

Supplementary information to

Independent assembly of the flight apparatus in a non-avian dinosaur clade

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Table S1 | Measurements of 130108-MHGU-F4281.

Measurements (in mm) of the holotype of *Norellraptor barsboldi* gen. et sp. nov. (130108-MHGU-F4281).

Abbreviations: L, left; R, right. Asterisk indicates incomplete element.

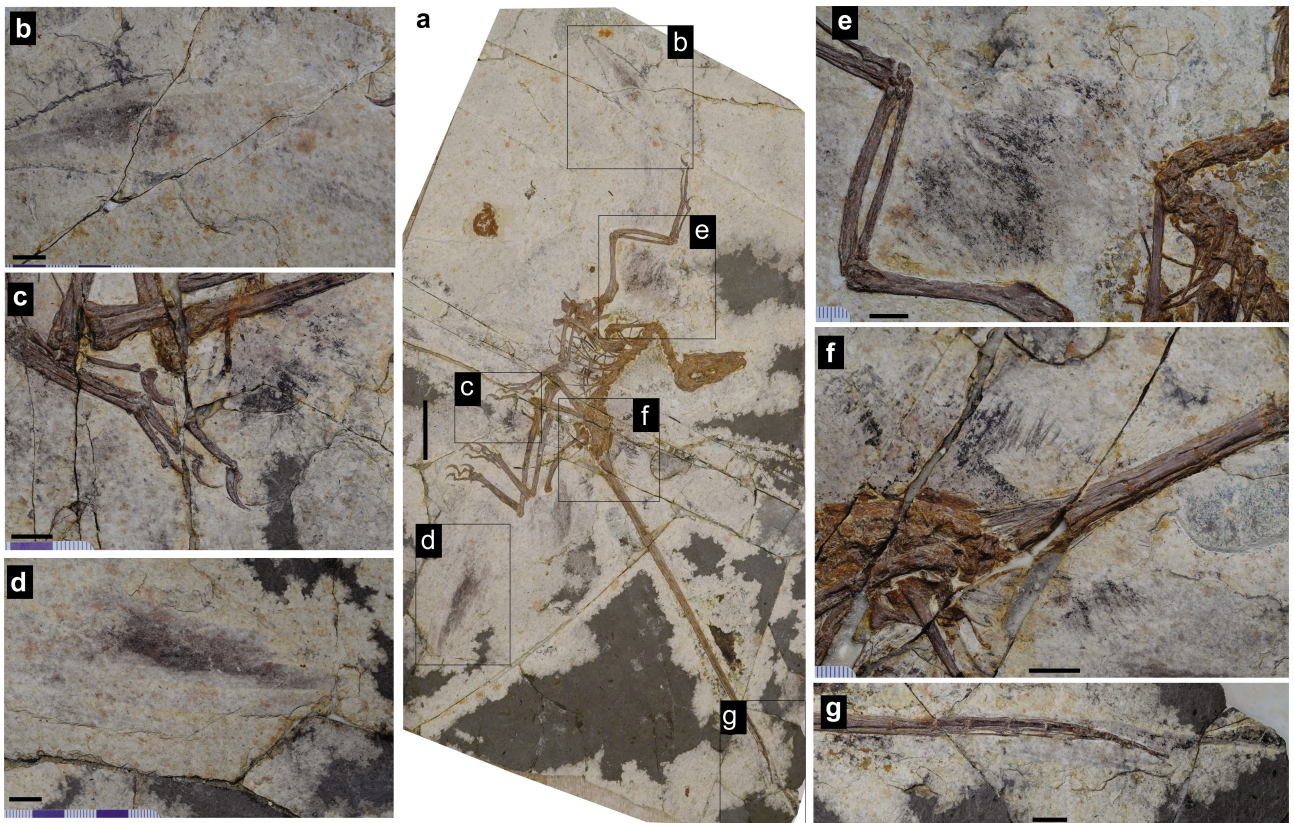
Element	Length		Element	Length
skull	67		pubis	65 (L)
sternum	30 (R)		ischium*	16 (L)
furcular ramus	24 (L)		femur	71 (L)
scapulocoracoid	42 (R)		tibia	94 (R)
humerus	61 (L)		fibula	92 (R)
ulna	55 (L)		tail	326
metacarpal I	9 (R)		metatarsal II	54 (R)
manual digit I-1	21 (R)		pedal digit II-1	7 (R)
manual digit II-2	16 (R)		pedal digit II-2	8 (R)
metacarpal II	34 (R)		metatarsal III	51 (L)
manual digit II-1	18 (R)		pedal digit III-1	12 (L)
manual digit II-2	17 (R)		pedal digit III-2	8 (L)
manual digit II-3	12 (R)		pedal digit III-3	7 (L)
metacarpal III	33 (R)		pedal digit III-4	9 (L)
manual digit III-1	13 (R)		metatarsal IV	50 (L)
manual digit III-2	4 (R)		pedal digit IV-1	9 (L)
manual digit III-3	11 (R)		pedal digit IV-2	6 (L)
manual digit III-4	7 (R)		pedal digit IV-3	5 (L)
metatarsal I	7 (R)		pedal digit IV-4	5 (L)
pedal digit I-1	8 (L)		pedal digit IV-5	11 (R)
pedal digit I-2	4 (L)		metatarsal V	30 (R)

Table S2 | List of the character states shared by Microraptorinae and Avialae and internode ranking in the two clades.

Characters (numeration follows phylogenetic data set)20	Description (when not explicitly stated, the character statement refers to the condition in mature post-juvenile semaphoronts20)	Microraptorine internode rank	Avialae internode rank
37	Maxilla, dorsal process, reduced posterior extent, less than half of the posteroventral ramus.	3	5
60	Lacrima, anterodorsal process, length less than 2/5 of the lacrimal height.	3	10
160	Maxillary and dentary teeth, basal region between the root and the crown constricted relative to middle of crown.	4	1
171	External mandibular fenestra, anteroposterior diameter subequal or longer than 1/4 of the length of the mandible.	5	1
189	Surangular, anterior process, dorsoventral depth less than twice depth of the angular.	3	5
290	Radius, mid-shaft width less than 3/5 of the mid-shaft diameter of the ulna.	1	2
299	Metacarpal I, proximal surface, medial half not contacting distal carpals.	2	1
311	Metacarpal II and distal carpals fused, suture obliterated.	6	5
314	Manual digit II (P1-II + P2-II + P3-II), proximodistal length less than 4/5 of proximodistal length of the humerus.	1	4
315	Manual phalanx P1-II, ventrolateral margin bearing a ridge/shelf.	1	5
316	Manual phalanx P2-II, proximodistally length longer than manual phalanx P1-II.	4	4
322	Metacarpal III, mediolateral width of mid-shaft less than 3/5 of metacarpal II mid-shaft width.	5	5
335	Sternal plates fused medially.	5	1
351	Caudal vertebrae, median and distal centra, mediolateral width of the distal articular surface more than 3/2 of the dorsoventral diameter of the same articular surface.	1	2
386	Ilium, postacetabular process, lateral surface less than half supracetabular surface.	1	9
397	Ilium, pubic peduncle, distal surface, anteroposterior length less than 2 times its mediolateral width.	1	8
398	Ilium, preacetabular process, anteroposterior extent not longer than the postacetabular process.	1	11

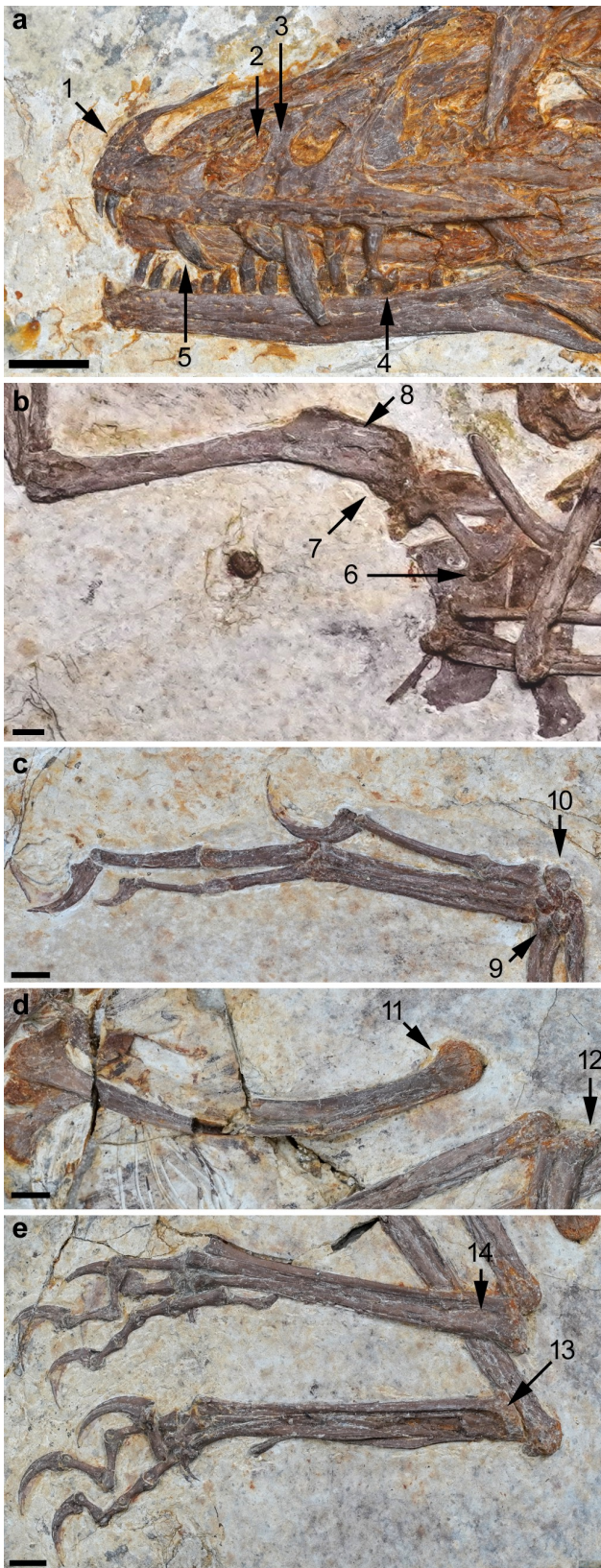
Characters (numeration follows phylogenetic data set)20	Description (when not explicitly stated, the character statement refers to the condition in mature post-juvenile semaphoronts20)	Microraptorine internode rank	Avialae internode rank
399	Ilium, preacetabular processes, orientation in dorsal view anteromedially directed, contacting the neural spines of the anterior sacra.	1	12
407	Pubis, shaft, shape in lateral view posteriorly concave.	2	2
409	Pubis, distal foot, posterior process poorly developed.	1	10
422	Ischium, dorsal margin close to iliac peduncle, shape bearing a proximodorsal process.	1	1
476	Metatarsals II-IV, shafts, proximal ends fused.	5	3
478	Metatarsal III, proximodistal length more than 1/2 of tibial length.	2	2
481	Metatarsal II, distal articular surface, shape markedly concave, with distinct extensor groove.	4	6
486	Metatarsal III, proximal surface, anterior margin, position relative to the anterior margins of the proximal surfaces of both metatarsals II and IV is more posteriorly/plantarly.	1	11
488	Metatarsal III, distal end, mediolateral diameter less than the mediolateral diameter of the distal end of metatarsal II.	4	7
494	Pedal digit IV, length subequal to or less than pedal digit II.	5	6
501	Pedal phalanx P1-II, proximodistal length longer than 3 times the proximodistal length of its distal trochlear eminence.	5	1
512	Alula present.	1	8
517	Ischium, shaft, obturator process, position terminal.	2	2
579	Sternum, lateral margin broadly concave at mid-length.	6	8
580	Tibiotarsus, astragalocalcaneum fused to the tibia.	4	5
596	Coracoid, laterodistal margin bearing a distinct projection.	6	1
688	Deltpectoral crest of humerus fenestrated.	4	6
701	Sternum, anteroposterior length more than 3/2 of the mediolateral width of the anterior half.	6	11
702	Sternum, anterolateral margin with distinct processes.	3	10
799	Humerus, distal lateral epicondyle, lateral expansion prominent and distinct from distal surface.	6	6
825	Metatarsal III, shaft, proximal half, posterior margin mediolaterally constricted/sharp.	1	6
827	Radius, distal articular surface medially flared.	4	8

Characters (numeration follows phylogenetic data set)20	Description (when not explicitly stated, the character statement refers to the condition in mature post-juvenile semaphoronts20)	Microraptorine internode rank	Avialae internode rank
830	Metacarpal III, shape in dorsal/ventral view laterally bowed.	1	1
910	Metatarsal I, distal end, position at the same level of the distal end of metatarsal II.	1	6
933	Tarsometatarsus, distinct intercotylar eminence.	5	11
945	Metacarpal III, proximal end ventrally displaced relative to metacarpal II.	1	6
1105	Ulna comparably robust as tibiotarsus.	6	2
1384	Furcula width more than 4/5 scapula proximal width.	1	4
1387	Manual phalanges, penultimate phalanx on digits, diaphysis just proximal to the distal epiphysis, diameter narrower, distal epiphysis expanded dorsoventrally.	1	8
1392	Mandible, large internal mandibular fenestra.	1	8
1517	Pedal ungual I, ventral margin, shape in lateral/medial view is curved ventrally.	1	1
1696	Distal carpal 1+2, dorsomedial process prominent.	5	8
1698	Semilunate carpal (1+2), proportion in extensor/flexor view as deep or deeper than mediolaterally wide.	6	8
1701	Coracoid, supracoracoid nerve foramen, position on bone closer to the anterior/medial margin.	6	2
2234	Radius, mid-shaft width in immature semaphoronts less than 3/5 of the mid-shaft diameter of the ulna.	1	2
2258	Manual digit II (P1-II + P2-II + P3-II) in immature semaphoronts, proximodistal length in adult less than 4/5 of proximodistal length of the humerus.	1	2
2367	Ischium, shaft in immature semaphoronts, dorsal margin proximal to distal third bearing a distinct mediodorsal process.	1	1
2427	Metatarsal III, shaft in immature semaphoronts, proximal half, mediolateral diameter relative to mid-shaft width is constricted.	1	11
2551	Manual digit I in immature semaphoronts, proximodistal length (sum of the lengths of metacarpal I and manual phalanges P1-I and P2-I) less than the proximodistal length of metacarpal II.	1	7
910 (reversion)	Metatarsal I, distal end proximally to the distal end of metatarsal II.	5	4



Supplementary Fig. S1 | Plumage of *Norellraptor barsboldi* 130108-MHGU-F4281. a, whole specimen.

b, distal tips of primary feathers. **c**, tibial plumage. **d**, distal tip of metatarsal feathers. **e**, plumage adjacent to humerus and thorax. **f**, plumage adjacent to ilium and tail base. **g**, distal tail feathers. Scale bars = 10 mm.



1. premaxilla with length of prenasal part half the depth of the subnasal body.
2. large promaxillary fenestra occupying the whole rostral third of the antorbital fossa*.
3. *pila promaxillaris* narrower than the *pila interfenestralis* and both less than half the diameter of the maxillary fenestra*.
4. basally-constricted dentary crowns.
5. rostralmost maxillary teeth enlarged.

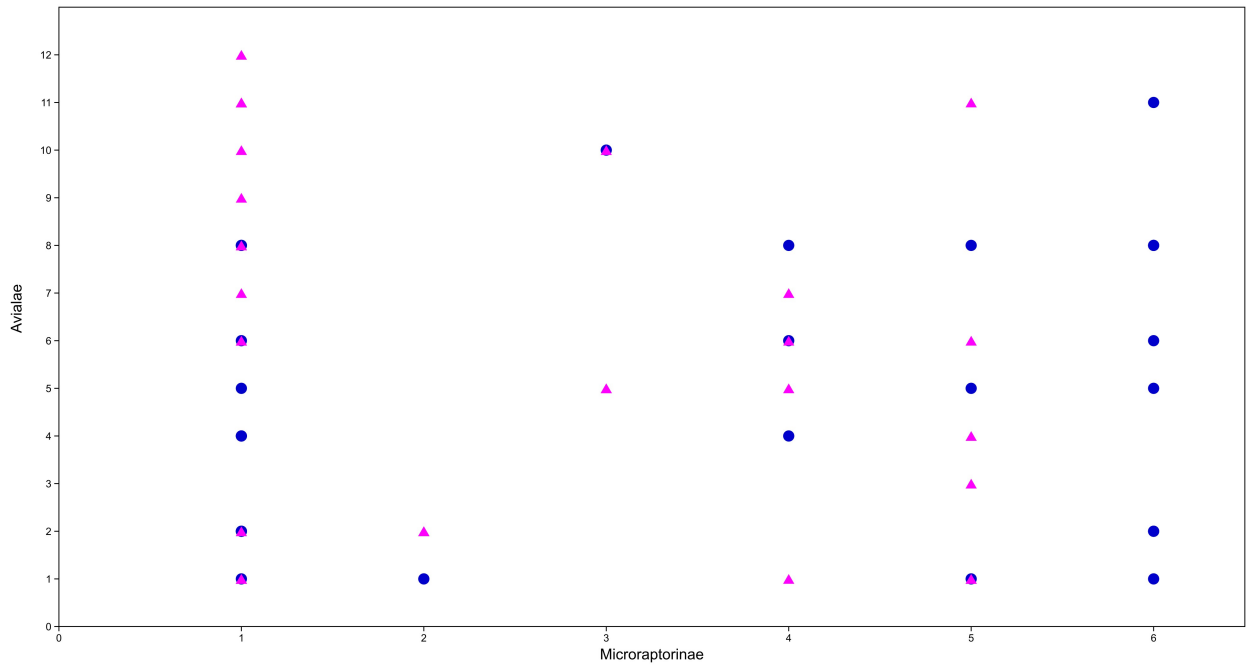
6. prominent lateral process of the coracoid.
7. moderate caudal inclination of the internal tuberosity of the humerus
8. small fenestra in deltopectoral crest.

9. bulbous distal process of the ulna.
10. semilunate carpal proximally extended, capping most of metacarpal I and barely capping metacarpal II.

11. pubis gently curved caudoventrally with small foot having the posterior projection less than the diameter of the pubic shaft*.
12. prominent proximolateral spur on the tarsometatarsus.

13. metatarsals II-IV fused proximally.
14. proximal end of metatarsal III overlapped by adjacent metatarsals in extensor view.

Supplementary Fig. S2 | Details of the unique combination of features diagnostic of *N. barsboldi*. **a**, close-up of the snout. **b**, humerus and pectoral region. **c**, hand. **d**, pubis and ankle joint. **e**, feet. Autapomorphies marked by asterisk. Scale bars = 5 mm.



Supplementary Fig. S3 | Spearman's rank correlation analysis between the sequence of acquisition of the novelties shared by avialans and microraptorines along the internodes in Fig. 5. The blue circles indicate the forelimb skeleton and pectoral girdle features, the pink triangles the other skeletal features. $N = 57$. Spearman's rank correlation coefficient for all features = -0.08 , $p = 0.50$; for the forelimb and pectoral features alone = 0.15 , $p = 0.47$. Data provided in Supplementary Table 2.