

---

## The Linear Angiosperm Phylogeny Group (LAPG) III: a linear sequence of the families in APG III

ELSPETH HASTON<sup>1\*</sup>, JAMES E. RICHARDSON<sup>1</sup>, PETER F. STEVENS<sup>2,3</sup>, MARK W. CHASE<sup>4</sup> and DAVID J. HARRIS<sup>1</sup>

<sup>1</sup>Royal Botanic Garden Edinburgh, 20a Inverleith Row, Edinburgh, EH3 5LR, UK

<sup>2</sup>Missouri Botanical Garden, PO Box 299, St Louis, Missouri 63166-0299, USA

<sup>3</sup>Department of Biology, University of Missouri at St Louis, St Louis, Missouri 63121, USA

<sup>4</sup>Jodrell Laboratory, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3DS, UK

Received 20 August 2009; accepted for publication 4 September 2009

---

The publication of the third Angiosperm Phylogeny Group (APG) classification (APG III, 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* **161**: 128–131) has resulted in the need for a revised systematic listing of the accepted families. This linear APG III (LAPG III) sequence of families is presented here. © 2009 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2009, **161**, 128–131.

ADDITIONAL KEYWORDS: angiosperm classification – family arrangement – floras – herbarium curation.

---

Linear sequences of families are required for herbarium curators who wish to arrange collections systematically rather than alphabetically, and there are currently a wide range of systems in use. Over time, in most herbaria, as the understanding of relationships changed, these classifications have become outdated and no longer represent the best estimate of relationships. Curators have updated these systems, usually by adding suffixes or making composite numbers such as '145a' or '145.01' to incorporate changes in an existing sequence. In many cases, however, these modifications have not been published and have often been herbarium-specific, resulting in herbaria that originally used the same system diverging over time.

The linear sequence of families based on the Angiosperm Phylogeny Group (APG) II classification system (LAPG II; Haston *et al.*, 2007) was founded on the best estimate of family relationships at that time. In revising the linear sequence of families to the new APG III classification (APG III, 2009), we provide a clear and explicit update according to the current best

estimate of relationships. In LAPG II, we decided to allocate a family number to each of the families listed in the APG II classification, including the 'bracketed' families that were presented as 'acceptable monophyletic alternatives to the broader circumscription favoured here' (APG II, 2003). In doing this, we felt that we would be giving herbaria the greatest flexibility in accepting or rejecting the 'bracketed' families. The APG III classification has tended to accept the broader circumscription of families and does not allow the option of 'bracketed' families. The number of accepted families has therefore significantly declined. In addition, our understanding of relationships in several parts of the phylogenetic tree has improved and these changes have been incorporated here.

In considering linear sequences derived from phylogenetic trees, it is important to remember that the sequence is dependent on the methodology used and that loss of phylogenetic information in the conversion is unavoidable. The choice of methodology is controversial (Hawthorne *et al.*, 2008), and the linear sequence can be misleading if not understood in the context of a tree. Linear sequences systematically ordered are, however, used to arrange most of the large herbaria worldwide and therefore merit some

---

\*Correspondence: Elspeth Haston.  
E-mail: e.haston@rbge.org.uk

**Table 1.** The Linear Angiosperm Phylogeny Group III (LAPG III) sequence of families

Amborellaceae.....1	Philesiaceae.....57	Berberidaceae.....113	Datisceae.....169
Hydatellaceae.....2	Ripogonaceae.....58	Ranunculaceae.....114	Begoniaceae.....170
Cabombaceae.....3	Smilacaceae.....59	Sabiaceae.....115	Lepidobotryaceae.....171
Nymphaeaceae.....4	Corsiaceae.....60	Nelumbonaceae.....116	Celastraceae.....172
Austrobaileyaceae.....5	Liliaceae.....61	Platanaceae.....117	Huaceae.....173
Trimeniaceae.....6	Orchidaceae.....62	Proteaceae.....118	Connaraceae.....174
Schisandraceae.....7	Boryaceae.....63	Trochodendraceae.....119	Oxalidaceae.....175
Chloranthaceae.....8	Blandfordiaceae.....64	Haptanthaceae.....120	Cunoniaceae.....176
Canellaceae.....9	Asteliaceae.....65	Buxaceae.....121	Elaeocarpaceae.....177
Winteraceae.....10	Lanariaceae.....66	Myrothamnaceae.....122	Cephalotaceae.....178
Saururaceae.....11	Hypoxidaceae.....67	Gunneraceae.....123	Brunelliaceae.....179
Piperaceae.....12	Tecophilaeaceae.....68	Dilleniaceae.....124	Pandaceae.....180
Lactoridaceae.....13	Doryanthaceae.....69	Peridiscaceae.....125	Rhizophoraceae.....181
Hydnoraceae.....14	Ixioliriaceae.....70	Paeoniaceae.....126	Erythroxylaceae.....182
Aristolochiaceae.....15	Iridaceae.....71	Altingiaceae.....127	Rafflesiaceae.....183
Myristicaceae.....16	Xeronemataceae.....72	Hamamelidaceae.....128	Euphorbiaceae.....184
Magnoliaceae.....17	Xanthorrhoeaceae.....73	Cercidiphyllaceae.....129	Centroplacaceae.....185
Degeneriaceae.....18	Amaryllidaceae*.....74	Daphniphyllaceae.....130	Ctenolophonaceae.....186
Himantandraceae.....19	Asparagaceae.....75	Iteaceae.....131	Ochnaceae.....187
Eupomatiaceae.....20	Arecaceae/Palmae.....76	Grossulariaceae.....132	Picrodendraceae.....188
Annonaceae.....21	Hanguanaceae.....77	Saxifragaceae.....133	Phyllanthaceae.....189
Calycanthaceae.....22	Commelinaceae.....78	Crassulaceae.....134	Elatinaceae.....190
Siparunaceae.....23	Philydraceae.....79	Aphanopetalaceae.....135	Malpighiaceae.....191
Gomortegaceae.....24	Pontederiaceae.....80	Tetracarpaeaceae.....136	Balanopaceae.....192
Atherospermataceae.....25	Haemodoraceae.....81	Penthoraceae.....137	Trigoniaceae.....193
Hernandiaceae.....26	Strelitziaceae.....82	Haloragaceae.....138	Dichapetalaceae.....194
Monimiaceae.....27	Lowiaceae.....83	Cynomoriaceae.....139	Euphroniaceae.....195
Lauraceae.....28	Heliconiaceae.....84	Vitaceae.....140	Chrysobalanaceae.....196
Acoraceae.....29	Musaceae.....85	Krameriaceae.....141	Lophopyxidaceae.....197
Araceae.....30	Cannaceae.....86	Zygophyllaceae.....142	Putranjivaceae.....198
Tofieldiaceae.....31	Marantaceae.....87	Quillajaceae.....143	Passifloraceae.....199
Alismataceae.....32	Costaceae.....88	Fabaceae/Leguminosae.....144	Lacistemataceae.....200
Butomaceae.....33	Zingiberaceae.....89	Surianaceae.....145	Salicaceae.....201
Hydrocharitaceae.....34	Dasygogonaceae.....90	Polygalaceae.....146	Violaceae.....202
Scheuchzeriaceae.....35	Typhaceae.....91	Rosaceae.....147	Goupiaceae.....203
Aponogetonaceae.....36	Bromeliaceae.....92	Barbeyaceae.....148	Achariaceae.....204
Juncaginaceae.....37	Rapateaceae.....93	Dirachmaceae.....149	Caryocaraceae.....205
Zosteraceae.....38	Xyridaceae.....94	Elaeagnaceae.....150	Humiriaceae.....206
Potamogetonaceae.....39	Eriocaulaceae.....95	Rhamnaceae.....151	Irvingiaceae.....207
Posidoniaceae.....40	Mayacaceae.....96	Ulmaceae.....152	Linaceae.....208
Ruppiaceae.....41	Thurniaceae.....97	Cannabaceae.....153	Ixonanthaceae.....209
Cymodoceaceae.....42	Juncaceae.....98	Moraceae.....154	Calophyllaceae.....210
Petrosaviaceae.....43	Cyperaceae.....99	Urticaceae.....155	Clusiaceae/Guttiferae.....211
Nartheciaceae.....44	Anarthriaceae.....100	Nothofagaceae.....156	Bonnetiaceae.....212
Burmanniaceae.....45	Centrolepidaceae.....101	Fagaceae.....157	Podostemaceae.....213
Dioscoreaceae.....46	Restionaceae.....102	Myricaceae.....158	Hypericaceae.....214
Triuridaceae.....47	Flagellariaceae.....103	Juglandaceae.....159	Geraniaceae.....215
Velloziaceae.....48	Joinvilleaceae.....104	Casuarinaceae.....160	Vivianiaceae.....216
Stemonaceae.....49	Ecdeiocoleaceae.....105	Ticodendraceae.....161	Melanthaceae.....217
Cyclanthaceae.....50	Poaceae/Gramineae.....106	Betulaceae.....162	Combretaceae.....218
Pandanaceae.....51	Ceratophyllaceae.....107	Apodanthaceae.....163	Lythraceae.....219
Campynemataceae.....52	Eupteleaceae.....108	Anisophylleaceae.....164	Onagraceae.....220
Melanthiaceae.....53	Papaveraceae.....109	Corynocarpaceae.....165	Vochysiaceae.....221
Petermanniaceae.....54	Circaeasteraceae.....110	Coriariaceae.....166	Myrtaceae.....222
Alstroemeriaceae.....55	Lardizabalaceae.....111	Cucurbitaceae.....167	Melastomataceae.....223
Colchicaceae.....56	Menispermaceae.....112	Tetramelaceae.....168	Crypteroniaceae.....224

**Table 1.** *Continued*

Alzateaceae.....225	Brassicaceae/	Cornaceae.....320	Plantaginaceae.....368
Penaeeaceae.....226	Cruciferae.....273	Hydrangeaceae.....321	Scrophulariaceae.....369
Aphloiaceae.....227	Aextoxicaceae.....274	Loasaceae.....322	Stilbaceae.....370
Geissolomataceae.....228	Berberidopsidaceae.....275	Balsaminaceae.....323	Linderniaceae.....371
Strasburgeriaceae.....229	Balanophoraceae.....276	Marcgraviaceae.....324	Pedaliaceae.....372
Staphyleaceae.....230	Olacaceae.....277	Tetrameristaceae.....325	Lamiaceae/Labiatae.....373
Guametalaceae.....231	Opiliaceae.....278	Fouquieriaceae.....326	Phrymaceae.....374
Stachyuraceae.....232	Santalaceae.....279	Polemoniaceae.....327	Paulowniaceae.....375
Crossosomataceae.....233	Loranthaceae.....280	Lecythidaceae.....328	Orobanchaceae.....376
Picramniaceae.....234	Misodendraceae.....281	Sladeniaceae.....329	Lentibulariaceae.....377
Biebersteiniaceae.....235	Schoepfiaceae.....282	Pentaphragmataceae.....330	Acanthaceae.....378
Nitrariaceae.....236	Frankeniaceae.....283	Sapotaceae.....331	Bignoniaceae.....379
Kirkiaceae.....237	Tamaricaceae.....284	Ebenaceae.....332	Thomandersiaceae.....380
Burseraceae.....238	Plumbaginaceae.....285	Primulaceae.....333	Schlegeliaceae.....381
Anacardiaceae.....239	Polygonaceae.....286	Theaceae.....334	Verbenaceae.....382
Sapindaceae.....240	Droseraceae.....287	Symplocaceae.....335	Byblidaceae.....383
Rutaceae.....241	Nepenthaceae.....288	Diapensiaceae.....336	Martyniaceae.....384
Simaroubaceae.....242	Drosophyllaceae.....289	Styracaceae.....337	Stemonuraceae.....385
Meliaceae.....243	Dioncophyllaceae.....290	Sarraceniaceae.....338	Cardiopteridaceae.....386
Gerrardinaceae.....244	Ancistrocladaceae.....291	Roridulaceae.....339	Phyllonomaceae.....387
Tapisciaceae.....245	Rhabdodendraceae.....292	Actinidiaceae.....340	Helwingiaceae.....388
Dipentodontaceae.....246	Simmondsiaceae.....293	Clethraceae.....341	Aquifoliaceae.....389
Cytinaceae.....247	Physenaceae.....294	Cyrillaceae.....342	Rousseaceae.....390
Muntingiaceae.....248	Asteropeiaceae.....295	Mitrastemonaceae.....343	Campanulaceae.....391
Neuradaceae.....249	Caryophyllaceae.....296	Ericaceae.....344	Pentaphragmataceae.....392
Malvaceae.....250	Achatocarpaceae.....297	Oncothecaceae.....345	Stylidiaceae.....393
Sphaerosepalaceae.....251	Amaranthaceae.....298	Metteniusaceae.....346	Alseuosmiaceae.....394
Thymelaeaceae.....252	Stegnospermataceae.....299	Icacinaceae.....347	Phellinaceae.....395
Bixaceae.....253	Limeaceae.....300	Eucommiaceae.....348	Argophyllaceae.....396
Sarcocaulaceae.....254	Lophiocarpaceae.....301	Garryaceae.....349	Menyanthaceae.....397
Cistaceae.....255	Barbeuiaceae.....302	Rubiaceae.....350	Goodeniaceae.....398
Dipterocarpaceae.....256	Gisekiaceae.....303	Gentianaceae.....351	Calyceraceae.....399
Akaniaceae.....257	Aizoaceae.....304	Loganiaceae.....352	Asteraceae/Compositae.....400
Tropaeolaceae.....258	Phytolaccaceae.....305	Gelsemiaceae.....353	Escalloniaceae.....401
Moringaceae.....259	Sarcobataceae.....306	Apocynaceae.....354	Columelliaceae.....402
Caricaceae.....260	Nyctaginaceae.....307	Vahliaceae.....355	Bruniaceae.....403
Limnanthaceae.....261	Molluginaceae.....308	Boraginaceae.....356	Paracryphiaceae.....404
Setchellanthaceae.....262	Montiaceae.....309	Convolvulaceae.....357	Adoxaceae.....405
Koerberliniaceae.....263	Didiereaceae.....310	Solanaceae.....358	Caprifoliaceae.....406
Bataceae.....264	Basellaceae.....311	Montiniaceae.....359	Pennantiaceae.....407
Salvadoraceae.....265	Halophytaceae.....312	Sphenocleaceae.....360	Torricelliaceae.....408
Emblingiaceae.....266	Talinaceae.....313	Hydroleaceae.....361	Griselinaceae.....409
Tovariaceae.....267	Portulacaceae.....314	Plocospermataceae.....362	Pittosporaceae.....410
Pentadiplandraceae.....268	Anacampserotaceae.....315	Carlemanniaceae.....363	Araliaceae.....411
Gyrostemonaceae.....269	Cactaceae.....316	Oleaceae.....364	Myodocarpaceae.....412
Resedaceae.....270	Hydrostachyaceae.....317	Tetrachondraceae.....365	Apiaceae/Umbelliferae.....413
Capparaceae.....271	Curtisiaceae.....318	Calceolariaceae.....366	
Cleomaceae.....272	Grubbiaceae.....319	Gesneriaceae.....367	

\*[Correction added after online publication, 14 October 2009: 'Alliaceae' corrected to 'Amaryllidaceae']

attention. This paper provides, for herbarium curators, a simple linear numbered sequence to the families recognised in APG III (Table 1).

The methodology used to translate the phylogenetic tree into a linear sequence was described in detail in

Haston *et al.* (2007). This methodology was questioned by Hawthorne *et al.* (2008), but in the absence of any obviously better way of generating a linear sequence from a phylogenetic tree we have retained the same method. We agree that there is potential to

modify this method in the future, especially to ensure stability.

The main changes in the order of families in the sequence are within the rosoid clade. Additional resolution has clarified the circumscription of the fabid (rosoid I) and malvid (rosoid II) clades. Of these changes, the following have had the greatest impact on the linear sequence: Geraniales are now sister to Myrtales in the malvid clade; Crossosomatales are sister to the remaining malvid families; Malvales are now sister to Brassicales (Wang *et al.*, 2009); and Huerteales are now sister to the Malvales/Brassicales clade (Worberg *et al.*, 2009).

Elsewhere in the sequence there have been more minor changes, the more significant of which are listed here. Ceratophyllaceae have moved from within magnoliids and are now sister to the eudicots (Jansen *et al.*, 2007; Moore *et al.*, 2007). Aextoxicaceae and Berberidopsidaceae are now sister to the Santalales/Caryophyllales/asterid clade (Moore *et al.*, 2009). Dilleniaceae are probably now sister to the Saxifragales/rosids clade (Moore *et al.*, 2009), but this is not well supported at present. In addition, there were changes to the sequence when clades were rotated as a result of changes in the number of terminals caused by the sinking of families or, more rarely, the recognition of new families.

The individual trees on which this sequence is based are mostly published (Stevens, 2001; Jansen *et al.*, 2007; Moore *et al.*, 2007 onwards; and papers referenced in Haston *et al.*, 2007), but see also Wang *et al.* (2009), Tank & Donoghue (in press), Moore *et al.* (2008, 2009); Refulio-Rodriguez & Olmstead (2008); Wurdack & Davis (2009) and papers in Stevens (2001 onwards). For justification of family limits adopted, see APG III (2009).

In LAPG III, we suggested that composite numbers be used for minor changes such as new families (Haston *et al.*, 2007). We would continue to recommend the use of composite numbers for families that are added or moved and would add that they may be useful to enable herbaria to change systems in a more gradual process. We would also reiterate that amendments that involve major changes in relationships will require a revised linear sequence. However, we anticipate that changes in the future will be infrequent and less disruptive to the linear sequence.

## REFERENCES

- APG II. 2003.** An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* **141**: 399–436.

**APG III. 2009.** An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* **161**: 105–121.

**Haston E, Richardson JE, Stevens PF, Chase MW, Harris DJ. 2007.** A linear sequence of Angiosperm Phylogeny Group II families. *Taxon* **56**: 7–12.

**Hawthorne WD, Hughes CE. 2008.** Optimising linear taxon sequences derived from phylogenetic trees – a reply to Haston *et al.* *Taxon* **57**: 1–7.

**Jansen RK, Cai Z, Raubeson LA, Daniell H, dePamphilis CW, Leebens-Mack J, Muller KF, Guisinger-Bellian M, Haberle RC, Hansen AK, Chumley TW, Lee SB, Peery R, McNeal JR, Kuehl JV, Boore JL. 2007.** Analysis of 81 genes from 64 plastid genomes resolves relationships in angiosperms and identifies genome-scale evolutionary patterns. *Proceedings of the National Academy of Sciences of the United States of America* **104**: 19369–19374.

**Moore M, Bell C, Soltis PS, Soltis DE. 2008.** Analysis of an 83-gene, 86-taxon plastid genome data set resolves relationships among several deep-level eudicot lineages. *Botany* **2008**. *Botany without borders*, 97.

**Moore MJ, Bell CD, Soltis PS, Soltis DE. 2007.** Using plastid genome-scale data to resolve enigmatic relationships among basal angiosperms. *Proceedings of the National Academy of Sciences of the United States of America* **104**: 19363–19368.

**Moore MM, Soltis PS, Bell CD, Burleigh JG, Soltis DE. 2009.** Phylogenetic analysis of 83 plastid genes resolves relationships among major clades of eudicot angiosperms and reveals multiple rapid radiations. *Proceedings of the National Academy of Sciences*. In press.

**Refulio-Rodriguez NF, Olmstead R. 2008.** Lamiales phylogeny. *Botany 2008*. *Botany without borders*, 112.

**Stevens PF. 2001.** Angiosperm phylogeny website, version 9, June 2008 [and more or less continuously updated since]. Available at <http://www.mobot.org/MOBOT/research/APweb/>

**Tank DC, Donoghue MJ. In press.** Phylogeny and phylogenetic nomenclature of the Campanulidae based on an expanded sample of genes and taxa. *Systematic Botany*.

**Wang HC, Moore MJ, Soltis PS, Bell CD, Brockington SF, Alexandre R, Davis CC, Latvis M, Manchester SR, Soltis DE. 2009.** Rosid radiation and the rapid rise of angiosperm-dominated forests. *Proceedings of the National Academy of Sciences of the United States of America* **106**: 3853–3858.

**Worberg A, Alford MH, Quandt D, Borsch T. 2009.** Huerteales sister to Brassicales plus Malvales, and newly circumscribed to include *Dipentodon*, *Gerrardina*, *Huerteia*, *Perrottetia*, and *Tapiscia*. *Taxon* **58**: 468–478.

**Wurdack KJ, Davis CC. 2009.** Malpighiales phylogenetics: gaining ground on one of the most recalcitrant clades in the angiosperm tree of life. *American Journal of Botany* **96**: 1551–1570.