

First Ornithomimid (Theropoda, Ornithomimosauria) from the Upper Cretaceous Djadokhta Formation of Tögrögiin Shiree, Mongolia

Tsogtbaatar Chinzorig^{1, 3 *},

Yoshitsugu Kobayashi²,

Khishigjav Tsogtbaatar³,

Philip J. Currie⁴,

Mahito Watabe⁵,

Rinchen Barsbold³,

¹ Department of Natural History Science, Graduate School of Science, Hokkaido University, Sapporo, 060-0810, Japan

² Hokkaido University Museum, Hokkaido University, Sapporo, 060-0810, Japan

³ Division of Vertebrate Paleontology, Institute of Paleontology and Geology, Mongolian Academy of Sciences, Ulaanbaatar, 15160, Mongolia

⁴ Biological Sciences, University of Alberta, Edmonton, T6G 2E9, Canada

⁵ School of International Liberal Studies, Waseda University, Tokyo, 169-8050, Japan

* chinzorig.tsogtbaatar@gmail.com

April 25, 2017

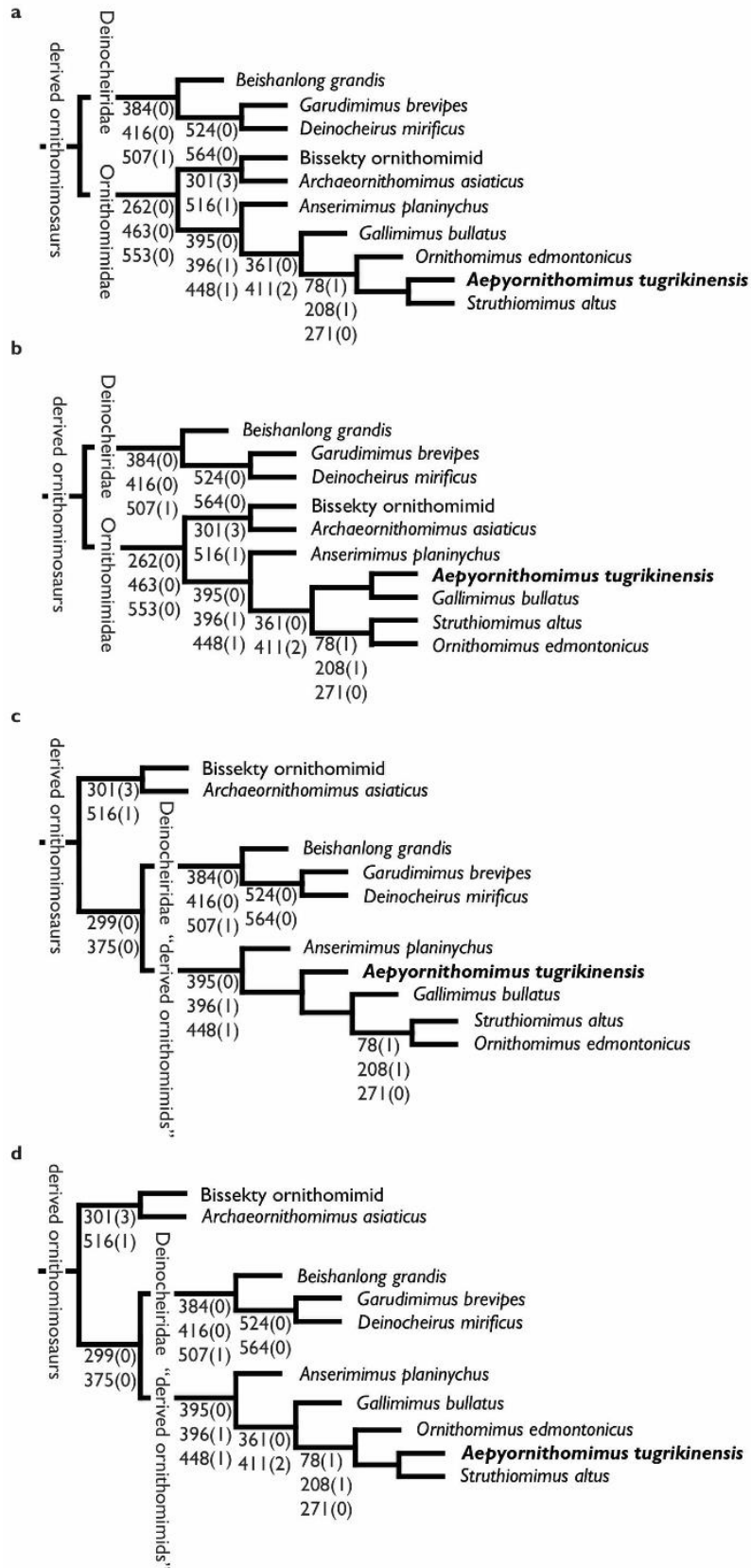
Supplementary Table S1. The ratios of the fourth metatarsal length to the third metatarsal length and the second metatarsal length to the third metatarsal length. *Abbreviations:* (Mt II), the second metatarsal, (Mt III), the third metatarsal, and (Mt IV), the fourth metatarsal, (AM), Albany Museum, (AMNH), American Museum of Natural History, (MPC-D), Institute of Paleontology and Geology of Mongolian Academy of Sciences (=Mongolian Paleontological Center), (ROM), Royal Ontario Museum, and (UALVP), University of Alberta.

Group	Taxa	Specimen #	Mt II Length	Mt III Length	Mt IV Length	Average of same taxa	Mt II length proportion	Mt III length proportion	Mt IV length proportion
Ornithomimids	<i>Aepyornithomimus tugrikinensis</i>	MPC-D 100/130	201	211	207	0.981042654	0.324	0.340	0.334
Ornithomimids	<i>Anserimimus planinychus</i>	MPC-D 100/300	270	300	268	0.893333333	0.322	0.357	0.319
Ornithomimids	<i>Archaeornithomimus asiaticus</i>	AMNH 6565	258	282	262	0.929078014	0.321	0.351	0.326
Deinocheirids	<i>Deinocheirus mirificus</i>	MPC-D 100/127	497	600	553	0.921666667	0.301	0.363	0.335
Ornithomimids	<i>Dromiceiomimus brevitertius</i>	ROM 797	253	298	273	0.916107383	0.307	0.361	0.331
Ornithomimids	<i>Dromiceiomimus</i>	ROM 852	325	370	340	0.918918919	0.314	0.357	0.328
Ornithomimids	<i>Gallimimus bullatus</i>	MPC-D 100/10	144	157	148	0.938194444	0.320	0.350	0.329
Ornithomimids	<i>Gallimimus bullatus</i>	MPC-D 100/11	480	530	500				
Ornithomimids	<i>Gallimimus bullatus</i>	UALVP cast from Warsaw	435	470	440				
Ornithomimids	<i>Gallimimus bullatus</i>	MPC-D 100/52	256	283	263				
Ornithomimids	Ornithomimidae indet.	MPC-D 100/121	273	305	283	0.927868852	0.317	0.354	0.328
Ornithomimids	Ornithomimidae indet.	MPC-D 100/138	458	500	467	0.934	0.321	0.350	0.327
Deinocheirids	<i>Garudimimus brevipes</i>	MPC-D 100/13	195	229	212	0.925764192	0.306	0.360	0.333
Basal ornithomimosaur	<i>Harpymimus okladnikovi</i>	MPC-D 100/29	292	310	304	0.980645161	0.322	0.342	0.335
Basal ornithomimosaur	<i>Nqwebasaurus thwazi</i>	AM 6040	118	125	124	0.992	0.321	0.340	0.337
Ornithomimids	<i>Ornithomimus edmontonicus</i>	ROM 851	265	310	295	0.951612903	0.304	0.356	0.339
Ornithomimids	<i>Rativates evadens</i>	ROM 1790	277	300	285	0.95	0.321	0.348	0.330
Ornithomimids	<i>Sinornithomimus dongi</i>	Alashan#3	100	111	105	0.945945946	0.316	0.351	0.332
Ornithomimids	<i>Struthiomimus altus</i>	AMNH 5257	342	370	352	0.925675676	0.319	0.353	0.326
Ornithomimids	<i>Struthiomimus altus</i>	AMNH 5339	328	370	333				

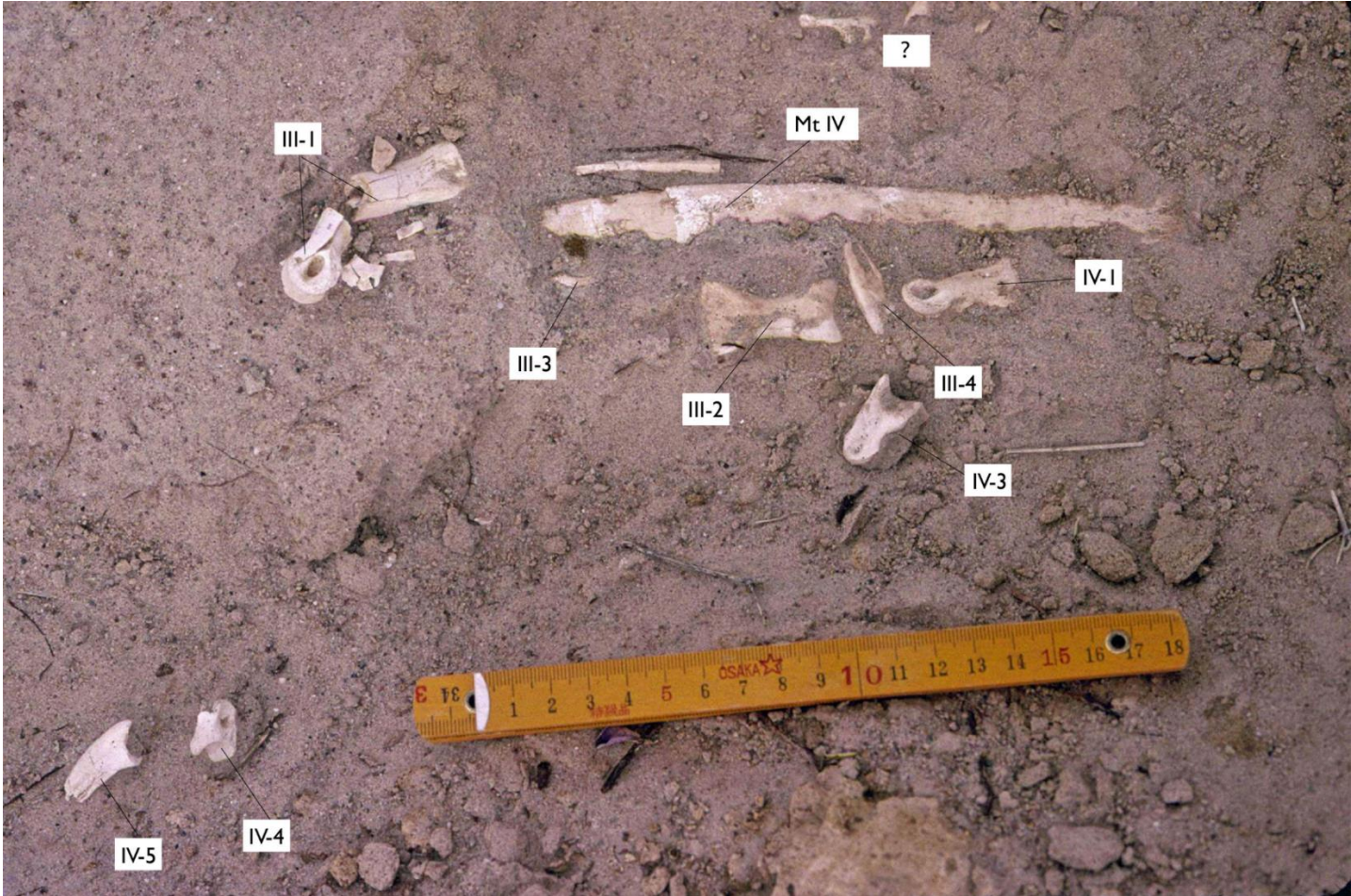
Supplementary Table S2. The ratios of the length of the third metatarsal and the distal end to the medial expansion of the third metatarsals (in, mm). (Mt III), the third metatarsal length, (DE-ME), the length from the distal end to the medial expansion of the third metatarsal, and (MPC-D), Institute of Paleontology and Geology of Mongolian Academy of Sciences (=Mongolian Paleontological Center).

Taxa	Mt III	DE-ME	Ratio (%)
<i>Harpymimus okladnikovi</i> (MPC-D 100/29)	310	135	0.436
<i>Deinocheirus mirificus</i> (MPC-D 100/127)	600	240	0.4
<i>Garudimimus brevipes</i> (MPC-D 100/13)	229	81	0.354
Ornithomimidae indet. (MPC-D 100/14)	271	78	0.288
<i>Aepyornithomimus tugrikinensis</i> gen. et sp. nov. (MPC-D 100/130)	211	34	0.161

Supplementary Figure S1. Possible dispersal patterns of derived ornithomimosaur between Asia and North America. Topologies of four most parsimonious trees, including a position of *Aepyornithomimus tugrikinesis* gen. et. sp. nov. with ornithomimosaur. *Explanation:* (384(0), 448(1)... 271(0)), the character numbers with changing character codes in every stages.



Supplementary Figure S2. Field view of *Aepyornithomimus tugrikinensis*. Abbreviations: (Mt IV), the fourth metatarsal, (III-1 to III-4 and IV-1, IV-3 to IV-5), phalanges of the third and the fourth digits, and (?), unrecognized parts of the specimen.



Supplementary Data S1. List of characters coded for *Aepyornithomimus tugrikinensis* and followed by modified character-taxon list used in this study.

Characters coded for *Aepyornithomimus tugrikinensis*

530. Condyles indistinct or poorly separated. The condyles are separated by a prominent vertical tendinous groove on the anterior surface (530(1)) in Alvarezsauroidea and Avialae. [0]
531. Astragalus and calcaneum: separate from tibia. Among Ornithomimosauria, these tarsals fuse to each other and to the tibia late in ontogeny (531(1)) only in *Deinocheirus mirificus*. [0]
532. Fibular facet on astragalus large and facing partially proximally. This facet is either reduced and faces laterally or is absent (532(1)) in Oviraptorosauria, Troodontidae, and Alvarezsauroidea. [0]
536. Fossa on anterior surface of mesial base of ascending process of astragalus, sometimes bearing accessory fenestrations is presented. [1]
537. Ascending process of astragalus and astragalar body: confluent or only slightly offset from astragalar body. [0]
538. Astragalar condyles significantly expanded proximally on anterior side of tibia and face anterodistally. A common feature for Coelurosauria and outgroup taxa. [1]
539. Horizontal groove across astragalar condyles anteriorly absent. Reversal to this plesiomorphic state is a synapomorphy for the clade Ornithomimosauria + Maniraptora. [0]
540. Calcaneum: well-developed facet for tibia present. [1]
541. Distal tarsals separate, not fused to metatarsals. They are fused to the metatarsals (541(1)) in Avialae and a few other taxa. [0]
542. Metatarsals co-ossification: not co-ossified. The metatarsals are co-ossified (542(1)) in *Avimimus portentosus* and Avialae. [0]
543. Shafts of Mt II and Mt IV: closely appressed throughout most of metatarsus, adjacent surfaces flattened for contact. A common condition for Coelurosauria and outgroup taxa, reversed in Therizinosauria. [1]
545. Mt I is absent. [1]
549. Mt II proximal end of flexor surface: large quadrangular flange present. A synapomorphy for Ornithomimosauria more derived than *Nqwebasaurus thwazi*. [1]
550. Distal end of MT II smooth, not ginglymoid. A ginglymoid distal end of Mt II (550(1)) is characteristic for Dromaeosauridae. [0]
551. Tuber along extensor surface of Mt II absent. This tuber is present (551(1)) in some avialans. [0]
552. Posteromedial margin of Mt II diaphysis: well-developed flange absent or area rugose. This flange is present (552(1)) in Oviraptorosauria, Troodontidae, Alvarezsauroidea, and Avialae. [0]
553. Distal end of Mt III: smooth, not ginglymoid. A ginglymoid distal end of Mt III (553(1)) is characteristic for Deinonychosauria and Avialae. [0]
554. Mt III pinched between Mt II and Mt IV and not visible in anterior view proximally. A synapomorphy for Ornithomimidae. [1]
556. Medial side of anterior surface of distal end of Mt III unexpanded. [0]
557. Mt III shape of shaft in cross section wedge-shaped, plantar surface pinched. This derived character-state is found in all Ornithomimosauria except *Harpymimus*, *Garudimimus*, and *Deinocheirus*. [1]
558. Shaft of Mt IV round or thicker dorsoventrally than wide in cross section. The derived character-state is present in Dromaeosauridae and a few other taxa. [0]
559. Length of Mt IV markedly longer than Mt II. This character is present some Ornithomimosauria except *Anserimimus planinychus*. [1]
560. Posterolateral margin of Mt IV diaphysis: well-developed flange absent or area rugose. This flange is present (560(1)) in Deinonychosauria. [0]
562. Pedal digit IV is significantly shorter than digit-3 and subequal in length to digit II, foot is symmetrical. [0]
563. Extensor ligament pits on dorsal surface of phalanges of pedal digit IV shallow, extensor ridges not sharp. This plesiomorphic character-state is characteristic for all Ornithomimosauria except *Nqwebasaurus thwazi*. [0]

564. Pedal phalanges of digit IV. Anteroposteriorly long, proximal and distal articular surfaces well-separated.

[1]

565. Shape of ventral surface of pedal unguals. Ventrally concave in lateral view. Except *Garudimimus*, *Deinocheirus*, and *Qiupalong*, which have pedal unguals that are ventrally concave in lateral view, other ornithomimosaurians are presented a straight in lateral view (565(1)). [0]

566. Ungual and penultimate phalanx of pedal digit II is similar to those of digit III. [0]

567. Ventral surface of pedal unguals with a pronounced flexor fossa on ventral surface of proximal end. A synapomorphy for Ornithomimosauria, reversed in *Qiupalong* and *O. edmontonicus*. [1]

568. Form of flexor fossa on pedal unguals: without development of flexor tubercle. In ornithomimosaurians there is often presented low longitudinal ridge in the flexor fossa instead of the flexor tubercle. The flexor tubercle or ridge in the flexor fossa (568(0)) is distinct in Alvarezsauridae and Dromaeosauridae. [0]

Six characters are assigned as autapomorphic characters of *Aepyornithomimus tugrikinesis*, as follow, a presence of notch on medial edge of the ascending process of the astragalus [ch.535 (1)], a presence of fossa on anterior surface of medial base of ascending process of astragalus [ch.536(1)], shape of proximal end of Mt III [ch.555], markedly longer Mt II than Mt IV [ch.559(1)], rounded and shallow extensor ridges present at depressions on dorsal surfaces of phalanges of digit IV [ch.563(0)], and anteroposteriorly long, well-separated proximal and distal articular surfaces of digit IV phalanges [ch.564(1)].

Data matrix

#NEXUS

begin data;

dimensions ntax=99 nchar=568;

format missing=? symbols="0~6";

matrix

Acrocanthosaurus_atokensis ???010100?0??101?0??10?0?10??0?1?0110001001000?0?0?0112011??0?000010
10??1110??11?0??0??0?01101111?00??10110??01001?1120?0??1?0?0?0??0?1?0?0?0??1??0101?0?10000??
??10?0??0??0??0??200??0000??10??0?0111??0?0?0?0?101??000021001?00?0?0?0?1?0??1000?1??1?11
1110??001?11?0?0?10??2?1??01??0?10?1?00??01?0?1??????0?02?????10?1?0????1?010????????0??1?1
01?10?0?100000??10??02??00?101?0?0?0?01111?0?10100220002??100?0??00??10????????????10????
??????101010??0?0{01}0??0?0??00?11?10?00??01012?1001?011?0??00100?101????0?0????0?0??100??
??001?000?00??0?1010??2?01000?

Afrovenator_abakensis ?????0??????1?101001?0??11010100110?00000?1??????0?201100??0?0010100111
00??00????????00010?01?0?0??010000001?010??????0?0?0????????????????????????????????????
????????????????????????????????????????????????????????????02000100000??????0100?0110110?10?1?0001?1?1
1??0100?{01}?1010?????1?00?????0?????????0??0?0?0?0?100??????11?00????????????????????????
?0??0?01?????00?????????1??011?1?0?????12100?2??01000000100100??0??0?00010000100?000000
?0?0?01??000100010011010000??0?0?1100010001000100????0?0?????001????0?0000100?111??1?0?110
????01?????2??0???

Albertosaurus_sarcophagus ??1????0000011??0????10?1?????0?0?0100000101110?11??00201100110001111
1011201??000?120000010111100112010101?001010100103000001000000000001?00010?1??1000?0011000
0100?10??00??0000?001??00??0?00?00?1000010111?011100??010??00?10?00?0?0000000?0001010??01
1?0??????0000011?00????0?0?0??????1?0000?00?00410?00??10?0?00??0?0?0?0?0??0?0000?0?100
0010??00?000011?001?????00?0?00?0?1000000010?0??????320?0??0000????????10101?100000000?
20??1000000?010?0001??00010000000102000101?1101100110000100100000001?1110011001?1000100?
2000110?001?0011000001111000?0?1000?

Allosaurus_fragilis ??0010{01}01001010?0000?0000?1000010?110?0100100001?1?011?1?000000000101??
{01}100??1110100000?01000?010?0??01?0100010101120?00010?000100101?00?00?10?0010100110010
0?1?10?0?0?0?000000010000??0000?00?1000011111?000100101010200000021001000000000000010100000

00100101000100100000001?111????0??????0?2?????????????0100??1???1000011101010001111?00?01
00100011?00011110230010?0000?011011210110100000101000001001100011?11100010112000110111100?
11000102?110102010100?

Beipiaosaurus_inexpectus ?????????????????????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????????
???1?00???1?1??10?101??100?????????????11?????0220001100132010001010?0?????????????????????1?
??0??????0??????????????0??????????????????????????0????????????00?1001001?10000?0100??????
??10????????0???00100?????????022?????1?00?0000?0101110011?????1??????????????????????0????
??????????0??????1?????00?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?
0?

Beishanlong_grandis ?????????????????????????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????????
?????????????????????????????????????????????????????????????????????????????????????????1?11?????
?????????????????????????????????????????????????????????????????????????????????????????111101?01000?0020?000010000000?
??000? ?????????????????????????????????????000002?0?????????????????????????????????????????????1????
????????10?0?0002100110?10001010???1100010?0?1010100?1000110??1?001????00??10??001011

Bissekty_ornithomimid ?????????????????????????????????????????????????????????????????????????????
?1?0010010????????????????????????????????????????????????????????????????????????????????????
?????????????????????????????????????????????????????????????????????????????????????????10?1020221000?01121100
00102000100100000000011?30?01?000?0000000?0100200?0?0?????????????????111101?11?000??200?0001
???010000??????????101?10111100??10??????01??1?010??????100?110??0000?100????????????????
?????????????????????010110001100100011000000101110?1?100?0010002000110?001?????100001?110?
0??001?11

Buitreraptor_gonzalezorum ?????????0000?1?10??0?1??0?????????1??????0??????????00????0?????
??????????1?10?010?0?001?0????0??0?10?001????????????????????????????????????????????0????????????
?????????1?0?0?0?0?0?01010????????????????????????????????????0?01?0020??00?00?00?0??110?010?0?2012101
10??12??010??????0?1????0??1?1??01??0??????1??01??10?2?01?????1??2??10??2?1??11??101110
01?????????0?1?????1?110????????????22?????????????0100?????????01?10?0???11?111?1??0
10????20112122?0112?0?1001??????1??1?????????????????????1?????????1?20001????01?0011?10??1?0
1001?0??1??

Byronosaurus_jaffeei ?000000110000010001?100110?000001110001????00001000?0000??0????110??111
01110?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?0?
10111?????0?000?00000?0110?0?010?????????????101?001002201?002000120010??10?0??10??????????2?
?0?????210?1?????????1??1????0????????????????0??2????????????????????????????????????????
?????????????????????????????????????????????????????????????????????????????????????????1?
????????????????????????????????????1?????????0?0?01??11?????????0?0????????????????????????????????
?1??

Carnotaurus_sastrei ??10000000001000??0?00?010000100010001??1?1001110??200000000?000?1010100
0???10?11000000001?1101100101000010000?00????0?0??1000??2??0?????0?????00?1001?0?0?????????
??????1?101100?00?01000?100?01000?0?11101000101000?01000000?0?0000000??0?000010101101?1
0?00??11102?10100?00100?10?10000111?110040?11?0?????00????0????0000??0?0????00?0?0000?010
01010?221?0110?200000?000111000????????????????????????????????????11000?0000?????00?00?00?0?
00000100????1000000100?000?0?00000??000?10000?0111011??011?00?110?0????????????????????????
????????????????????????

Caudipteryx_houi
100000?0?111?0?0000??????0?0?0?11?????????00??01????000?01?0?????1?0101?10??10?000010??0
?00??0??00?000?00?0000?????1????????????????????????????0?????????????????0201?0011011111
00?110?1?0?0?0?0?0?0?10??1101?????12?22????01??0??????0?0?????1?00?????????01}0??00?
??????????????04?1?0?0??2100??11????0?00?0?0?1?011?00?110?00?0??1?001?0?0????1?10?0?0000?0?

?0001?110?0000?0111110?22??021?100?000000100101001??0?1?10?0?000????00??????01??2011110?
?00102?0?0?100?111111?0?????10?00?????????011??10??01200011?1001??0??01?1?0??1?0??000?
Ceratosaurus_nasicornis ??10100010001100??00?00?0100000001000010001111010101101?1000000001110
?11100?0010010?000000010?011101010010100010?00?0?00?0??1000?02??01??000?0??1?1??10?00??
0??????????1????000????0??0?10?001000?0?????100?100??000?11000?0000?0?0?0?00?0000111?11
011000000011??0?00101?00100????10000011011004001?0?1?000?01000?0?01000010??10000????????000
10?01001000????????????10001100101????0100?100010101110?1??????2????1100?0000????1?000000
100100000000?000101000100100000010?00000?0?11000000000011011000111011110?0?0000?1000??00
1000011????????????00?0??????0?0?

Chirostenotes_pergracilis ??1??????1?00?????1101????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????????
????10?0?0111111100?100?10?0?0?00?0?0????????????1????????2????????????????????110?211?0?0??
?12??1??????010?1??1????????5210????0??1?0????????????0????????????????20?100??0?10????????
????????????????????????0??????2200??????10000??1000?100010000??1?010000?000000?12??00??
??201111023001121000?01????0?0?????0?0?11??0?0?????00????????00?????1??0?1?0?0??00?01?010?
0?0??00??

Citipati_osmolskae ??1000000010100101?0?110100?00020111000????0000100101?0010100001000?1101100
101?10?11110000100?0?001200?000?000000??010?01101111101?0??01?01010?010112000000?0?001??11
111110?0000021?0201101111100?110?10?01010001100?0111?????1????????2????????????????10??110??
???210010?1????1?0?1??????1??1000?0?1?52????0??10?????1????0?2?01?1????0?00011111200?????
0?110010?1?????1?00?0??000?0?1?10?00??0?0????0?22??0?0??0010000????0?100?0??001?1??????0?01
000?110??0110??20?11102300102?000?01??????2110010?0?10????0?0????????????0000?0000??001?
?0??00?00?0?0?0?0??000?

Coelophysis_bauri ??000011??0?000??????0?00?0101001?1?10??0?00001001??00000000000?0??11100?
?00100?0?0?0000?0?1?00??0?0????0??????0????0000?0??01????0?0??1??0?0?1000?????????????
??0?001?000?0?0011??10?100?0000?????????1010?010?020000000????000?00?1??0100?11000?02??00
10?0?10000{01}0002001000????0?00?0?03?00??100000020?000100?01?0?????00?????????0??0011?00
?0?1?0?1000010?0100????000??1?0000001?00?0?0?100??111100?0??001000?0000????100000001101??0
00??0?00??0001101100????10?1?0?0??1100?0?0?0000000?00101?0?110????0?001????001000000??0?
??10??0?0?0????1001000?

Compsognathus_longipes ??00?011000????1010?1?00??1101000??0000??000000000??00001000000?0?0?
111?0?????1?1101??1?000?0?001000?0?0????0?0????????????0??????1????????????????010?0?0?????????
??????????0011000?0?00?00?0?000100?0?000??1210?101000100210110010000000000100?0?0??1010?1?
0?0?00010?0?1?0?10?0200????????100010?103????0?0000?0?000?01000010000?1?1000??1????00010?1
11?00000?0??1??1?0?01??000000????0?0101??0?10?1?22??12??10000011001??0?1000??0??0?0?0??
????00?01111??00100001000100010100?0??1?????000??1??1?1??00?0?????00?0?????0?0001000?10?0
01?0011000?00?0?0?02001000?

Conchoraptor_gracilis ???0??0011100?0?00??1????0?020????????????01????1????110??010?0????????1
01?10??10?00001??0?0?1?????0?000000?0?????????1??1????????????0?????0?2??1????00??110?????
??0??21?0?01101??1100?110?1??0?0?000??0??111?????1????????2????????????????????????0??
??????1????????????????01??0????11??0?????1????????????????????0?????1?12?010??0??0100?0?1??
????00?0??0????????????0????0?0??0????00100100??0?100?11?001?1??????0?10000?110?00?1
??20??1????010?000?0??????11?001??0?10????0????????????????0?????????01??0??00?00?0??0
?0??0???

Confuciusornis_sanctus
11?000?01?000000????0?01?0??00110011000????00000?0?01?11?111001?1?0?0??1?0????10??00?00?10?
?0?000?0??0?00?000??1????????0?0????????????????????1????0?????????????????????0?10??000??001
1000?100?0100?1?000?0??011?????1????????2????????????????????0????????????????????0??0?0??
?0??100??1??05????0??20?01??1??0?????010110?????11111010?0?????1?0?111110020??1101110001?1

????1?110?01?11100?1000????????????0????????????0?00?0?00?000?00010100?0??????1101?10?00?0?1?
2110?0???01??00001??00010?01?0???01?0?110?0020?????0?0?0?0????????????????00010??????????100?
1001????????????????????????????????????????????????????????????????????????????????????????????110?010000
00????????????????????0100100010000100100011101011000000?????????1??1001111001?????000?0???00?
???001?0?

Megalosaurus_bucklandii ?????000100?1?000??????0?1000????1100001101????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????????????
?????1?000?000??00??010100????0?????????????????0001000000?0000?010100?????????0????????????
?????0?{01}?1??00?????100?????0???300010100?0?0?2????0?0?0?1?????????????????????0?0?0?0?0?????201
1?0201?????00?0????????????????????????????????????????????????????????????010?10000110000000?01000?100000100??00
000????000100010?1??0?????000000100000001000100?1010101100?0?????????????????????????????????00
1?00?0?????????

Mei_long ?00000011011?00????0?00?12100000?11000????00001000?01??11?0?11?0?0??12?01110?0?11
00?000?0??001100?0??????10??11??????????0??????????????????110??????0?????????????????0?0?????
?00?0000?0110?0??????100?????1????10?0?0?001201?0020??0??0??0?0?110000????101210110??10100
1?0?11000?00????00?00111040??1??0?1000?0001??2??0?0?0?1?0???12??1111?20110?110011010000010?1
1100110??????0?????????????1??????2?????????0000001????????0?000?1?0011000?0110000????01001?
0101??10??0?20??10?10?01??1110110?0?11?000?????????011?0?100??0112000110?00100011??1?1??10
112101010?

Microraptor_gui
100????01000??1?????00?0?0????????????????00000??0?????1?0?0??????????1?0?????????????0?0?0?0?
0????????????????????????????????????0????????????????????????????????????????????????????????10?0??000?000?
?0?????????01??1????10??01?02?0?0?0?10000????0??10?????????????????????0?111??1????00?0?1?????????10
0?0?1?004??1????10??1?001??1??1?01?1??????120011101??0?????1??111110?11??0??110??????000?11
0000000101?0?0?22?02??1001000000100101?0?111??1?1??????0?011?1?20??010?1?0011121?2??01101
1010?1??????11?111????10??0?0?????00?????0?0?0??0001??10110011?10?11?0?0?1?101010?

Microvenator_celer ?????????????????????????????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????????????{12}
0????11?1101100?????00?00?????????????????????0??????2??2?????????????????1101?110??????0010?01?1?1
02??11000?001001000?0?10?0?????????????1?11?000?2????????????????????????????2001????00?0?0?010110??02
?0010000?000?0??????0??0????????????2??0010?00001000?1001101001??1010000?00?0010100?0101??
?20??????0?????????1??11?10121010000100?000??11?001??001000000120001101?????????????????????
??????0?

Monolophosaurus_jiangi ?001000100101?10000?00?01110001000?0000?001111000100201100000001111?
?11100??00100000000?000110011000?0011000001??010??????0000?0000?1??00?0??1010100?100000?
??????????????0?001110?0000?00?100?01001????0100211?1010000002000?00000000000?010100??1101?1
0?1?100?01011?0001000101010000011?0000?1001003000?0?????0?2????0?????0????????????????????
????????????????????????????????????????????????????????????????????????????????????0100100000100100?0?0100001
000000000??0101000100100?00110?100?0????????????????????????????????????????????????????????????
?????????????????????????

Mononykus_olecranus ?????????????????????????????????????????????????????????????????????????????????
?????????????????????????????????????????????????????????????????????????????????????????????????1100?????????????1001011??0?1?
?????????????????????????????????????????????????????????????????????????????????????????????????1212?1??0?????10?0??????0????1010?11??121101
011020010000??101??1010??2??1?????0121?0?1????????????????????110??001000?01?10100002300001011
1?0021000111011?10101111101101100221112??111011?120?0?0?????????????????1?00111?00?30??????1?
??00?0?0000?????????0??1001112?20010010111000011011110011?11??1011??1101101001?0011000102?1
1000?010100?

Neovenator_salerii ?00?01010000101000010000?1100010011000101000101110????????????????????????????
????????????????????????0?????????????????????????????1????????????????????????????????????????
???1?100??000?000??000?????????????????102100000?100100000000010?010100001111011111100001011?

100011?????00?10?10?????1??1112?????011?11010??????1?0??????00100101?????0211011???01001???
??????????0?0?????111200010001110000111111??10111??000010{12}001100110??????1????000?????
010?0?

Pelecanimimus_polyodon ??0000021000101000111011?0?00010011100????00000?00000001111?000??0?0?
?1120111011202?1?01?000?0?00?????????????0?010?00??1??10??????1?00?01??????????1??01????1?
????10?????0?00?001000?1??00?0?0001010??1?0?0?0??1030001103201?102110201010??10?0??101010?1
?????00010?1??1000?1?????????????????0?????????????????????00?110?????000??101?????1?11
000?0?200?0001?00?0100?0000011??00?1010011?1110?22100112100011210?????????????????????????
????????????????????????????????????????????????????????????????????????????????????????
????????????????????

Piatnitzkysaurus_floresi ?????0?????????1?????????1000?????110?00100?1????????????????????????????
?????????0?????????????????0?????????????????????????????????????0?????01??0?0??10??1?1?0?10?0010?010???????
??00?????0?10?????????????0?????????????????????????????????0?1?01?00?0?0?0?????010011110?10?1010?1?0011?
??10001?1010?????11000??1?00?230?0??0??0?02????0?????????????????????????????0??11?0?0?00?0?1?0?1
0?00?0?0?100????0?????????????????????????????????????0100?0?0?????????????010000?????????1?00????0
000?010?????11?1??0???110010?0100010?0100?0??10111??0?0?0??0?????????????????????????????01?0???
????????

Proceratosaurus_bradleyi ??10?000000011101001100111000?001110000?????0??1??010?001100010000?????
01?0?????01?????????????00?0?0?????0110?0000??112?0?0?0?0?000110101??011?????????????????0?????????
?????????????001?000?00001000?100000?111100??0??01010000102101?0010000000010100?0?????????????
????????????????????????????????????????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????
?????

Rahonavis_ostromi ?????????0?????????????0????????????????????????????????????????????????????????
????????????????????????????????????????????????????????????????????????????????????????????
?????????????????????????????????????????????????????????????????????????????????????????01201110
0000?10010010010?041001?000??10120010010020??????1?1112?????????????????1100110?????2??????100
01010000?????????????????????????????????00?????01000?21011110011100010000?011100211??00111??00112
10000011121011010001112?2011000010000010111110011100100100012000110100110011011110101110
?001010?

Rinchenia_mongoliensis ??1?????011100?0?00??1?????????????0?????????01?????1?????0100?010?0?10?????
101?0?????0?00?????0?0?0?????00?000?00?????????1??1??1?????????0?????????0????????????????????
?????21?0?011?11111?0??0?10?0?0?0?0?0??111?????1?????????2????????????????????????????
?????????????????????????????????????0?????????????????????1?????????????11?????????0??1?0?0?0???
?????0??0?????????1?????????????????????????00?000?????102??111?01?1????????????????????????
?????????????????????????????????????0?????????0?????????????????????????????0?????????????????0?????
?

Sapeornis_chaoyangensis ??0000000?010??1?1??0??????0??????1?00?????00001000??????11?002?00?????12
?0????10?11??0??100?0?0000?0?0????????????????????????????????????????????????????????????
??????10?001001010?00?0?0?00?0?1?101??0?0010100?100?011?2120?2?????????0?0?????0?????????2?
?????211??0?????0?????????????????05??01??0?210?0??1?0000?????0?????????????11??2010??11001101111
012?001?011100?1000000111100010101111?1022??020010010000001000?11010?????1?1??010000?0?100?
3110101101?01010?10001011010011010?11112?2?11??00100?0?????????????1?????????11??1001??1110001
0??0?10??10?0?0?000?

Sauornithoides_mongoliensis ??1000??1100000??10?01?0?????0??0?01??01000??0?????????1??????????
??110?????????????0?????0?00??0?????????????????????1?01?????00?11?????????1?????????????0?0?0?????
??0?0?11?0?000?0?100000??011??0?0?????????????1?????0?000??02101?0010001000101010?0????????????
??????????1??0?00?????0000?00?0?000?0?010?000??001????00????????????????????????????
?????????????????????????????????????????????????????????????0????????????????????????????
????????????????

000011?100?0??1??01?0001??0??0?1??0?01??10?00?0??0??0?00?20001101001?001100?00?0??0020??0
00?
Sinovenator_changii ??1??0001010??0010?1100111000?11??000??000??011??0??0??0??0??0??0??
??0??0??0?000??0??01??0??00??12??011??0??0??0?00100??00?0??0100?110??0?10??11001010
?001??1?0??0??000??011100?0??0?1?0?0??0??0101?00?0?2?1?0?10?010??1?01?0??0??0??10??0?210?
10??01??000??0??00?01??100??0?1?401?00??10??1??01??2??0??0??0??0??1??0??0??20110??10?101??
????????????????????0??10?001????????????????????0000??????????111??01????0?11?00?211??01
0??0011210??0011210010?10?01?11110110?0?11?00?11?111?0011??1000?10?0001??001????00?10
??1?1?1??1??
Sinraptor_dongi ??001000000000?10000000?010?000110110000?0000001000000200000000100101??11210
??1100110000?010010011000?00010000010?0113000001000010000101?00000?10?00101000100100??10?
?0?0?0?00?1011000?0000?010100?0111010000??010101010000002100?00000000000?010100110111010?
10100001011?00110011010101010011000001?0100300000????0002?00?0??1?1001??1??1??10??000???
??1010100?0????0????????????????????0??11101210????1000000100100101001??0000?0?1000
01000000001100??11010000100000011010000?00010?1000110011001000101010111?000000?00?00000010
00011000?00110000001010?0100?000?
Struthiomimus_altus ??0??0021000??1?10?110?110?0000011?000??0000100?11??1110?00010?0??11?0
1111?12000?0010100?0?0000?00010010112?1011??01?0??1??0??0?1000??0??0??0000?0??0?010??110?
0?100010?000?0001001011000?00?0101?1?1010?0??011??0??1??0??0??0??0??0??0??0??0??0??0??0??
2100??002??0000??0??0??1??0000??0?00401?00??100?0??00??0??1?01?0??0??0?10??0??0??111110??11?0
000020010001200001000000001?0?000101001111110022100112?000112100100101??10001100?10??0?101
000000100100001?0000100010001010000?110?01?00011001?0010?0?000??1100010?0?10?0100?200011??
00101??100?01011010?0001010
Suchomimus_tenerensis ???101201????0?0????1?0?111??0?01?001000?01????????????????000?0?0?????
0????100????????000????0??1????????????10????????0????????????????????????????????????????
????????110????0?0?????????1????????????3??00022000?01?1?2??0?0??0?1?01??1?10??0?????11??
0?1?0?1?1??10????11000001?01?0????????????0????0??0??0??0??0??0??0??0??0??0??0??0??0??0??0??
2?1??0?21001??10????????????????100??0????0100????0?0?10000????1??0?01?0??0?0??00????0?
{01}{01}00?0??00?11?10??0??01011?1001?010?0?0??0??0?10111??1?1?0?00????110001????????????
????????????????
Syntarsus_rhodesiensis ??0?0211?0?000??0??0000?0101001?1110??1010?001001?11?0000000000?0??12
2?0??00120100????0000?00?00??0110??00?0?010??00??1?0000?0??01??100??0?0?0?0?10000?0010?
??0?????????1?100??0011?100??10101000?????????1010?010?010?00000??1??00?00?0110??0?1100?0
0??001000?0000010002??100010?00??0?00?03010??1?0000020?000?00001?1?0?1?00????????0??1000?
1000?0?1?0?10001100??1??0??0?0?1?0000001?001000110?0?11110000??011000?0000??1000?000110
1??0001?0?00??0001101100010110010000?0?110000??00000{01}010000101?10110?000?10?1010??1001
000000?10?0?100?0??000??1001000?
Tanycolagreus_topwilsoni ??1??000?00?00????????????????????1?0000??0????????00000?1??12
201?00????????0?00?110?1????????????000?010????????????????????????????????????????????
????????????????????????????????1000????101??01??0?10??0??000?0??????????011??1??0??1??????
??????0?0?00100????1001100?001?0?0????????00?0??????20?00????1????????????00010?1?10000??101
110?011?0111000000010??11000010100?110002210?20?100000000????????????????????????????111
101?1????0?????????????????10101100011000100100000?010111?00100011000100?2000111100100010?0
?00010?0002001000?
Tarbosaurus_bataar ??0??00000011010000?100110?000000?0000????110010100120110011000?111101??
100001??01000??0?1010?112?111011001010??01031000010000?000??01?10010?1?000001001??0000?????
?0??????0??0011?00??0000?00?100001?11110111001010101000010200??0?0000000?00010????????????
????????????????????????????????????0????????????????????????????????????????????????????
????0?0????????????????????????0????????32????????????????????????????????????????????????

