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Mass extinctions among families of non-marine tetrapods : the data

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Abstract — There are 858 families of living and extinct non-marine tetrapods. Of these, 776 have a fossil record. The geological ranges of these milies are tabulated, accurate to the level of the stratigraphic stage (mean duration, 6 Ma). These data are used to indicate the occurrence, and the gnitudes, of six mass extinction events. The fossil record of non-marine tetrapods is generally regarded as poor, and this question is explored. The mpleteness of the record varies from 0 % (no fossils) to apparently 100 % for some stages. Lissamphibians have the most incomplete record, and e synapsids and the mammals appear to have the most complete record.

Les crises biologiques dans les familles de tétrapodes non-marins : les données

Résumé. — Il y a 858 familles de tétrapodes non-marins fossiles et actuelles. 776 sont représentées à l'état fossile. Les distributions ratigraphiques de ces familles sont énumérées jusqu'au niveau de l'étage stratigraphique (durée moyenne, 6 Ma). Ces renseignements sont utilisés pour diquer l'existence et l'importance de six crises biologiques. Les documents fossiles concernant les tétrapodes non-marins sont considérés généralement mme incomplets et cette question est examinée. L'état des documents varie de 0 % (pas de fossiles) à, apparemment, 100 % pour quelques étages. s lissamphibiens sont le plus incomplètement représentés tandis que les synapsides et les mammifères semblent être le mieux représentés.

I. — INTRODUCTION.

The fossil record of non-marine tetrapods (amphibians, eptiles, birds, mammals) offers useful information on nass extinctions, adaptative radiations and rates of evolu- ion [e.g. Van Valen, 1973; Bakker, 1977; Martin & Klein, 984; Russell, 1984; Benton, 1985b, c; Padian & Clemens, 985]. However, the fossil record of non-marine tetrapods s very poor in parts, and it might be considered too atchy for worthwhile evolutionary studies. In this paper, tabulate the record of families of terrestrial tetrapods, nd attempt to assess the completeness of that record for lifferent time intervals and for different taxonomic roups. The listing may be used as a supplement to the ompendium of families of marine invertebrates and ertebrates by Sepkoski [1982].

II. — THE DATA SET.

A compilation of the fossil and living families of on-marine amphibians, reptiles, birds and mammals was nade (see Appendix). Fully marine groups were excluded (i.e. mesosaurs, ichthyosaurs, placodonts, nothosaurs, plesiosaurs, marine lizards (mosasaurs, aigialosaurids, dolichosaurids), marine turtles (carettochelyids, protostegids, toxochelyids, dermochelyids, cheloniids), and marine mammals (cetaceans, sirenians, desmostylians, pinnipeds). A number of remaining families are partially marine in habits, but they were retained in the list.

The list of families was compiled from the latest general taxonomic reviews, where possible, and supplemented by more recent papers, up to 1985. The main sources of data are noted at the beginning of each major group, and subsidiary references are indicated for some families. The total number of living and extinct families of non-marine tetrapods is 858. Of these, 82 families have no fossil representatives, leaving a total of 776. Further, 77 families of extinct tetrapods are represented by only one species (often based on a single specimen from a single locality). These families are listed in the Appendix, but calculations were based on the remaining 699 families alone.

The total range in geological age for each family was determined from the most recent literature, and this was resolved to the level of the stratigraphic stage. The Miocene and Pliocene were not divided into stages, and ages were determined as Lower Miocene, Middle Miocene, Upper Miocene, or Pliocene. The duration of the stratigraphic stages during which tetrapods lived varies from 2-19 Ma (mean duration, 6 Ma).

This compilation of data is a slightly revised version of the data set used in a number of other publications [Benton, 1985b, c, 1986].

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III. — Mass extinctions.

Mass extinctions of non-marine tetrapods may be detected in a broad way by examining a plot of total family diversity through time (fig. 1). There is a general rising trend in total family diversity from the Famennian to the present-day, and this trend is particularly marked in the late Cretaceous and Cenozoic parts of the diagram. The number of families present remained below about 50 until the late Cretaceous (Campanian), when it rose to 70-80, and it increased thereafter to the present total of 337. These results are discussed in more detail in Benton [1985b].

Declines in diversity occurred several times. These declines could be interpreted as extinction events, or as the result of a particularly poor fossil record. Benton [1985 b] argued that there were probably six mass extinctions in the record of non-marine tetrapods (fig. 1), and that the declines in the mid-Permian, the early to mid Jurassic, and the mid-Cretaceous were caused by a particularly poor fossil record. This topic deserves further study.

IV. — Completeness of the record.

The fossil record of non-marine tetrapods is very patchy, and palaeontologists rely heavily on a relatively small number of fossil Lagerstätten for their information in much of the pre-Cenozoic. In some cases, the record is

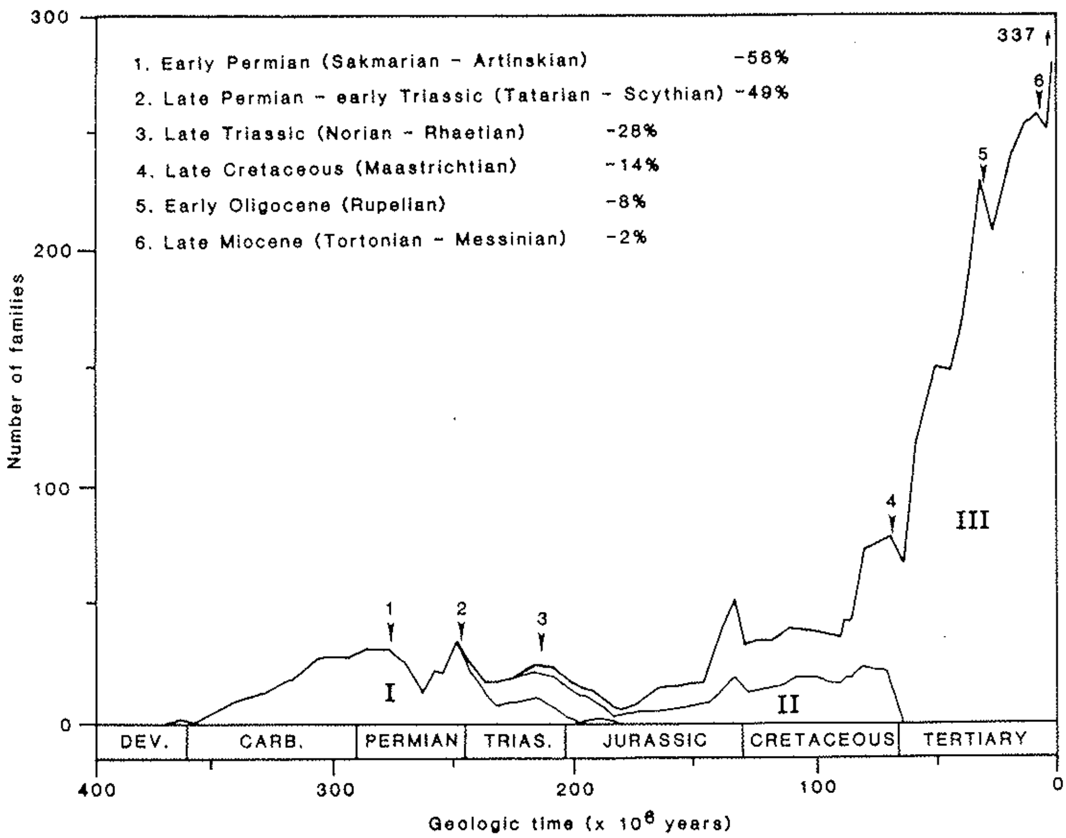

Fig. 1. — Standing diversity with time for families of terrestrial tetrapods. The upper curve shows total diversity with time, and six apparent mass extinctions (numbered 1-6) are indicated by drops in diversity. The relative magnitude of each drop is given in terms of the percentage of families that disappeared. Three assemblages of families succeeded each other through geological time : I, labyrinthodont amphibians, anapsids, mammal-like reptiles; II, early diapsids, dinosaurs, pterosaurs; III, the "modern" groups : frogs, salamanders, lizards, snakes, turtles, crocodiles, birds, mammals. (Further details are given in Benton [1985b]). Carb. = Carboniferous; Dev. = Devonian; Trias = Triassic.

Fig. 1. — *Diversité des tétrapodes non-marins en fonction des temps géologiques. La courbe supérieure montre la diversité totale, et six crises biologiques possibles (énumérées 1-6) sont indiquées par des réductions de la diversité. L'importance relative de chaque réduction est donnée en pourcentage de familles qui disparaissent. Trois groupes de familles se sont succédées au cours des temps géologiques : I, labyrinthodontes, anapsides, synapsides; II, diapsides primitifs, dinosaures, ptérosaures; III, les groupes "modernes" : grenouilles, salamandres, lézards, serpents, tortues, crocodiles, oiseaux, mammifères. (Pour en savoir plus, voir Benton [1985b]).* Carb. = *Carbonifère;* Dev. = *Dévonien;* Trias = *Trias.*

so poor that there are only one or two specimens known from a stratigraphic stage, and in the Aalenian (middle Jurassic), there are no records at all.

There are various ways of assessing the completeness of a fossil record [Paul,1982]. The simplest is to compare the number of taxa that have been recorded with the number that are known to have occurred in each stratigraphic stage. If a family is known from below and above a stage, it must have occurred during the intervening interval, even if specimens have not been found (this phenomenon has been termed the Lazarus effect by Jablonski [1983, 1986]). ["Then said Jesus unto them plainly, Lazarus is dead... And he that was dead came forth, bound, hand and foot with grave-clothes..." : John, xi, 1-44]. The more "Lazarus" taxa there are in a stratigraphic stage, the more incomplete that part of the fossil record is.

In order to calculate the completeness metrics, the full ranges of all 699 families of non-marine tetrapods that are known as fossils were plotted. A survey was made of the records for each family, and fossils were noted as "present" or "absent" for each stage during which the family is known to have existed. A matrix of 3 861 records was generated, of which 2 628 were known occurrences. The remaining 1 233 records then represent "Lazarus" taxa. A simple completeness metric for the entire record of non-marine tetrapods is 2 628/3 861 = 68.07 %. This value is a measure of the several factors that contribute to "completeness" : volume of sediment deposited during a stage, area of exposure, intensity of palaeontological study, and so on.

The summary data for completeness are listed by stratigraphic stage in table I. Completeness metrics range from 0 % (Aalenian) to 100 % (Famennian, Serpukhovian, Ufimian, Tatarian, Scythian). There are particularly poor fossil records (completeness metric < 50 %) in the late Carboniferous (Gzelian), the early to middle Jurassic (Toarcian-Bajocian), the middle to late Jurassic (Callovian-Oxfordian), the early Cretaceous (Berriasian-Aptian), and the late Cretaceous (Cenomanian-Santonian). Even in the Tertiary, there are a number of rather poor fossil records (completeness metric, 50-75 %) in the early Palaeocene (Danian), the middle to late Eocene (Lutetian-Priabonian), the late Oligocene (Chattian), and the middle to late Miocene (see fig. 2).

These simple completeness metrics do not give a perfect measure of the relative incompleteness of the fossil record. When a stage with a poor record occurs between two stages with good records, then there will be many "Lazarus" taxa, and the metric will be fairly accurate. However, if there is a succession of poor records, we will detect relatively fewer "Lazarus" taxa because fewer families can span a wide time interval, and the metric becomes less reliable (this is illustrated in simple terms in fig. 3). For example, the fossil record in the Sinemurian and Pliensbachian (early Jurassic) is probably much worse than the metrics of 88.2 % and 76.9 % would seem to suggest. The only way to improve the accuracy of the

TABL. I. — Completeness of the fossil record of non-marine tetrapods, measured by stratigraphic stage, and by taxonomic class. The total numbers of families present in each stage are given (column 1), followed by the numbers known as fossils (column 2). The difference between these two figures corresponds to the "Lazarus" taxa. The completeness metrics are plotted in figure 2.

TABL. I. — *Perfection des documents fossiles des tétrapodes non-marins, indiquée par étage stratigraphique, et par classe taxonomique. Les nombres totaux de familles dans chaque étage (colonne 1) sont suivis par les nombres connus à l'état fossile (colonne 2).*

	AMPHIBIA		'REPTILIA'		AVES		MAMMALIA		TOTAL		completeness
	1	2	1	2	1	2	1	2	1	2	metric (%)
DEVONIAN											
1. Famennian	2	2							2	2	100
CARBONIFEROUS											
1. Tournaisian	0	0							0	0	-
2. Visean	7	7							7	7	100
3. Serpukhovian	12	9							12	9	75
4. Bashkirian	19	17							19	17	89.5
5. Moscovian	25	24	2	2					27	26	96.3
6. Kasimovian	22	12	6	6					28	18	64.3
7. Gzelian	22	5	6	2					28	7	25.0
PERMIAN											
1. Asselian	23	18	8	7					31	25	80.6
2. Sakmarian	22	20	9	9					31	29	93.5
3. Artinskian	15	14	10	10					25	24	96.0
4. Kungurian	8	3	6	6					14	9	64.3
5. Ufimian	11	11	11	11					22	22	100
6. Kazanian	6	2	14	14					20	16	80.0
7. Tatarian	9	9	27	27					36	36	100
TRIASSIC											
1. Scythian	11	11	17	17					28	28	100
2. Anisian	4	3	13	13					17	16	94.1
3. Ladinian	4	4	13	12					17	16	94.1
4. Carnian	4	4	18	17					22	21	95.5
5. Norian	4	3	19	18			1	1	24	22	91.7
6. "Rhaetian"	3	2	16	13			3	3	22	18	81.8
JURASSIC											
1. Hettangian	1	0	14	12			3	3	18	15	83.3
2. Sinemurian	1	0	14	13			2	2	17	15	88.2
3. Pliensbachian	2	1	10	9			1	0	13	10	76.9
4. Toarcian	2	1	6	3			1	0	9	4	44.4
5. Aalenian	1	0	5	0			1	0	7	0	0
6. Bajocian	2	1	6	2			1	0	9	3	33.3
7. Bathonian	2	0	8	6			6	6	16	12	75.0
8. Callovian	2	0	10	7			4	0	16	7	43.8
9. Oxfordian	2	0	11	4			4	0	17	4	23.5
10. Kimmeridgian	3	2	30	28			9	9	42	39	92.9
11. Tithonian	4	2	37	26	1	1	10	10	52	39	75.0
CRETACEOUS											
1. Berriasian	4	0	24	2	0	0	6	0	34	2	5.9
2. Valanginian	4	0	24	13	1	1	6	3	35	17	48.6
3. Hauterivian	4	1	25	13	1	0	7	3	37	17	45.9
4. Barremian	4	1	27	15	1	0	6	2	38	18	47.4
5. Aptian	5	1	30	13	1	0	4	4	40	18	45.0
6. Albian	5	1	30	18	2	1	3	3	40	23	57.5
7. Cenomanian	5	0	28	16	1	0	2	0	36	16	44.4
8. Turonian	5	0	28	7	2	1	2	0	37	8	21.6
9. Coniacian	5	0	30	8	5	4	2	0	42	12	28.6
10. Santonian	5	0	31	13	3	0	5	3	43	16	37.2
11. Campanian	8	4	44	38	3	2	17	17	72	61	84.7
12. Maastrichtian	10	9	48	45	8	8	15	15	81	77	95.1
CENOZOIC											
1. Danian	9	5	25	8	4	0	32	30	70	43	61.4
2. Thanetian	19	15	32	24	6	2	68	66	125	107	85.6
3. Ypresian	19	7	34	22	22	19	78	75	153	123	80.4
4. Lutetian	18	7	35	23	27	11	74	51	154	92	59.7
5. Bartonian	18	2	32	19	26	10	93	70	169	101	59.8
6. Priabonian	18	2	32	21	42	30	95	73	187	126	67.4
7. Rupelian	19	9	36	24	51	30	121	117	227	180	79.3
8. Chattian	20	7	37	18	50	10	100	83	207	118	57.0
9. Lower Miocene	22	11	38	25	69	45	115	109	244	190	77.9
10. Middle Miocene	24	14	39	25	73	32	121	103	257	174	67.7
11. Upper Miocene	24	11	40	24	73	22	122	99	259	156	60.2
12. Pliocene	23	14	40	24	78	41	113	99	254	178	70.1
13. Pleistocene	23	16	38	29	113	107	107	87	281	239	85.0
TOTALS	575	324	1173	781	663	377	1360	1146	3861	2628	
Completeness metric (%)	56.3		78.2		56.9		84.3		68.1		

completeness metrics would be to try to estimate the numbers of absent "non-Lazarus" taxa, those that died out or arose at some unknown time during the gap in the record. Such an estimate, or measure of probability, would depend on several factors : (1) the numbers of families known at each end of the interval, (2) the mean family duration of the relevant taxa, and (3) the potential numbers of taxa that arose and died out during the gap. This has not been attempted here.

It is commonly asserted that the fossil record of, say, birds is relatively very poor, compared to that of mammals because flying animals are only rarely preserved [e.g. Fisher, 1967]. This kind of opinion can now be tested. Simple completeness metrics were calculated for the fossil records of various groups of non-marine tetrapods, and these are listed in table II.

In fact, the lissamphibians (frogs, salamanders, etc.) have the worst fossil record (42.0 % complete), probably because of their small size and the extreme delicateness of their bones. The fossil record of lepidosaurs (lizards, snakes, *Sphenodon*) is also poor (48.6 % complete), probably for the same reasons. The birds as a whole have

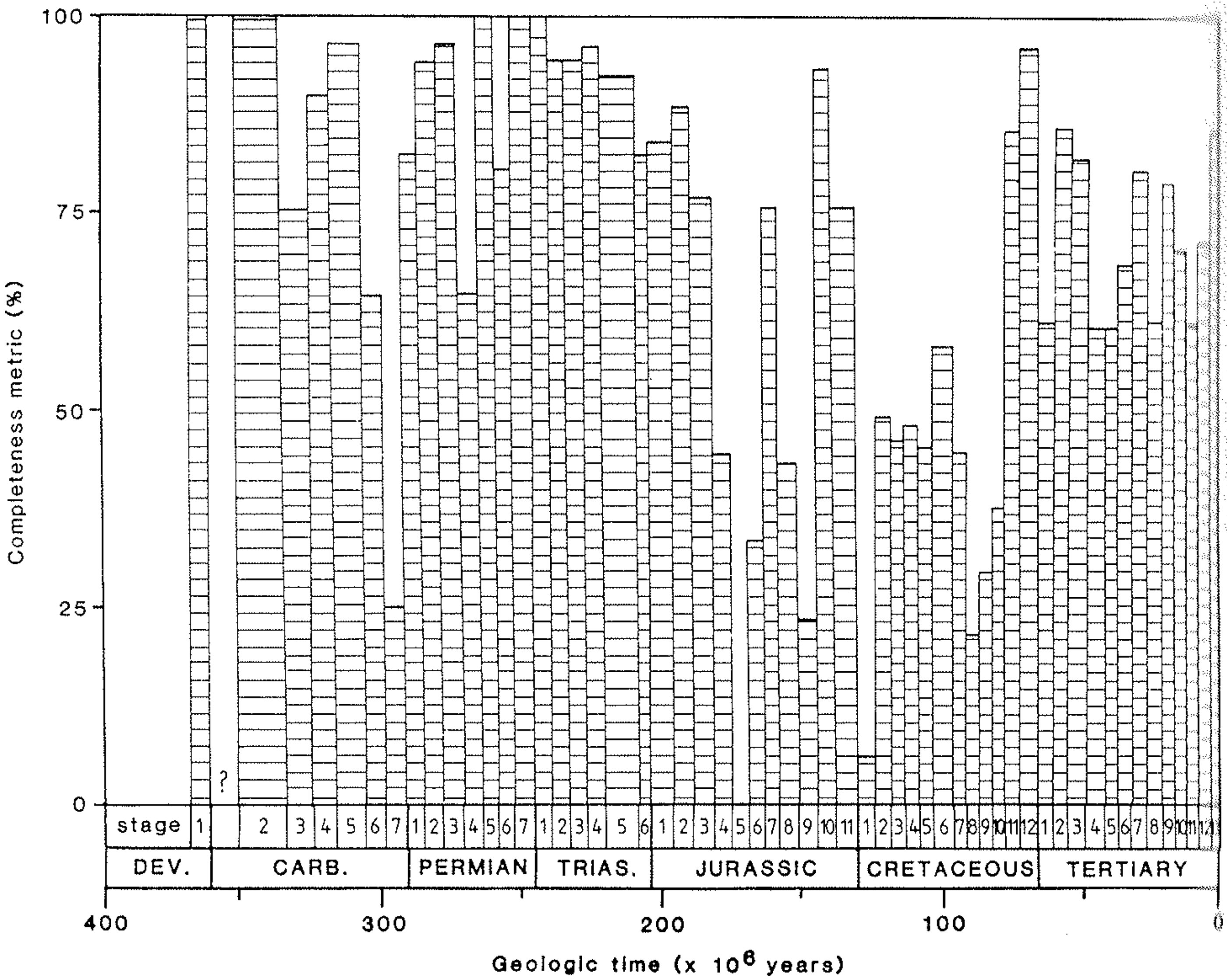

FIG. 2. — Completeness of the fossil record of non-marine tetrapods measured stage by stage. The completeness metric is a simple measure of the proportion of families that have been found as fossils in each stratigraphic stage to the numbers that are known to have been present. The stratigraphic stages are numbered as in table I. Data from table I.

FIG. 2. — *Niveau de perfection des documents fossiles des tétrapodes non-marins, indiqué pour chaque étage stratigraphique. La mesure de perfection montre simplement le rapport entre les familles qui sont connues à l'état fossile à chaque étage stratigraphique et le nombre de familles réellement présentes. Les étages stratigraphiques sont énumérés suivant le tableau I. Données tirées du tableau I.*

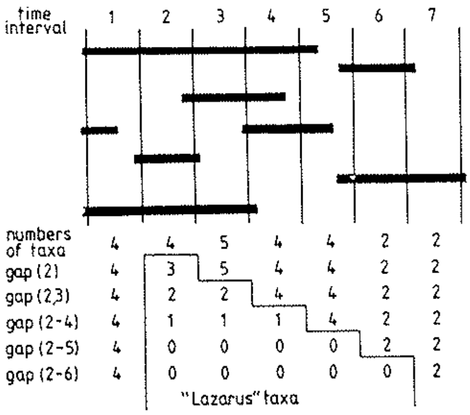

FIG. 3. — Estimates of the completeness of the fossil record become relatively worse as the gap increases. In many cases, it is known that families not found as fossils within a particular stage must have been present because they are known from both sides of the gap. These "Lazarus" taxa can only be predicted from such gap-spanning distributions, and the larger the gap, the less taxa span it. This can have the effect of making simple completeness metrics higher than they should be.

FIG. 3. — *Les estimations de la perfection des documents fossiles deviennent proportionnellement moins exactes en fonction des lacunes. Souvent, nous savons que des familles qui ne sont pas connues à l'état fossile dans un étage donné, étaient en fait présentes parcequ'elles sont connues de part et d'autre de la lacune. Ces taxons "Lazare" ne peuvent être reconnus que par de telles distributions qui traversent la lacune. Plus grande est la lacune, moins nombreux sont les taxons qui la traversent. Il en résulte que les mesures de perfection peuvent être surestimées.*

TABL. II. — Completeness metrics for particular taxonomic groups, extracted from the data in table I.

TABL. II — *Mesures de perfection pour quelques groupes taxonomiques, dérivées des données du tableau I.*

	Total assumed	Total fossils	Completeness metric (%)
AMPHIBIA	575	324	56.3
Labyrinthodontia	165	126	76.4
Lepospondyli	68	51	75.0
Lissamphibia	350	147	42.0
"REPTILIA"	1173	781	78.2
Testudines	154	107	69.5
Diapsida	813	485	59.7
Lepidosauria	259	126	48.6
Archosauria	520	328	63.1
Synapsida	110	104	94.5
AVES	663	377	56.9
Passeriformes	75	47	62.7
MAMMALIA	1360	1146	84.3
Marsupalia	107	79	73.8
Eutheria	1130	983	87.0
Edentata	55	47	85.5
Carnivora	63	62	97.1
Insectivora	33	27	81.8
Chiroptera	65	50	75.7
Primates	85	59	70.3
Artiodactyla	155	149	96.6
Perissodactyla	78	75	96.2
Rodentia	225	199	88.4

a rather better fossil record than might have been expected (56.9 % complete), about the same as the amphibians as a whole (56.3 % complete), and not much worse than the Diapsida as a whole (59.7 %complete). The best fossil records are those of mammal-like reptiles (synapsids : 94.5 % complete), placental mammals (87.0 % complete), and mammals as a whole (84.3 % complete). Amongst placental mammals, the main orders have generally good fossil records, the best being those of the carnivores (97.1 % complete), the artiodactyls (96.6 %), and the perissodactyls (96.2 %). As might be expected, the primates (70.3 %) and bats (75.7 %) have rather poorer fossil records.

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(References for the paper and the appendix. Many of the papers cited in the appendix are not listed here, in order to save space. They may be found in Benton [1985c]).

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APPENDIX

Listing of families of non-marine tetrapods.
* families that contain one species from one locality (often a single specimen): omitted from calculations.
+ living families with no fossil representatives.
Families that are still living are designated "REC". Those that survived until historic times, but are now extinct, are termed "HOL".
Stratigraphic abbreviations: ALB, Albian; ANI, Anisian; APT, Aptian; ART, Artinskian; ASS, Asselian; BAJ, Bajocian; BAR, Barremian; BAS, Bashkirian; BER, Berriasian; BRT, Bartonian; BTH, Bathonian; CAL, Callovian; CEN, Cenomanian; CHT, Chattian; CMP, Campanian; CON, Coniacian; CRN, Carnian; DAN, Danian; FAM, Famennian; GZE, Gzelian; HAU, Hauterivian; HET, Hettangian; KAS, Kasimovian; KAZ, Kazanian; KIM, Kimmeridgian; KUN, Kungurian; LAD, Ladinian; LMI, Lower Miocene; LUT, Lutetian; MAA, Maastrichtian; MMI, Middle Miocene; MOS, Moscovian; NOR, Norian; OXF, Oxfordian; PLB, Pliensbachian; PLE, Pleistocene; PLI, Pliocene; PRB, Priabonian; RHT, Rhaetian; RUP, Rupelian; SAK, Sakmarian; SAN, Santonian; SCY, Scythian; SER, Serpukhovian; SIN, Sinemurian; TAT, Tatarian; THA, Thanetian; TOA, Toarcian; TTH, Tithonian; TUR, Turonian; UFI, Ufimian; UMI, Upper Miocene; VAL, Valanginian; VIS, Visean; YPR, Ypresian.

AMPHIBIA (Carroll and Winer 1978; Anderson and Cruickshank 1978)

ICHTHYOSTEGALIA		
Ichthyostegidae	FAM	
*Acanthostegidae	FAM	
LOXOMMATOIDEA		
Loxommatidae	VIS - MOS	
TRIMERORACHOIDEA		
Colosteidae	VIS - MOS	
Saurerpetontidae	BAS - ART	
Trimerorachidae	KAS - UFI	
Dvinosauridae	UFI - TAT	
EDOPOIDEA		
Dendrerpetontidae	SER - BAS	
Cochleosauridae	BAS - ASS	
Edopidae	MOS - ASS	(A. R. Milner 1980)
ERYOPOIDEA		
Eryopidae	?KAS - UFI	(Gubin 1983)
Dissorophidae	?BAS - KAZ	(Gubin 1980)
Intasuchidae	UFI	
Branchiosauridae	MOS - SAK	
Micromelerpetontidae	MOS - SAK	
*Doleserpetontidae	ART	
Trematopsidae	KAS - ART	
Parioxyidae	SAK	
Zatracheidae	MOS SAK	
Archegosauridae	ASS - UFI	(A. R. Milner 1980)
Melanosauridae	UFI - TAT	
RHINESUCHOIDEA		
Rhinesuchidae	KAZ - TAT	
Lydekkerinidae	SCY	
*Sclerothoracidae	SCY	
*Peltobatrachidae	TAT	
Uranocentrodontidae	TAT - SCY	
CAPITOSAUROIDEA		
*Latiscopidae	NOR	
Benthosuchidae	TAT - SCY	
Capitosauridae	SCY - RHT	
Mastodonsauridae	SCY - LAD	
RHYTIDOSTOIDEA		
Rhytidosteidae	SCY	
*Laidleriidae	SCY	
TREMATOSAUROIDEA		
Trematosauridae	SCY	
Indobrachyopidae	SCY	(Cosgriff and Zawiskie 1979)
BRACHYOPOIDEA		
*Kourerpetontidae	?Perm	
Brachyopidae	TAT - LAD	
Chigutisauridae	CRN - TOA	(Warren and Hutchinson 1983)
METOPOSAUROIDEA		
Metoposauridae	CRN - NOR	
*Almasauridae	NOR	
PLAGIOSAUROIDEA		
Plagiosauridae	SCY - RHT	

AMPHIBIA: BATRACHOSAURIA

PALAEOSTEGALIA		
*Crassigyrinidae	SER	(Panchen 1980)
HERPETOSPONDYLI		
Proterogyrinidae	VIS - SER	
EMBOLOMERI		
Eogyrinidae	SER - ASS	
Archeriidae	MOS - ART	
Anthracosauridae	BAS - MOS	
GEPHYROSTEGIDA		
Gephyrostegidae	SER - MOS	
Eoherpetontidae	VIS - SER	
SEYMOURIAMORPHA		
Seymouriidae	SAK - UFI	
Discosauriscidae	ASS - SAK	
Kotlassidae	UFI - TAT	
Lanthanosuchidae	UFI - TAT	(Ivakhnenko 1980)
Chroniosuchidae	TAT	
INCERTAE SEDIS		
Limnoscelidae	BAS - SAK	
*Solenodonsauridae	MOS	
*Tseajaiidae	ASS	
*Nycteroletoridae	UFI	
Diadectidae	?ASS - UFI	

AMPHIBIA: LEPOSPONDYLI

AISTOPODA		
Ophiderpetontidae	VIS - GZE	
Phlegethontiidae	BAS - MOS	
*Lethiscidae	VIS	
NECTRIDEA (A. C. Milner 1980)		
Keraterpetontidae	SER - KUN	
Scincosauridae	MOS - SAK	
Urocordylidae	SER - ART	
MICROSAURIA		
Tuditanidae	BAS - GZE	
Hapsidopareiontidae	BAS - ART	
Pantylidae	BAS - SAK	
Gymnarthridae	BAS - KUN	
Ostodolepidae	ART	
*Trihacetontidae	KAS/ GZE	
Microbrachidae	BAS MOS	
INCERTAE SEDIS		
Adelogyrinidae	VIS - SER	(Smithson 1980)
Lysorophidae	MOS - ART	
Acherontiscidae	VIS - SER?	

AMPHIBIA: LISSAMPHIBIA (Carroll and Winer 1978)

ANURA (Estes and Reig 1973)		
*Triadobatrachidae	SCY	
Ascaphidae	PLB - REC	
Discoglossidae	KIM - REC	
Pipidae	?APT - REC	
Palaeobatrachidae	TTH - PLE	
Rhinophrynidae	THA - REC	
Pelobatidae	MAA - REC	
Pelodytidae	MMI - REC	
Leptodactylidae	THA - REC	
Bufonidae	THA - REC	
Ceratophrynidae	?MMI - REC	
Hylidae	THA - REC	
Microhylidae	LMI - REC	
Rhacophoridae	PLE - REC	
Ranidae	CHT - REC	
GYMNOPHIONA (Estes 1981)		
Caeciliidae	THA - REC	
CAUDATA (Estes 1981; Milner 1983)		
*Karauridae	?U.Jur.	
Cryptobranchidae	THA - REC	
+Hynobiidae	REC	
Prosirenidae	BAJ - UMI	
Proteidae	THA - REC	
Batrachosauroididae	CMP - PLI	
Amphiumidae	MAA - REC	
Dicamptodontidae	THA - REC	
Scapherpetontidae	CMP - YPR	
Ambystomatidae	RUP - REC	
Plethodontidae	LMI - REC	
Salamandridae	THA - REC	
Sirenidae	CMP - REC	

REPTILIA: EARLY ANAPSID FORMS (Anderson and Cruickshank 1978)

Romeriidae	MOS - ART	(Reisz 1979)
Captorhinidae	SAK - TAT	(Ricqlès and Taquet 1982)
Bolosauridae	ASS - ART	
*Acleistorhinidae	ART	
*Eunotosauridae	KAZ	
*Nyctiphuretidae	UFI	
Procolophonidae	TAT - RHT?	(Olsen 1980)
Millerettidae	KAZ - TAT	
Rhiphaeosauridae	UFI	
Pareiasauridae	KAZ - TAT	

REPTILIA: TESTUDINES (Gaffney 1975, 1979; Młynarski 1976)

PROGANOCHELYDIA	
Proganochelyidae	NOR - PLB (Olsen and Galton 1984)
PLEURODIRA	
Pelomedusidae	TUR - REC
Chelidae	?CHT - REC
BAENOIDEA	
Glyptopsidae	KIM - TTH
Baenidae	TTH - BRT
TRIONYCHOIDEA	
Kinosternidae	RUP - REC
Dermatemyidae	TTH - REC
Trionychidae	?CMP - REC
CHELONIOIDEA	
Plesiochelyidae	KIM - TTH
TESTUDINOIDEA	
Chelydridae	MAA - REC (Whetstone 1978)
Emydidae	?YPR - REC
Testudinidae	LUT - REC
INCERTAE SEDIS	
Pleurosternidae	TTH - APT
Meiolaniidae	?MAA - PLE

REPTILIA: DIAPSIDA: EARLY FORMS (Benton 1985a)

*Petrolacosauridae	?KAS
Araeoscelidae	ASS - ART
*Galesphyridae	TAT
Weigeltisauridae	KAZ - TAT
*Claudiosauridae	TAT
*Heleosauridae	TAT
Kuehneosauridae	CRN - NOR
*Monjurosuchidae	?Jur.
Thalattosauridae	LAD - CRN
Claraziidae	LAD
Champsosauridae	ALB - YPR? (Sigogneau-Russell and Efimov 1984)
Trilophosauridae	CRN
RHYNCHOSAURIA	
*Mesosuchidae	SCY
*Howesiidae	SCY
Rhynchosauridae	ANS - CRN
PROLACERTIFORMES	
Protorosauridae	KAZ
Prolacertidae	SCY - LAD
Tanystropheidae	ANS - NOR
YOUNGINIFORMES	
Younginidae	TAT
Tangasauridae	TAT
*Saurosternidae	TAT
LEPIDOSAUROMORPHA INC. SED.	
*Paliguanidae	SCY
*Palaeagamidae	TAT

REPTILIA: DIAPSIDA: ARCHOSAURIA (Benton and Norman 1986)

"THECODONTIA"	
Proterosuchidae	TAT - SCY
Erythrosuchidae	SCY - ANS ?
Proterochampsidae	LAD - CRN
Euparkeriidae	SCY
Phytosauridae	CRN - RHT
Aetosauridae	CRN - RHT
Rauisuchidae	SCY - RHT
Poposauridae	LAD - NOR
Ornithosuchidae	CRN - NOR
Lagosuchidae	LAD
*Scleromochlidae	CRN
*Erpetosuchidae	CRN
CROCODYLOMORPHA (Buffetaut 1982; Benton and Norman 1986)	
*Trialestidae	CRN
Saltoposuchidae	NOR
Sphenosuchidae	CRN - SIN
Protosuchidae	RHT - SIN
*Orthosuchidae	HET/ SIN
Libycosuchidae	BAR - CEN
Uruguaysuchidae	APT - MAA
Notosuchidae	MAA
Hsisosuchidae	?KIM - CMP
Baurusuchidae	CON - LUT
Sebecidae	THA - PLI
*Crocodileimidae	KIM
Trematochampsidae	?CON - CMP
Goniopholididae	KIM - MAA
Pholidosauridae	BTH - CEN
Bernissartidae	KIM - HAU?
Paralligatoridae	CMP
Atoposauridae	KIM - APT
Alligatoridae	CMP - REC
Nettosuchidae	UMI - PLI
Crocodylidae	CMP - REC
Pristichampsidae	THA - PLE
Gavialidae	?LUT - REC
Thoracosauridae	CMP - THA?
*Dolichochampsidae	?U. Cret.
Euthecodontidae	YPR - PLE
PTEROSAURIA (Wellnhofer 1978; Benton and Norman 1986)	
Dimorphodontidae	NOR - SIN
*Eudimorphodontidae	NOR
*Anurognathidae	TTH
Rhamphorhynchidae	TOA - TTH
Pterodactylidae	KIM - TTH
Germanodactylidae	TTH
Ctenochasmatidae	TTH - SAN
*Pterodaustridae	?L. Cret.
*Ornithodesmidae	BAR
Ornithocheiridae	?TTH - CMP
Dsungaripteridae	KIM - APT
Pteranodontidae	ALB - MAA
*Criorhynchidae	VAL/ HAU
Azhdarchidae	TUR - MAA

DINOSAURIA: EARLY FORMS (Benton and Norman 1986)	
*Staurikosauridae	CRN
*Herrerasauridae	CRN
DINOSAURIA: THEROPODA (Benton and Norman 1986)	
*Procompsognathidae	NOR
Podokesauridae	CRN - PLB?
Coeluridae	KIM - MAA
*Noasauridae	MAA
*Shanshanosauridae	U. Cret.?
Compsognathidae	TTH
*Segisauridae	HET
*Avimimidae	?U. Cret.
Ornithomimidae	KIM - MAA
*Garudimimidae	?U. Cret.
*Deinocheiridae	MAA
Dromaeosauridae	APT - MAA
Saurornithoididae	CMP - MAA
Oviraptoridae	CMP - MAA
*Caenagnathidae	CMP
Elmisauridae	CMP - MAA
Megalosauridae	HET - MAA
Allosauridae	OXF - SAN
Ceratosauridae	KIM - TTH
Dryptosauridae	CMP - MAA
Spinosauridae	VAL - SAN
Tyrannosauridae	ALB - MAA
*Itemiridae	?U. Cret.
Segnosauridae	SAN - CMP
Therizinosauridae	CEN - TUR (MAA?)
DINOSAURIA: SAUROPODOMORPHA (Benton and Norman 1986)	
Anchisauridae	NOR - TOA
Plateosauridae	NOR - PLB
Melanorosauridae	?RHT - SIN
*Barapasauridae	TOA
*Vulcanodontidae	PLB/ TOA?
Cetiosauridae	BAJ - ALB
Camarasauridae	KIM - MAA
Brachiosauridae	KIM - BAR?
Diplodocidae	KIM - MAA
Titanosauridae	BAR - MAA
DINOSAURIA: ORNITHISCHIA (Benton and Norman 1986)	
Fabrosauridae	SIN - TTH
Heterodontosauridae	HET - PLB
Hypsilophodontidae	CAL - MAA
Iguanodontidae	CAL - ALB
Hadrosauridae	APT - MAA
Pachycephalosauridae	BAR - MAA
*Scelidosauridae	SIN
Stegosauridae	BTH - CON
Nodosauridae	CAL - MAA
Ankylosauridae	CON - MAA
Psittacosauridae	APT?
Protoceratopsidae	SAN - MAA
Ceratopsidae	CMP - MAA

REPTILIA: DIAPSIDA: LEPIDOSAURIA

PRIMITIVE FORMS (Benton 1985a)	
Sphenodontidae	CRN - REC
Sapheosauridae	TTH
Pleurosauridae	KIM - BER
*Gephyrosauridae	HET/ SIN

SAURIA (Estes 1983)	
*Fulengidae	HET/ SIN
Iguanidae	MAA - REC
Euposauridae	KIM
*Arretosauridae	PRB
Agamidae	CMP - REC
Chamaeoleonidae	THA - REC
Ardeosauridae	TTH
Bavarisauridae	TTH
Gekkonidae	THA - REC
Teiidae	CMP - REC
+Gymnophthalmidae	REC
Lacertidae	THA - REC
Scincidae	MAA - REC
+Dibamidae	REC
Paramacellodidae	KIM - TTH
Xantusiidae	THA - REC
Cordylidae	?PRB - REC
Xenosauridae	MAA - REC
Dorsetisauridae	KIM - TTH
Anguidae	CMP - REC
Necrosauridae	MAA - RUP
Helodermatidae	MAA - REC
Varanidae	CMP - REC
AMPHISBAENIA (Estes 1983)	
*Oligodontosauridae	THA
Amphisbaenidae	?RUP - REC
Rhineuridae	THA - REC
Hyporhinidae	RUP - CHT
+Bipedidae	REC
+Trogonophidae	REC
SERPENTES (Rage 1984)	
Typhlopidae	?YPR - REC
+Leptotyphlopidae	REC
+Lapparantopheidae	?L. Cret.
Simolopheidae	CEN
Aniliidae	CMP - REC
+Uropeltidae	REC
*Dinilysiidae	CMP
+Xenopeltidae	REC
Boidae	CMP - REC
Palaeopheidae	MAA - LUT
Acrochordidae	MMI - REC
Nigeropheidae	DAN - LUT
*Anomalopheidae	YPR
*Russellopheidae	YPR
Colubridae	RUP - REC
Elapidae	LMI - REC
Viperidae	LMI - REC
REPTILIA: SYNAPSIDA (Anderson and Cruisksbank 1978; Kemp 1982)	
"PELYCOSAURIA"	
Eothyrididae	?KAS - ART
Caseidae	ART - KUN
Edaphosauridae	KAS - ART (Reisz et al. 1982)
Ophiacodontidae	MOS - ART
Varanopidae	?KAS - KUN
Sphenacodontidae	KAS - ART (Reisz et al. 1982)
DINOCEPHALIA	
Estemmenosuchidae	UFI
Brithopodidae	KUN - UFI
Anteosauridae	UFI - KAZ
Titanosuchidae	KAZ
Tapinocephalidae	UFI - KAZ
EOTHEROSUCHIA	
Phthinosuchidae	KUN - UFI
*Eotitanosuchidae	UFI
Ictidorhinidae	KAZ - TAT
Gorgonopsidae	KAZ - TAT
ANOMODONTIA (Cluver and King 1983)	
*Otsheriidae	UFI
Venjukoviidae	KUN - UFI
Dromasauridae	KAZ - TAT
Eodicynodontidae	?UFI
Endothiodontidae	TAT
Cryptodontidae	TAT
Aulacocephalodontidae	TAT
Dicynodontidae	TAT
Kannemeyeriidae	SCY - CRN
Pristerodontidae	TAT
Emydopidae	TAT - SCY
Cistecephalidae	TAT
Robertiidae	UFI
Diictodontidae	KAZ - TAT
Kingoriidae	TAT - SCY
THEROCEPHALIA	
*Crapartinellidae	KAZ
Pristerognathidae	UFI - KAZ
Moschorhinidae	TAT
Whaitsiidae	TAT
Ictidosuchidae	KAZ - SCY
Scaloposauridae	TAT - SCY
*Ericiolacertidae	SCY
Bauriidae	SCY - ANS
"CYNODONTIA" (Battail 1982)	
Silphestidae	TAT
Procynosuchidae	TAT
Dviniidae	TAT
Galesauridae	TAT - SCY
Cynognathidae	SCY - ANS
Diademodontidae	SCY - ANS
Trirachodontidae	SCY - ANS
Traversodontidae	SCY - HET
Chiniquodontidae	ANS - NOR?
Tritylodontidae	RHT - CAL
Tritheledontidae	?NOR - PLB (Chatterjee 1983)
AVES (Fisher 1967; Feduccia 1980)	
ARCHAEOPTERYGIFORMES	
Archaeopterygidae	TTH
HESPERORNITHIFORMES	
Enaliornithidae	ALB
Baptornithidae	CON - MAA
Hesperornithidae	CON - CMP
ICHTHYORNITHIFORMES	
Ichthyornithidae	TUR - CON (Fox 1984)
Apatornithidae	CON
?Enantiornithes	MAA (Walker 1981)
SPHENISCIFORMES	
Spheniscidae	YPR - REC
RATITAE	
*Eleutherornithidae	YPR
Struthionidae	PLI - REC
Aepyornithidae	YPR - HOL
Dromiceiidae	PLI - REC
Dromornithidae	PLE
Casuariidae	PLE - REC
Emeidae	UMI - HOL
Dinornithidae	PLI - HOL
Apterygidae	?PLE - REC
Rheidae	YPR - REC
*Gobipterygidae	CMP
Tinamidae	PLI - REC
GAVIIFORMES	
Lonchodytidae	MAA
Gaviidae	THA - REC
PODICIPITIFORMES?	
Podicipitidae	LMI - REC
PROCELLARIIFORMES	
Diomedeidae	?LUT - REC
Procellariidae	RUP - REC
Oceanitidae	UMI - PLE
Pelecanoididae	?PLE - REC
PELECANIFORMES	
Phaethontidae	YPR - REC
Pelecanidae	LMI - REC
Cyphornithidae	LMI
Pelagornithidae	LMI - MMI
Sulidae	RUP - REC
Elopterygidae	MAA - BRT
Phalacrocoracidae	MAA - REC
Anhingidae	?BRT - REC
Fregatidae	YPR - REC
*Cladornithidae	RUP
ODONTOPTERYGIFORMES	
*Odontopterygidae	YPR?
Pseudodontornithidae	LMI - UMI
CICONIIFORMES	
Ardeidae	YPR - REC
+Scopidae	REC
Ciconiidae	?PRB - REC
+Balaenicipitidae	REC
*Plegadornithidae	SAN
Plataleidae	PRB - REC
PHOENICOPTERYGIFORMES	
Torotigidae	?VAL - MAA
*Scaniornithidae	DAN
*Telmabatidae	YPR
Agnopteridae	PRB - CHT
Palaelodidae	LMI - PLI

Presbyornithidae	YPR
Phoenicopteridae	PRB - REC
ANSERIFORMES	
Anhimidae	PLE - REC
Anatidae	PRB - REC
FALCONIFORMES	
*Neocathartidae	PRB
Cathartidae	YPR - REC
Teratornithidae	PLE - HOL
Sagittariidae	PRB - REC
Accipitridae	PRB - REC
Pandionidae	PLE - REC
Falconidae	MMI - REC
GALLIFORMES	
Gallinuloididae	LUT - MMI
Opisthocomidae	MMI - REC
Cracidae	YPR - REC
Megapodidae	PLE - REC
Tetraonidae	LMI - REC
Phasianidae	RUP - REC
Numididae	HOL - REC
Meleagrididae	PLE - REC
GRUIFORMES	
+Mesitornithidae	REC
Turnicidae	PLE - REC
*Geranoididae	YPR
Eogruidae	PRB - UMI
Gruidae	YPR - REC
Aramidae	RUP - REC
+Psophiidae	REC
Ergilornithidae	RUP
Orthocnemidae	?PRB
Rallidae	MAA - REC
+Heliornithidae	REC
+Rhynochetidae	REC
+Eurypygidae	REC
Bathornithidae	RUP - CHT
Cariamidae	RUP - REC
Psilopteridae	LMI - PLE
Phororhacidae	RUP - PLE
Brontornithidae	RUP - MMI
*Cunampaiidae	RUP
Otididae	LUT - REC
DIATRYMIFORMES	
Gastornithidae	YPR - PRB
Diatrymidae	YPR - LUT
CHARADRIIFORMES	
Jacanidae	PLE - REC
Rhegminornithidae	LMI - REC
Rostratulidae	LUT - REC
Haematopodidae	LMI - REC
Charadriidae	RUP - REC
Scolopacidae	MAA - REC
Recurvirostridae	YPR - REC
?Phalaropodidae	PLE - REC
+Dromadidae	REC
Burhinidae	LMI - REC
+Glareolidae	REC
+Thinocoridae	REC
+Chionididae	REC
Stercorariidae	PLE - REC
Laridae	YPR - REC
+Rhynchopidae	REC
Alcidae	YPR - REC
COLUMBIFORMES	
Pteroclidae	?PRB - REC
Columbidae	LMI - REC
Raphidae	HOL
PSITTACIFORMES	
Psittacidae	LMI - REC
MUSOPHAGIFORMES	
+Musophagidae	REC
CUCULIFORMES	
Cuculidae	?PRB - REC
STRIGIFORMES	
Tytonidae	LMI - REC
Protostrigidae	?THA - BRT
Strigidae	?PRB - REC
CAPRIMULGIFORMES	
+Steatornithidae	REC
+Aegothelidae	REC
+Podargidae	REC
Caprimulgidae	PLE - REC
Nyctibiidae	PLE - REC
APODIFORMES	
Aegialornithidae	?PRB
+Hemiprocridae	REC
Apodidae	?PRB - REC
Trochilidae	PLE - REC
COLIIFORMES	
+Coliidae	REC
TROGONIFORMES	
Trogonidae	?PRB - REC
CORACIIFORMES	
Alcedinidae	PRB - REC
Todidae	RUP - REC
Momotidae	LUT - REC
Meropidae	PLE - REC
Coraciidae	PRB - REC
+Brachypteraciidae	REC
+Leptosomatidae	REC
Upupidae	PLE - REC
Phoeniculidae	LMI - REC
Bucerotidae	LUT - REC
PICIFORMES	
Primobucconidae	YPR - LUT?
+Galbulidae	REC
Bucconidae	PLE - REC
Capitonidae	PLE - REC
+Indicatoridae	REC
Rhamphastidae	PLE - REC
Picidae	LMI - REC
PASSERIFORMES	
+Eurylaimidae	REC
Furnariidae	PLE - REC
Formicariidae	PLE - REC
+Conopophagidae	REC
Rhinocryptidae	?LMI/ MMI - REC
+Pittidae	REC
?+Philepittidae	REC
+Acanthisittidae	REC
Tyrannidae	PLE - REC
+Pipridae	REC
+Cotingidae	REC
+Phytotomidae	REC
+Menuridae	REC
+Atrichornithidae	REC
*Palaeospizidae	CHT
Alaudidae	PLI - REC
Hirundinidae	PLE - REC
Motacillidae	LMI - REC
+Campephagidae	REC
Pycnonotidae	PLE - REC
+Irenidae	REC
Laniidae	LMI - REC
+Vangidae	REC
Bombycillidae	PLE - REC
+Dulidae	REC
Cinclidae	PLE - REC
Palaeoscinidae	MMI - REC
Troglodytidae	PLE - REC
Mimidae	PLE - REC
Prunellidae	PLE - REC
Muscicapidae	LMI - REC
Paridae	PRB - REC
Sittidae	PLI - REC
Certhiidae	PLE - REC
+Dicaeidae	REC
+Nectariniidae	REC
+Zosteropidae	REC
Meliphagidae	HOL - REC
Emberizidae	PLI - REC
Parulidae	PLE - REC
+Drepanididae	REC
Vireonidae	PLE - REC
Icteridae	PLE - REC
Fringillidae	?MMI - REC
+Estrildidae	REC
+Viduidae	REC
Ploceidae	?LMI - REC
Sturnidae	PRB - REC
Oriolidae	PLE - REC
Dicruridae	PLE - REC
Calleidae	HOL - REC
+Grallinidae	REC
?+Artamiidae	REC
+Cracticidae	REC
+Ptilonorhynchidae	REC
+Paradisaeidae	REC
Corvidae	MMI - REC

MAMMALIA (Lillegraven et al. 1979; Savage and Russell 1983)

MULTITUBERCULATA	
Paulchoffatiidae	KIM - BAR?
Plagiaulacidae	KIM - BAR?
Neoplagiaulacidae	CMP - RUP
Ptilodontidae	CMP - THA
Cimolodontidae	CMP - THA
Taeniolabididae	SAN - YPR
Eucosmodontidae	SAN - YPR
Chulsanbaataridae	CMP
Sloanbaataridae	CMP
Cimolomyidae	CMP - THA
?Haramiyidae	NOR - BTH
TRICONODONTA	
Morganucodontidae	RHT - SIN
Amphilestidae	BTH - TTH
Triconodontidae	KIM - CMP
DOCODONTA	
Docodontidae	BTH - TTH
SYMMETRODONTA	
Kuehneotheriidae	RHT - HET
Amphidontidae	KIM - TTH?
Spalacotheriidae	TTH - CMP
"EUPANTOTHERIA"	
Amphitheriidae	BTH
Peramuridae	BTH - APT?
Paurodontidae	KIM - TTH
Dryolestidae	BTH - VAL
MONOTREMATA	
Ornithorhynchidae	MMI - REC
Tachyglossidae	PLE - REC
MARSUPIALIA	
Didelphidae	CMP - REC
Pediomyidae	CMP - MAA
Stagodontidae	CMP - MAA
Borhyaenidae	THA - PLI
Polydolopidae	THA - YPR
Caroloameghinidae	YPR
Bonapartheriidae	YPR
Groeberidae	PRB
Microbiotheriidae	RUP - REC
Caenolestidae	RUP - REC
Dasyuridae	MMI - REC
Peramelidae	?MMI - REC
Thylacoleonidae	?MMI - PLE
Phalangeridae	MMI - REC
Burramyidae	MMI - REC
Petauridae	MMI - REC
Wynyardiidae	MMI
Ektopodontidae	MMI - PLI
Macropodidae	MMI - REC
Vombatidae	MMI - REC
Potoroidae	MMI - PLI
Diprotodontidae	MMI - PLE/ HOL?
Sparassocynidae	UMI - PLI
Thylacosmilidae	UMI - PLI
Argyrolagidae	UMI - PLI
Thylacinidae	UMI - REC
Palorchestidae	PLI
+Myrmecobiidae	REC
+Notoryctidae	REC
+Thylacomyidae	REC
+Tarsipedidae	REC
EUTHERIA INCERTAE SEDIS	
*Endotheriidae	APT/ ALB
Aegialodontidae	VAL - ALB
Pappotheriidae	CMP
Deltatheriidae	SAN - MAA
EDENTATA	
Ernanodontidae	THA
Dasypodidae	THA - REC
Glyptodontidae	THA - PLE
Megalonychidae	?BRT - PLE/ HOL ?
Palaeopeltidae	RUP
Mylodontidae	RUP - PLE
Megatheriidae	RUP - PLE
Entelopsidae	LMI
Myrmecophagidae	LMI - REC
Peltephilidâe	LMI - UMI
+Bradypodidae	REC
+Choloepidae	REC
ANAGALIDA	
Zalambdalestidae	CMP - THA
Eurymylidae	THA - PRB
Pseudictopidae	THA - YPR
Anagalidae	THA - RUP
LEPTICTIDA	
Leptictoidea n. fam.	CMP - MAA
Leptictidae	DAN - RUP
MACROSCELIDEA	
Macroscelididae	RUP - REC
LAGOMORPHA	
Leporidae	BRT - REC
Ochotonidae	RUP - REC
CIMOLESTA	
Palaeoryctidae	CMP - BRT
TAENIODONTA	
Stylinodontidae	DAN - PRB
PANTODONTA	
Pantolambdidae	DAN - THA
Titanoideidae	DAN - THA
Pantolambdodontidae	THA - PRB
?Bemalambdidae	THA
Pastoralodontidae	THA - YPR
Phenacolophidae	THA
Harpyodidae	THA
Barylambdidae	THA
Cyriacotheriidae	THA
Coryphodontidae	THA - RUP
PANTOLESTA	
Pentacodontidae	DAN
Pantolestidae	DAN - RUP
Ptolemaiidae	RUP
APATOTHERIA	
Apatemyidae	DAN - RUP
CREODONTA	
Oxyaenidae	THA - PRB
Hyaenodontidae	DAN - UMI
CARNIVORA	
Miacidae	DAN - PRB
Amphicyonidae	PRB - UMI
Canidae	PRB - REC
Ursidae	PRB - REC
Viverridae	PRB - REC
Felidae	PRB - REC
Procyonidae	RUP - REC
Mustelidae	RUP - REC
Hyaenidae	LMI - REC
+Ailuropodidae	REC
INSECTIVORA	
Mixodectidae	DAN - THA
Erinaceidae	?DAN - REC
Soricidae	?DAN - REC
Talpidae	?BRT - REC
Geolabidae	RUP - CHT
Chrysochloridae	LMI - REC
Tenrecidae	?LMI - REC
+Solenodontidae	REC
+Nesophontidae	REC
DERMOPTERA	
Plagiomenidae	DAN - BRT?
Placentidentidae	YPR
Mixodectidae	YPR
+Cynocephalidae	REC
CHIROPTERA	
Icaronycteridae	YPR
Palaeochiropterygidae	YPR - BRT
Emballonuridae	BRT - REC
Rhinolophidae	BRT - REC
Vespertilionidae	BRT - REC
Hipposideridae	PRB - REC
Megadermatidae	RUP - REC
Phyllostomatidae	?CHT - REC
Molossidae	?CHT - REC
Pteropodidae	LMI - REC
Myzopodidae	PLI - REC
+Rhinopomatidae	REC
+Craseonycteridae	REC
+Nycteridae	REC
+Noctilionidae	REC
+Mormoopidae	REC
+Desmodontidae	REC
+Natalidae	REC
+Furipteridae	REC
+Thyropteridae	REC
+Mystacinidae	REC
SCANDENTIA	
Tupaiidae	PLE - REC

PRIMATES	
Paromomyidae	?MAA - BRT
Plesiadapidae	DAN - YPR
Carpolestidae	DAN - YPR
Picrodontidae	DAN - THA
?Uintasoricidae	THA - BRT
Adapidae	YPR - UMI
Omomyidae	YPR - CHT
?Microsyopidae	YPR - BRT
?Amphilemuridae	LUT - PRB
Tarsiidae	RUP - REC
Parapithecidae	RUP
Pliopithecidae	RUP - UMI
Cebidae	CHT - REC
Lorisidae	LMI - REC
Cercopithecidae	LMI - REC
Hominidae	LMI - REC
Oreopithecidae	UMI
Lemuridae	PLE - REC
+Cheirogaleidae	REC
+Indriidae	REC
+Daubentoniidae	REC
+Callitrichidae	REC
ARCTOCYONIA	
Arctocyonidae	MAA - PRB
Paroxyclaenidae	LUT - CHT
TILLODONTIA	
Esthonychidae	THA - PRB
TUBULIDENTATA	
Orycteropidae	LMI - REC
DINOCERATA	
Uintatheriidae	THA - BRT
Gobiatheriidae	YPR - PRB
ARTIODACTYLA	
Dichobunidae	YPR - CHT
Cebochoeridae	YPR - RUP
Amphimerycidae	YPR - RUP
Mixtotheriidae	LUT - RUP
Anoplotheriidae	LUT - CHT
Dacrytheriidae	LUT - RUP
Haplobunodontidae	LUT - PRB
Helohyidae	LUT - PRB
Anthracotheriidae	LUT - PLI
Choeropotamidae	BRT - RUP
Xiphodontidae	BRT - PRB
Leptomerycidae	BRT - UMI
Leptochoeridae	BRT - CHT
Agriochoeridae	BRT - LMI
Protoceratidae	BRT - UMI
Camelidae	BRT - REC
Hypertragulidae	BRT - MMI
Gelocidae	PRB - UMI
Cainotheriidae	PRB - LMI
Entelodontidae	PRB - LMI
Tayassuidae	PRB - REC
Suidae	?RUP - REC
Tragulidae	RUP - REC
Cervidae	RUP - REC
Bovidae	RUP - REC
Merycoidodontidae	RUP - UMI
Giraffidae	LMI - REC
Antilocapridae	LMI - REC
Hippopotamidae	MMI - REC
+Moschidae	REC
ACREODI	
Mesonychidae	DAN - RUP
ASTRAPOTHERIA	
Astrapotheriidae	YPR - MMI
PYROTHERIA	
Pyrotheriidae	YPR - RUP
Columbitheriidae	YPR
CONDYLARTHRA	
Periptychidae	DAN - THA
Hyopsodontidae	DAN - BRT
Mioclaenidae	DAN
Phenacodontidae	DAN - PRB
Tricuspiodontidae	THA
Meniscotheriidae	THA - YPR
Didolodontidae	THA - RUP
LITOPTERNA	
Proterotheriidae	THA - PLI
Macraucheniidae	THA - PLE
Adianthidae	PRB - LMI
PERISSODACTYLA	
Equidae	THA - REC
Chalicotheriidae	YPR - PLE
Lophiodontidae	YPR - BRT
Brontotheriidae	YPR - RUP
Isectolophidae	YPR - BRT.
Helaletidae	YPR - CHT
Lophialetidae	YPR - PRB
Hyracodontidae	YPR - CHT
Palaeotheriidae	LUT - RUP
Deperetellidae	LUT - RUP
Amynodontidae	LUT - LMI
Tapiridae	RUP - REC
Rhinocerotidae	RUP - REC
NOTOUNGULATA	
Perutheriidae	MAA (Marshall _et al._ 1983)
Arctostylopidae	THA - YPR
Henricosborniidae	THA - YPR
Notostylopidae	THA - BRT?
Oldfieldthomasiidae	THA - PRB
Isotemnidae	THA - MMI
Archaeohyracidae	THA - RUP
Interatheriidae	THA - UMI
Archaeopithecidae	YPR
Notohippidae	?BRT - LMI
Mesotheriidae	PRB - PLE
Hegetotheriidae	PRB - PLI
Homalodotheriidae	RUP - UMI
Leontiniidae	RUP - MMI
Toxodontidae	RUP - PLE
TRIGONOSTYLOPOIDEA	
Trigonostylopidae	THA - BRT?
XENUNGULATA	
Carodniidae	THA
EMBRITHOPODA	
Arsinoitheriidae	RUP
PROBOSCIDEA	
Moeritheriidae	LUT - RUP
Mammutidae	RUP - PLE
Gomphotheriidae	RUP - PLE
Deinotheriidae	LMI - PLE
Stegodontidae	UMI - PLE
Elephantidae	PLI - REC
HYRACOIDEA	
Pliohyracidae	RUP - LMI
Procaviidae	LMI - REC
Myohyracidae	LMI
PHOLIDOTA	
Epoicotheriidae	THA - RUP
Metacheiromyidae	THA - LUT
Manidae	LUT - REC
RODENTIA	
Ischyromyidae	?THA - LMI
Theridomyidae	YPR - MMI
Gliridae	YPR - REC
Ctenodactylidae	?YPR - REC
Chapattemyidae	LUT
Aplodontidae	BRT - REC
Geomyidae	BRT - REC
Zapodidae	BRT - REC
Cylindrodontidae	BRT - CHT
Protoptychidae	BRT
Eomyidae	BRT - PLI
Cricetidae	PRB - REC
Eutypomyidae	RUP - CHT
Eocardiidae	RUP - MMI
Phiomyidae	RUP - MMI
Sciuridae	RUP - REC
Heteromyidae	RUP - REC
Castoridae	RUP - REC
Erethizodontidae	RUP - REC
Dasyproctidae	RUP - REC
Chinchillidae	RUP - REC
Octodontidae	RUP - REC
Echimyidae	RUP - REC
Thryonomyidae	RUP - REC
Rhizomyidae	RUP - REC
Cephalomyidae	CHT
Mylagaulidae	CHT - UMI
Diamantomyidae	LMI
Miophiomyidae	LMI
Bathyergoididae	LMI
Kenyamyidae	LMI
Anomaluridae	LMI - REC
Pedetidae	LMI - REC
Bathyergidae	LMI - REC
Muridae	MMI - REC
Dipodidae	MMI - REC
Hystricidae	MMI - REC
Caviidae	MMI - REC
Dinomyidae	MMI - REC
Anomalomyidae	UMI
Hydrochoeridae	UMI - REC
Abrocomyidae	UMI - REC
Selevinidae	PLI - REC
Myocastoridae	PLI - REC
Capromyidae	PLE - REC
Ctenomyidae	PLE - REC
+Petromyidae	REC