

Contents

1	Introduction	1
2	Suggested Angiosperm Ancestors	5
2.1	Gnetales	5
2.2	Gigantopteriales	7
2.3	Glossopteridales	8
2.4	<i>Sanmiguelia</i>	9
2.5	<i>Leptostrobus</i>	9
2.6	<i>Caytonia</i>	10
2.7	Bennettitales	12
2.8	<i>Umkomasia</i>	13
2.9	<i>Problematospermum</i>	13
2.10	Dirhopalostachyaceae	14
2.11	<i>Ktalenia</i>	15
2.12	<i>Pentoxylales</i>	15
2.13	Summary	16
3	Angiosperms: Characters and Criteria	17
3.1	Angiospermous Characters	17
3.1.1	Leaf Venation	18
3.1.2	Vessel Elements in the Xylem	19
3.1.3	Closed Carpel, or Enclosed Ovule/Seed	19
3.1.4	Bitegmic Ovule	20
3.1.5	Double Fertilization	20
3.1.6	Tetrasporangiate Anther	21
3.1.7	Pollen Tube	21
3.1.8	Tectate-Columellate Pollen Grains	22
3.1.9	Developmental Pattern	23
3.1.10	Chemical Species	23
3.2	Criterion for Criteria	24
3.3	Criterion for Fossil Angiosperms	24
4	Background for the Plant Fossils	29
4.1	Stratigraphy	29

4.2	Faunas	34
4.2.1	The Jiulongshan Fauna	34
4.2.2	The Yixian Fauna	35
4.3	Floras	35
4.3.1	The Jiulongshan Flora	35
4.3.2	The Yixian Flora	36
5	Flowers from the Early Cretaceous	37
5.1	<i>Chaoyangia</i>	37
5.1.1	Previous Studies	37
5.1.2	Misunderstanding and Clarification	38
5.1.3	New Information	42
5.1.4	Emended Diagnosis	52
5.1.5	Description	53
5.1.6	Development	55
5.1.7	Pollination	56
5.1.8	Affinity	56
5.1.9	Problem Unsolved	63
5.2	<i>Archaeofructus</i>	64
5.2.1	<i>Archaeofructus</i> , a Great Discovery	64
5.2.2	Controversies over <i>Archaeofructus</i>	67
5.2.3	Diagnosis After Emendation	68
5.2.4	Ecology of <i>Archaeofructus</i>	69
5.2.5	The Discovery of <i>Archaeofructus</i>	69
5.3	<i>Sinocarpus</i>	70
5.4	<i>Callianthus</i>	71
5.4.1	Previous Studies	71
5.4.2	Misunderstanding and Clarification	72
5.4.3	New Information	72
5.4.4	Diagnosis	77
5.4.5	Description	78
5.4.6	Development	81
5.4.7	Pollination and Dispersal	84
5.4.8	Affinity	86
6	Flower-Related Fossils from the Jurassic	91
6.1	<i>Schmeissneria</i>	91
6.1.1	Previous Studies	91
6.1.2	Misunderstandings and Clarifications	94
6.1.3	New Information	96
6.1.4	Emended Diagnosis	106
6.1.5	Description	109
6.1.6	Development	115
6.1.7	Pollination	118
6.1.8	Fruit Dispersal	119
6.1.9	Affinity	119

6.1.10	Ecology and Environment	121
6.1.11	Comparison with Other Relatives	121
6.1.12	Summary	122
6.2	<i>Xingxueanthus</i>	122
6.2.1	Background	122
6.2.2	Features of the Plant	122
6.2.3	Description	131
6.2.4	Affinity	134
6.2.5	Evolutionary Implications	135
6.2.6	Problem Unsolved	136
6.2.7	Summary	137
6.3	<i>Solaranthus</i>	137
6.3.1	Possibly Related Previous Studies	137
6.3.2	New Information and Implications	138
6.3.3	Diagnosis and Description	145
6.3.4	Affinity	151
6.3.5	Implications for the Origin of Angiosperms	152
6.4	General Summary	153
7	Trace of Possible Angiosperms in the Jurassic	155
7.1	Taxon A	155
7.1.1	Diagnosis	155
7.2	Taxon B	159
7.2.1	Diagnosis	160
8	Making of the Flower	163
8.1	Definition of a Carpel	163
8.1.1	Difficulties for Applying the Classic Definition	163
8.1.2	Converging on a New Definition	164
8.1.3	Derivation of the Carpel	169
8.2	Ovule	173
8.3	Placenta	174
8.3.1	Isolation of Placenta from Carpel	174
8.3.2	Origin of Placenta	176
8.4	Enclosing Ovules	178
8.5	Flower	179
8.6	Angiosperm Prototype and Its Relationship to Other Seed Plants	180
8.7	Merits of the Unifying Theory	182
8.7.1	Simplicity and Directness	182
8.7.2	Evidence from Various Fields	182
8.7.3	Difficulties Negotiated	182
8.7.4	Wide Applicable Range	184
8.7.5	Controversies Settled	184
8.8	General Regularities in Seed Plant Evolution	184
8.8.1	Enclosure	184

8.8.2	Overgrowth and Reduction	185
8.8.3	Sterilization and Neofunctionalization	185
8.8.4	Fusion	185
8.8.5	Diverted Development	185
8.9	Problems Unsolved	186
8.9.1	From Unisexual to Bisexual	186
8.9.2	Boundary Between Cordaitales-Like Plants and Angiospermae	186
8.9.3	Prediction and Test	186
8.10	Implications for Seed Plant Phylogeny	187
9	General Conclusions	189
9.1	Origins and Ancestors of Angiosperms	189
9.1.1	Time of Origin	189
9.1.2	Location and Habitat of Early Angiosperms	190
9.1.3	Ancestors	191
9.2	Monophyly or Polyphyly	192
9.3	Animals and Plants	192
9.4	Road to Success	193
9.5	The Idiosyncrasy of Angiospermae or a Grade of Evolution? . . .	193
9.6	Digging Deeper	194
10	Appendix	195
10.1	List of Morphological Characters Used for Cladistic Analysis . . .	195
10.2	Morphological Matrix	199
10.3	List of Fauna Elements	204
10.3.1	The Jiulongshan Fauna	204
10.3.2	The Yixian Fauna	205
10.4	List of Flora Elements	208
10.4.1	The Jiulongshan Flora	208
10.4.2	The Yixian Flora	209
10.5	Morphological Matrix for Seed Plant Cladistics	210
	References	213
	Index	235