalmost point on the crista tibiofibularis (LM7) and ending at the proximalmost point on the cranial surface of the lateral condyle (LM8). Proceeding distally from a proximocaudal origin, and then proximocranially (Fig. S17).

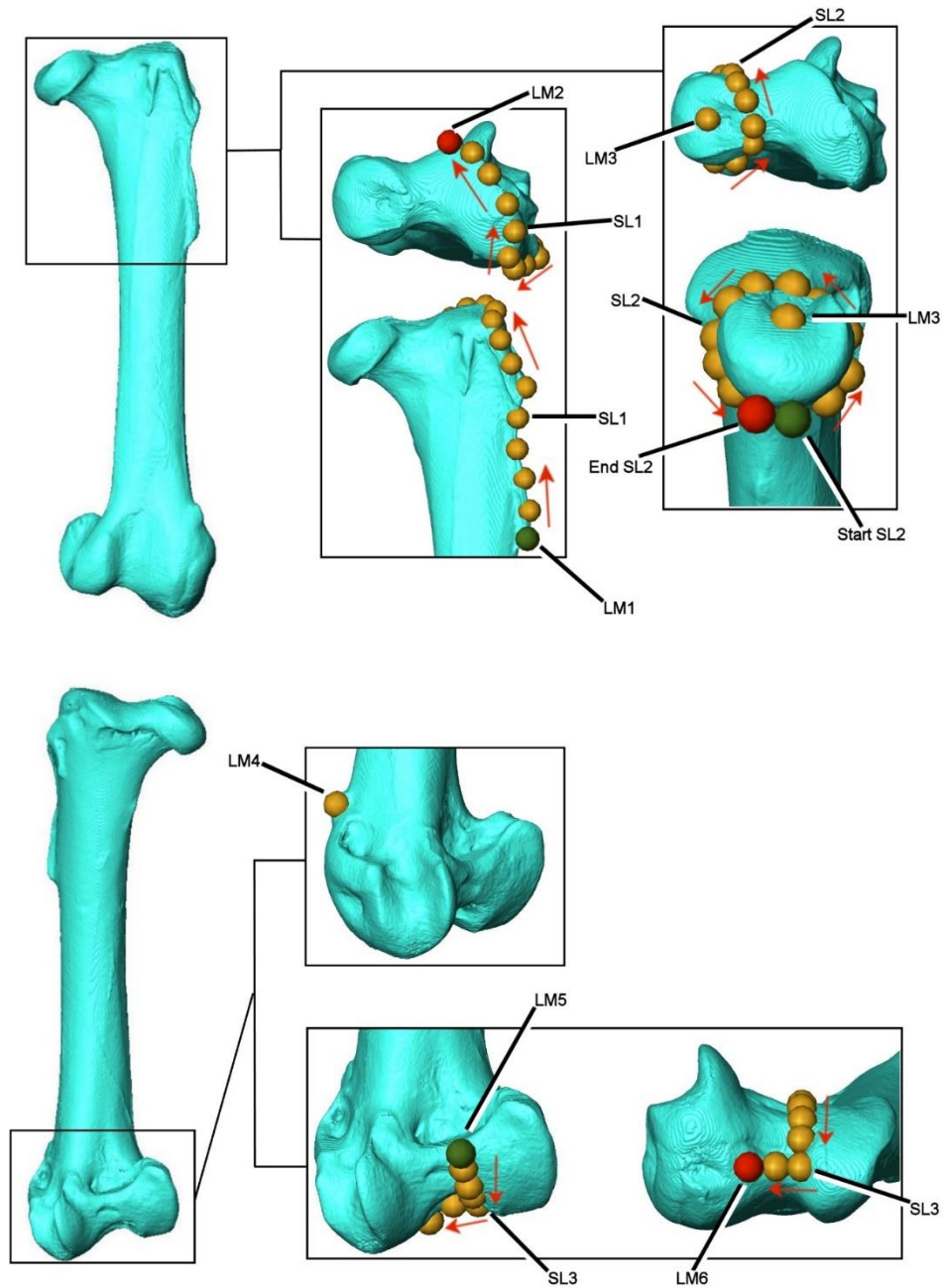
**Semilandmark series SL5. Lateral margin of intercondylar sulcus** Open curve of semilandmarks along the lateral margin of the intercondylar sulcus where it contacts the base of the crista tibiofibularis and lateral condyle, starting at the proximolateral

point of the intercondylar sulcus (LM9) and ending at its proximalmost point (LM10). Proceeding distally from a caudoproximal origin, then proximocranially (Fig. S17).

**Semilandmark series SL6. Margin of condylar ridge and medial condyle** Open curve of semilandmarks along the condylar ridge and medial condyle, starting from the lateralmost point of the condylar ridge (LM11) and ending at the proximalmost point on the cranial surface of the medial condyle (LM12). Proceeding from lateral to medial on the caudal surface of the ridge, then craniodistally along the medial margin of the medial condyle, and then cranioproximally (Fig. S17).

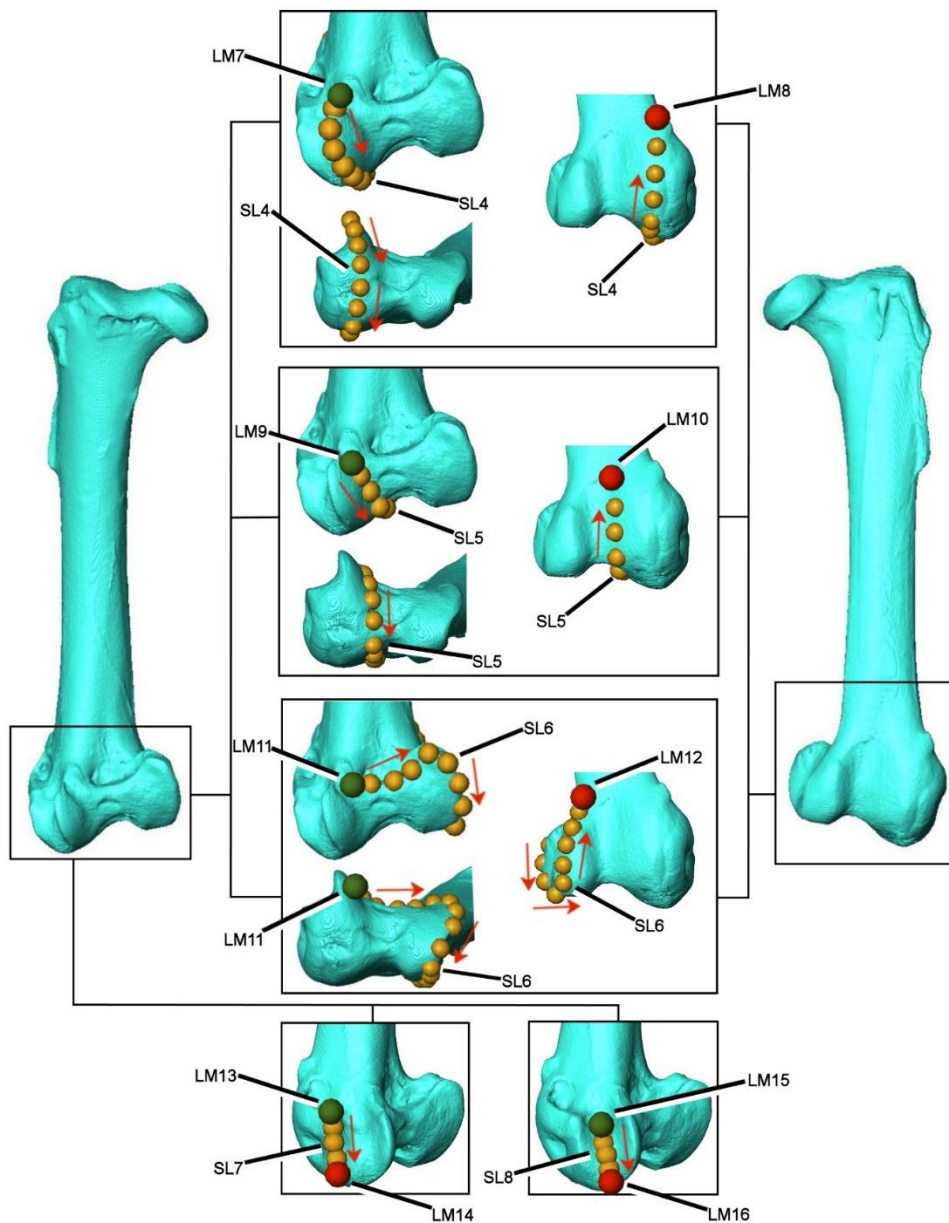
**Semilandmark series SL7. Trochlea fibularis** Open curve of semilandmarks along the caudal margin of the trochlea fibularis, starting from its proximalmost point (LM13) and ending at its distalmost point (LM14), proceeding from proximal to distal (Fig. S17).

**Semilandmark series SL8. Trochlea fibularis crista tibiofibularis depression** Open curve of semilandmarks along the lateral sulcus along the base of the crista tibiofibularis, starting from its proximalmost point (LM15) and ending at its distalmost point (LM16), proceeding from proximal to distal (Fig. S17).



**Figure S16: Femur landmarks and semilandmarks.** Femur landmarks (LM1–LM6) and semilandmark series (SL1–SL3) shown on the left femur of *Menura novaehollandiae* (FMNH 336751) in cranial view (top-left and associated, lower magnifications; upper magnifications are in proximal view) and in caudal view (bottom-left and associated bottom-left magnification; upper magnification is in caudolateral view and bottom-right magnification is in distal view). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.





**Figure S17: Femur landmarks and semilandmarks.** Femur landmarks (LM7–LM16) and semilandmark series (SL4–SL8) shown on the left femur of *Menura novaehollandiae* (FMNH 336751) in caudal view (left and associated upper left magnifications), cranial view (right and associated right magnifications), distal views (lower left magnifications) and caudolateral (lower panels). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## **Tibiotarsus**

**Landmark LM1. Cranial cnemial crest, distalmost point** The distalmost point on the cranial cnemial crest where it merges with the shaft (Fig. S18). This landmark marks the start of a series of semilandmarks along the cnemial crests (SL1, below).

**Landmark LM2. Lateral cnemial crest, lateralmost point** The lateralmost point of the lateral cnemial crest (Fig. S18). This landmark marks the end of a series of semilandmarks along the cnemial crests (SL1, below) and the start of a series of semilandmarks along the lateral margin of the proximal articular surface (SL2, below).

**Landmark LM3. Caudal intercondylar notch** The indentation in the caudal surface of the tibia, between the lateral and medial condyles of the proximal articular surface (Fig. S18). This landmark marks the end of a series of semilandmarks along the lateral margin of the proximal articular surface (SL2, below) and the start of a series of semilandmarks along the medial margin of the proximal articular surface (SL3, below).

**Landmark LM4. Meeting point of medial margin of proximal articular surface and cranial cnemial crest** The contact between the crest forming the medial margin of the proximal articular surface and the caudal part of the cranial cnemial crest (Fig. S18). This landmark marks the end of a series of semilandmarks along the medial margin of the proximal articular surface (SL3, below).

**Landmark LM5. Crista fibularis, distalmost point** The distalmost point of the crista fibularis where it merges with the shaft of the tibia (Fig. S18). This landmark marks the start of a series of semilandmarks along the crista fibularis (SL4, below).

**Landmark LM6. Crista fibularis, proximalmost point** The proximalmost point on the crista fibularis where it merges with the shaft of the tibia (Fig. S18). This landmark marks the end of a series of semilandmarks along the crista fibularis (SL4, below).

**Landmark LM7. Medial condyle, proximalmost point on cranial surface** The proximalmost point of the medial condyle on its cranial surface where it meets the shaft of the tibiotarsus (Fig. S18). This landmark marks the start of a series of semilandmarks around the margins of the distal condyles (SL5, below).

**Landmark LM8. Lateral condyle, proximalmost point on cranial surface** The proximalmost position of the lateral condyle on the cranial surface where it meets the shaft of the tibiotarsus (Fig. S18). This landmark marks the end of a series of semilandmarks around the margins of the distal condyles (SL5, below).

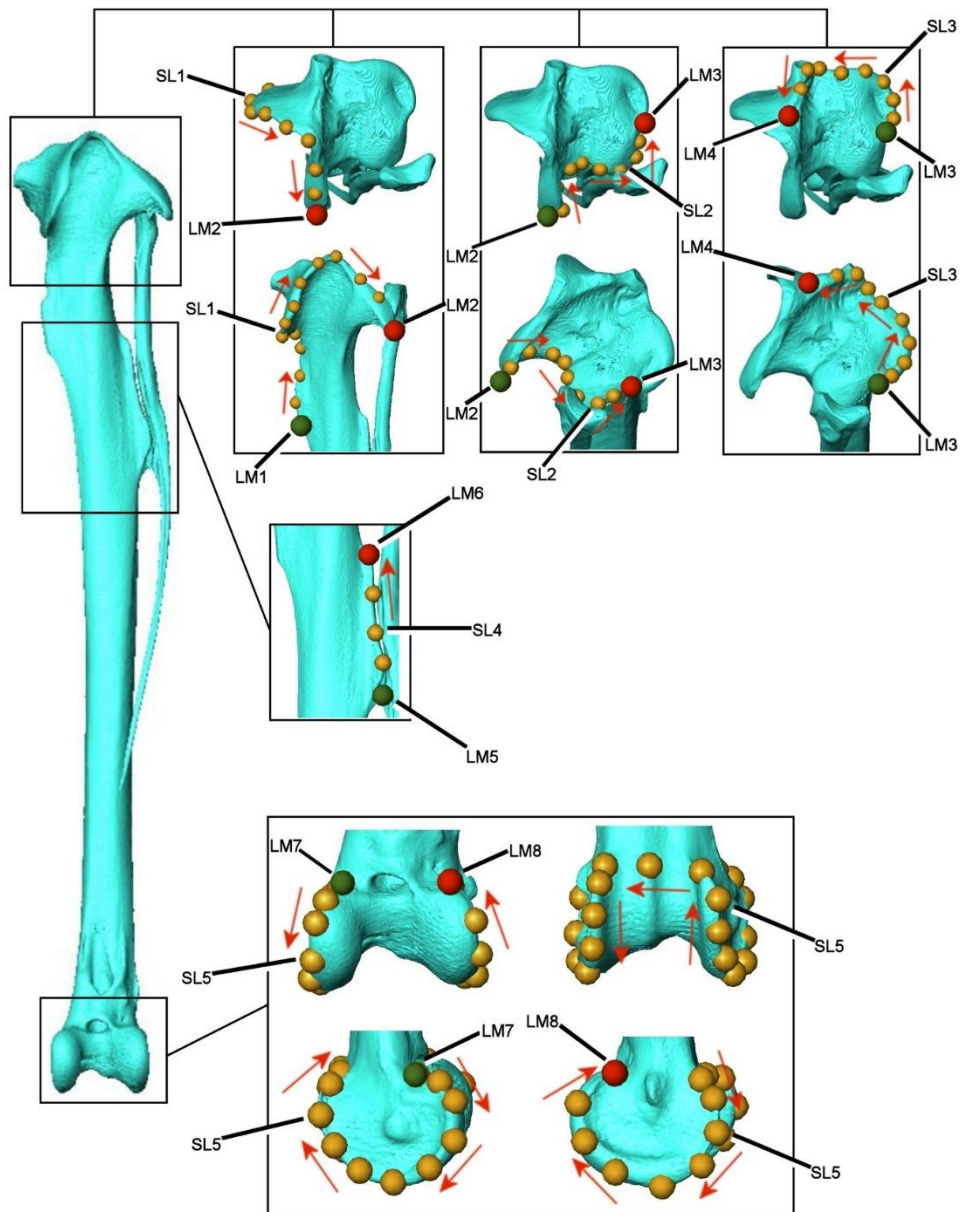
**Semilandmark series SL1. Cnemial crests** Open curve of semilandmarks along the cnemial crests, starting from the distalmost point of the cranial cnemial crest (LM1) and ending at the lateralmost point of the lateral cnemial crest (LM2), proceeding from distal to proximal along the cranial cnemial crest, and then medial to lateral along the lateral cnemial crest (Fig. S18).

**Semilandmark series SL2. Lateral margin of proximal articular surface** Open curve of semilandmarks along the lateral margin of the proximal articular surface, starting from the lateralmost point of the lateral cnemial crest (LM2) and ending at the caudal intercondylar notch (LM3) (Fig. S18). Proceeding craniolateral to caudomedial.

**Semilandmark series SL3. Medial margin of proximal articular surface** Open curve of semilandmarks along the medial margin of the proximal articular surface, starting at the caudal intercondylar notch (LM3) and ending at the meeting point between the crest margin the medial margin of the proximal articular surface with the caudal part of the cranial cnemial crest (LM4), proceeding from caudal to cranial (Fig. S18).

**Semilandmark series SL4. Crista fibularis** Open curve of semilandmarks along the crista fibularis, starting from its distalmost point (LM5) and ending at its proximalmost point (LM6), proceeding from distal to proximal (Fig. S18).

**Semilandmark series SL5. Margins of distal condyles** Open curve of semilandmarks around the margins of the lateral and medial condyles of the distal tibia, starting from the proximalmost point on the cranial surface of the medial condyle (LM7) and ending at the proximalmost position on the cranial surface of the lateral condyle (LM8) (Fig. S18).



**Figure SX: Tibiotarsus landmarks and semilandmarks.** Tibiotarsus landmarks (LM1–LM8) and semilandmark series (SL1–SL5) shown on the tibiotarsus of *Menura novaehollandiae* (FMNH 336751) in cranial view (left, bottom left magnification on upper panel, middle panel and top left magnification of lower panel), proximo craniolateral view (bottom centre and bottom right magnification on upper panel), dorsal view (top right magnification of lower panel), proximal view (top magnification on upper panel), medial view (bottom left magnification on lower panel) and lateral view (bottom right magnification on lower panel). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.

## Tarsometatarsus

**Landmark LM1. Eminentia intercotylaris** The apex or point of greatest projection of the intercotylar eminence between the lateral and medial cotyles (Fig. S19).

**Landmark LM2. Crista medialis hypotarsi, dorsoproximal point** The dorsoproximal point of the medial hypotarsal crest where it contacts the body of the tarsometatarsus (Fig. S19). This landmark marks the start of a series of semilandmarks along the medial hypotarsal crest (SL3, below).

**Landmark LM3. Medial crista hypotarsi, dorsodistal point** The dorsodistal point of the medial hypotarsal crest where it merges with the shaft of the tarsometatarsus (Fig. S19). This landmark marks the end of a series of semilandmarks along the medial hypotarsal crest (SL3, below).

**Landmark LM4. Distal vascular foramen** The distalmost point on the plantar surface of the distal vascular foramen (Fig. S19).

**Landmark LM5. Trochlea II, plantarmost point** The plantarmost point on the medial ligament pit of trochlea II (Fig. S19).

**Landmark LM6. Trochlea IV, plantarmost point** The plantarmost point on the lateral ligament pit of trochlea IV (Fig. S19).

**Landmark LM7. Trochlea II lateral ridge, proximalmost point on dorsal surface** The proximalmost point of the lateral ridge of the trochlea II on its dorsal surface (Fig. S19). This landmark marks the start of a series of semilandmarks around the lateral margin of trochlea II (SL4, below).

**Landmark LM8. Trochlea II lateral ridge, proximalmost point on plantar surface** The proximalmost point of the lateral ridge of trochlea II on its plantar surface (Fig. S19). This landmark marks the end of a series of semilandmarks around the lateral margin of trochlea II (SL4, below).

**Landmark LM9. Trochlea III medial ridge, proximalmost point on dorsal surface** The proximalmost point of the medial ridge of the trochlea III on its dorsal surface (Fig. S19). This landmark marks the start of a series of semilandmarks around the margin of trochlea III (SL5, below).

**Landmark LM10. Trochlea III lateral ridge, proximalmost point on dorsal surface** The proximalmost point of the lateral ridge of the trochlea III on its dorsal surface (Fig. S19). This landmark marks the end of a series of semilandmarks around the margin of trochlea III (SL5, below).

**Landmark LM11. Trochlea IV medial ridge, proximalmost point on its dorsal surface** The proximalmost point of the medial ridge of the trochlea IV on its dorsal surface (Fig. S19). This landmark marks the start of a series of semilandmarks around the medial margin of trochlea IV (SL6, below).

**Landmark LM12. Trochlea IV medial ridge, proximalmost point on its plantar surface** The proximalmost point of the medial ridge of the trochlea IV on its plantar surface (Fig. S19). This landmark marks the end of a series of semilandmarks around the medial margin of trochlea IV (SL6, below).

surface (Fig. S19). This landmark marks the end of a series of semilandmarks around the medial margin of trochlea IV (SL6, below).

**Semilandmark series SL1. Medial cotyle** Open curve of semilandmarks along the medial cotyle, starting from the dorsolateral point and ending just adjacent to it, proceeding anticlockwise as seen in the proximal view of the right tarsometatarsus, initially proceeding from lateral to medial (Fig. S19).

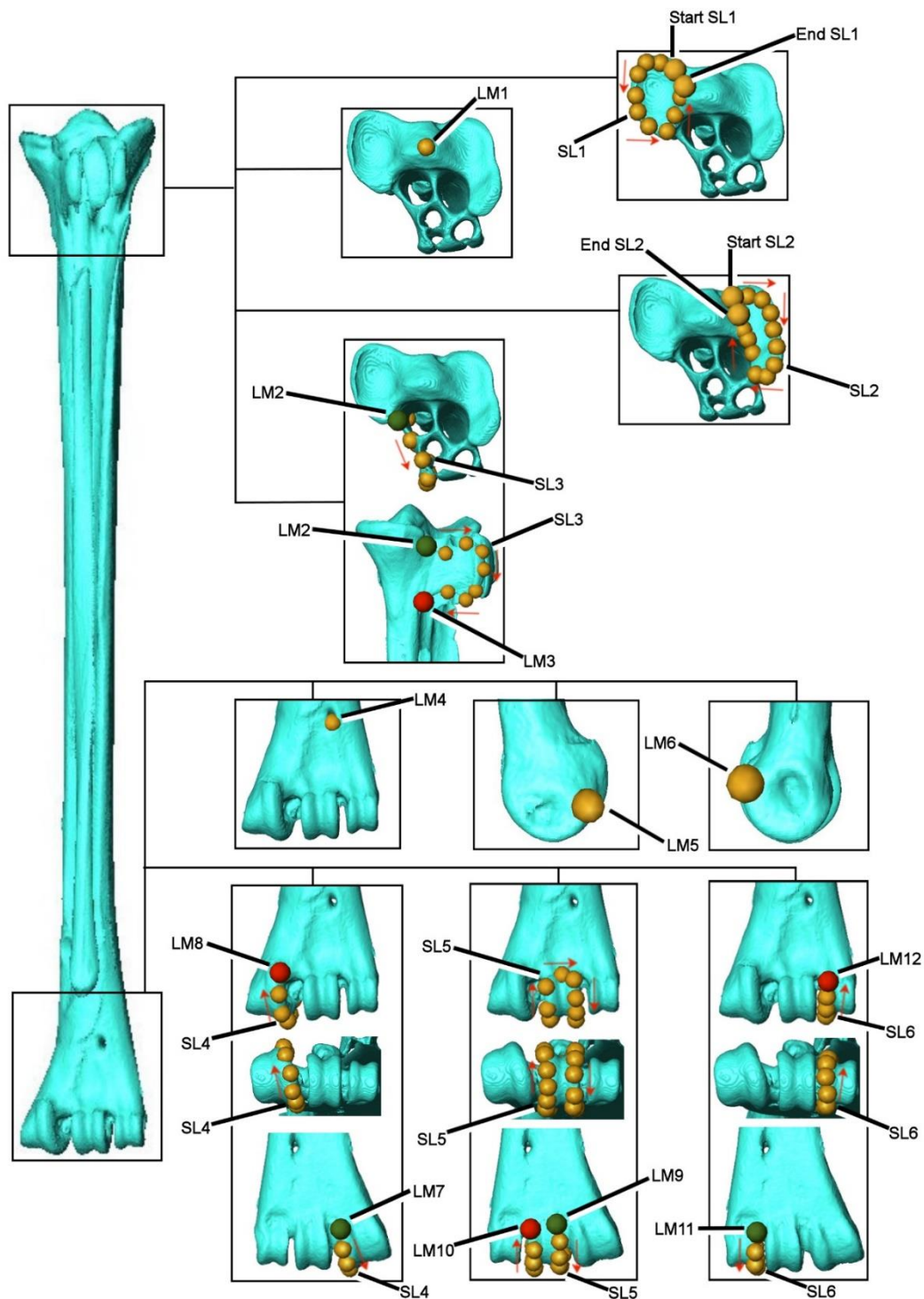
**Semilandmark series SL2. Lateral cotyle** Open curve of semilandmarks along the lateral cotyle, starting from the dorsomedial point and ending just adjacent to it, proceeding clockwise as seen in proximal view of the right tarsometatarsus, initially proceeding from medial to lateral (Fig. S19).

**Semilandmark series SL3. Crista medialis hypotarsi** Open curve of semilandmarks along the medial hypotarsal crest, starting from its dorsoproximal point (LM2) and ending at its dorsodistal point where it merges with the shaft of the tarsometatarsus (LM3), proceeding from dorsal to proximal to distal (Fig. S19).

**Semilandmark series SL4. Trochlea II, lateral margin** Open curve of semilandmarks along the lateral margin of trochlea II, starting from the proximalmost point on its dorsal surface (LM7) and ending at the proximalmost point on its plantar surface (LM8), proceeding distally from a proximodorsal position, and then proximopantarly (Fig. S19).

**Semilandmark series SL5. Trochlea III margin** Open curve of semilandmarks around the margin of trochlea III, starting from the proximalmost point of the medial ridge on its dorsal surface (LM9) and ending at the proximalmost point of the lateral ridge on its dorsal surface (LM10) (Fig. S19).

**Semilandmark series SL6. Trochlea IV, medial margin** curve of semilandmarks around the medial margin of trochlea IV, starting from the proximalmost point of the medial ridge on its dorsal surface (LM11) and ending at the proximalmost point of the medial ridge on its plantar surface (LM12), proceeding distally from a proximodorsal position, and then proximopantarly (Fig. S19).



**Figure S19: Tarsometatarsus landmarks and semilandmarks.** Tarsometatarsus landmarks (LM1–LM12) and semilandmark series (SL1–SL4) shown on the tarsometatarsus of *Menura novaehollandiae* (FMNH 336751) in proximal view (left and top of lower magnifications), proximal view (top panel), medial view (bottom magnification in top panel and centre magnification from middle panel), lateral view (right magnification on middle panel) and dorsal view (bottom of lower magnifications). Single landmarks are coloured yellow, and for semilandmark curves the green landmarks are the start point, yellow landmarks points on the curve, and red landmarks the end point.