

CONTENTS

Preface	xv	Chemical Fossils	32
Acknowledgments	xvii	Ancient DNA	33
About the Authors	xxi	Mummification	33
		Amber	33
		Summary Discussion	34
CHAPTER 1		Palynology	34
Introduction to Paleobotany,		Geochronology and Biostratigraphy	36
How Fossil Plants are Formed 1		Paleoecology	37
What Is Paleobotany?	1	Absolute Dating	38
The Objectives of Paleobotany	2	Geologic Timescale	39
Reconstructing the Plants	2	Biological Correlation	40
Evolution of Plant Groups	3	Systematics and Classification	40
Form and Function in Fossil Plants	4	Nomenclature of Fossil Plants	41
Biostratigraphy and Correlation	4	Classification of Organisms	42
Paleoecology: Plants in Their Environment	5	Background Reading	42
Determining Paleoclimate from Fossil Plants	6		
Tree Rings	6		
Nearest Living Relative	6		
Leaf Physiognomy	7		
Stomatal Index	7		
Summary	7		
Preservation: How Plant Fossils are Formed and		CHAPTER 2	
Preserved	8	Precambrian Life 43	
Depositional Environments of Fossil Plants	8	The Origin of Life on Earth	44
Compressions	10	Origin of Life: Theory and Biology	46
Cuticle	13	Earliest Record of Life on Earth	47
Biofilms and Plant Fossil Preservation	16	Historical Background	47
Electron Microscopy	17	Earliest Records of Life: Paleoproterozoic (3.6–3.2 Ga)	47
Confocal Microscopy	17	Geochemistry	47
Maceration and Dégagement	17	Microfossils (Body Fossils)	49
Other Techniques	18	Isua Greenstone Belt, Greenland	49
Coal and Charcoal	18	Warrawoona Group, Australia	49
Impressions	21	Barberton Greenstone Belt, South Africa	51
Molds and Casts	22	Stromatolites	52
Cellular Preservation	23	Sedimentary Evidence	53
Permineralization	25	Mesoproterozoic–Neoproterozoic Life	54
Peel Technique	25	Conclusions: Archean Life	55
Coal Balls	27	Oxygenation of the Earth (2.45–2.2 Ga)	57
Other Permineralizations	29	Proterozoic Life	59
Petrifaction	30	Paleoproterozoic	59
Unaltered Plant Material	30	Origin of Eukaryotes	61
		Mesoproterozoic	64
		Earliest Multicellular Life	64
		Neoproterozoic	64
		Bitter Springs Biota	65

Stromatolites	66	Dinophyta (Dinoflagellates)	139
Other Microfossils	67	Heterokontophyta	141
Doushantuo Formation	70	Bacillariophyceae (Diatoms)	141
Conclusions	70	Dictyochophyceae (Silicoflagellates)	142
		Xanthophyceae (Yellow-Green Algae)	142
		Phaeophyceae (Brown Algae)	143
CHAPTER 3		Prymnesiophyta (Haptophytes)	144
Fungi, Bacteria, and Lichens 71		Rhodophyta (Red Algae)	145
Fungi	71	Solenoporaceans	146
Earliest Fossil Fungi	73	Other Calcified Red Algae	149
Systematics of Fungi	77	Corallinales	149
Chytridiomycota	77	Uncalcified Red Algae	150
Zygomycota	82	Acritarcha (Acritarchs)	158
Glomeromycota	84		
Ascomycota	90	CHAPTER 5	
Basidiomycota	93	Hornworts and Bryophytes 161	
Other Fungal Remains	97	Early Fossil Evidence	163
Fungal Life-History Strategies	98	Anthocerotophyta (Hornworts)	165
Saprotrophism	98	Bryophyta (Bryophytes)	166
Parasitism	99	Marchantiophytina (Liverworts or Hepatophytes)	167
Mutualism	103	Bryophytina (Mosses)	174
Fungi-Animal Interactions	105		
Geologic Activities of Fungi	107	CHAPTER 6	
Epiphyllous Fungi	108	The Move to the Land 179	
Fungal Spores	111	Enigmatic Organisms	180
Fungal-like Organisms	112	Nematophytes	180
Peronosporomycetes (Oomycota)	112	<i>Prototaxites</i>	180
Eubacteria and Archaea	112	<i>Nematothallus</i>	183
Archaea	113	<i>Nematoplexus</i>	183
Eubacteria	113	<i>Nematasketum diversiforme</i>	183
Cyanobacteria	115	<i>Pachytheca</i>	184
Lichens	117	Spongiophytaceae	185
		<i>Spongiophyton</i>	185
CHAPTER 4		<i>Orestovia</i>	186
Algae 121		Other Enigmatic Organisms	186
Chlorophyta (Green Algae)	123	<i>Protosalvinia</i>	186
Prasinophyceae	124	<i>Parka</i>	188
Chlorophyceae	126	Isolated Fragments: Clues to the Transition to Land?	189
Volvocales	126	Cuticle and Cuticle-Like Material	189
Tetrasporales	126	Spores and Spore Tetrads	189
Chlorococcales	127	Tubes	192
Ulvophyceae	128	Land Plant Ancestors	193
Dasycladales	128	The Transition to Land	194
Receptaculitida and Cyclocrinales	130	Anchorage and Water Uptake	194
Caulerpales	130	Structural Support and Water Transport	195
Taxa <i>Incertae Sedis</i>	133	Protection Against Desiccation and Radiation	195
Charophyceae	133	Gas Exchange	195
Charales	134	Reproduction on Land	196
Zygnematales	138	Life History Biology	196
Euglenophyta	138		

Homologous Theory	196
Antithetic Theory	196
Animals	198
A Fungal Partner	198
Conclusion	199

CHAPTER 7**Introduction to Vascular Plant Morphology and Anatomy 201**

Plant Organography	202
Cell Types	203
Parenchyma	203
Collenchyma	203
Sclerenchyma	203
Tracheary Elements	204
Tracheids	204
Vessel Elements	206
Sieve Elements	206
Plant Tissues and Primary Growth	207
Xylem Tissue	207
Phloem Tissue	207
Meristems	208
Epidermis	208
Cuticle	209
Stomata	209
Trichomes	210
Anatomy of Stems and Roots	210
Arrangement of Primary Tissues	210
Primary Xylem Maturation Patterns	212
Secondary Development	212
Vascular Cambium	212
Cork Cambium (Phellogen)	213
Secondary Xylem	214
Secondary Phloem	216
Stele Types	216
Primitive Vascular Plants (Vascular Cryptogams)	216
Seed Plants	219
Leaf Morphology and Anatomy	221
Leaf Anatomy	221
Leaf Evolution	222
Further Reading	222

CHAPTER 8**Early Land Plants with Conducting Tissue 223**

Conducting Elements in Early Land Plants	224
History of Discovery	225

Rhyniophytes	227
Rhynie Chert Plants	228
<i>Aglaophyton major</i>	229
<i>Rhynia Gwynne-vaughanii</i>	235
<i>Horneophyton lignieri</i>	237
<i>Asteroxylon mackiei</i>	238
<i>Nothia aphylla</i>	239
<i>Trichopherophyton teuchansii</i>	241
<i>Venturura lyonii</i>	241
Gametophyte Generation	241
Other Rhyniophytes	246
Discussion: Rhyniophyte Evolution	251
Zosterophyllophytes	252
Zosterophyll Evolution	259
Trimerophytes	259
Trimerophyte Evolution	262
Early Land Plant Evolution	263

CHAPTER 9**Lycophyta 265**

Evolution of the Microphyll	267
Drepanophycales	268
Protolpidodendrales	271
Lepidodendrales	279
Vegetative Features	282
Stem Surface and Leaf Bases	282
Stem Anatomy	285
Cortical Tissues	286
Stem Development	287
Leaves	289
Underground Organs	289
Development of Underground Organs	293
Reproductive Biology	294
Microsporangiate and Bisporangiate Cones	295
Megasporangiate Cones	297
Gametophytes	302
Sigillariaceae	303
Leaf Bases	304
Leaves	305
Stem Structure	305
Underground Organs	306
Reproductive Biology	306
Other Lepidodendrid Genera	307
Lycopodiales	310
Selaginellales	312
Pleuromeiales	316
Isoetales	320
Putative Lycopside	325
Conclusions	326

CHAPTER 10

Sphenophytes 329

Pseudoborniales	331
Sphenophyllales	332
Devonian Sphenophyllales	333
Sphenophyllum	334
Leaves	334
Stem Anatomy	335
Roots	337
Reproductive Biology	337
Other Sphenophyllales	338
Ecology	341
Equisetales	342
Calamitaceae	343
<i>Archaeocalamites</i>	343
<i>Calamites</i>	345
Pith Casts	349
Stem Anatomy	350
Extraxylary Tissues	352
Growth and Development	352
Roots	353
Leaves	354
Other Calamitean Leaves	357
Reproductive Biology	358
Spores	366
Tchernoviaceae and Gondwanostachyaceae	368
Vegetative Body	368
Reproductive Biology	369
Equisetaceae	371
Forms with Uncertain Affinities	376
Sphenophyte Evolution	379

CHAPTER 11

Ferns and Early Fernlike Plants 383

Evolution of the Megaphyll	386
Cladoxylopsida	387
Pseudosporochnales	388
<i>Calamophyton</i> Plant	396
Iridopteridales	398
Phylogenetic Position of the Cladoxylopsids	400
Early Fernlike Plants	401
Rhacophytales	401
<i>Rhacophyton</i>	402
Other Taxa	403
Systematics of the Rhacophytales	404
Coenopterid Ferns	405
Stauropteridales	405
Zygopteridales	408

Zygopterid Evolution	417
Marattiales	418
Psaroniaceae: Vegetative Features	418
<i>Psaronius</i> Plant	418
Other Stem Taxa	425
Psaroniaceae: Reproductive Features	425
Paleozoic Compression Taxa	431
Mesozoic Marattiales	433
Marattialean Evolution	434
Ophioglossales	435
Leptosporangiate Ferns	436
Osmundales	436
Paleozoic Stem Taxa	437
Guaiacaceae	438
Mesozoic and Cenozoic Stem Taxa	438
Sterile and Fertile Foliage	440
Osmundalean Evolution	442
Botryopteridaceae	443
Vegetative Organs	443
Reproductive Organs	446
Other Genera	449
Anachoropteridaceae	449
Kaplanopteridaceae	451
Psalixochlaenaceae	452
Sermayaceae	453
Tedeaceae	454
Skaaripteridaceae	457
Tempskyaceae	457
Schizaeaceae	459
Hymenophyllaceae	462
Gleicheniaceae	462
Dicksoniaceae	464
Cyatheaceae	465
Matoniaceae	466
Loxsomataceae	469
Dipteridaceae	469
Polypodiales	470
Salviniales	472
Marsileaceae	472
Salvinaceae	473
Conclusions	476

CHAPTER 12

Progymnosperms 479

Archaeopteridales	480
<i>Archaeopteris</i> Leaves	481
Archaeopterid Reproduction	483
<i>Callixylon</i> Stems	484
Other Archaeopterids	487

Aneurophytales	489
<i>Aneurophyton</i>	489
<i>Tetraxylopteris</i>	489
<i>Triloboxylon</i>	491
<i>Rellimia</i>	492
Other Aneurophytes	494
Protopytales	496
Noeggerathians	497
Progymnosperm Evolution	501

CHAPTER 13

Origin and Evolution of the Seed Habit 503

Homospory, Heterospory, and the Seed Habit	503
Homospory	503
Heterospory	504
Sporangia	504
Endospory	507
Lycopsid Heterospory	508
Seed Habit	508
Evolution of the Integument	509
Evolution of Pollen Capture	510
Pollen	511
Cupules	511
Cupulate Devonian Seeds	511
Reproductive Biology	517
Carboniferous Seeds	518
Pollen Chamber Function	523
Microgametophytes	524
Diversity of Early Seeds	525
Paleozoic Seeds with Embryos	526

CHAPTER 14

Paleozoic Seed Ferns 529

Calamopityales	531
Buteoxylales	539
Lyginopteridales	540
<i>Lyginopteris</i> Plant	540
Vegetative Organs	540
Reproductive Structures	542
Other Lyginopterids: Vegetative Remains	546
<i>Heterangium</i>	547
<i>Microspermopteris</i>	550
<i>Schopfiastrum</i>	550
<i>Pitys</i>	551
Devonian–Mississippian Taxa	552
Problematic Lyginopterids	554
Other Lyginopterids: Seeds and Cupules	555
<i>Sphaerostoma</i>	556
<i>Salpingostoma</i>	556

<i>Conostoma</i>	556
<i>Coronostoma</i>	557
<i>Physostoma</i>	557
<i>Tyliosperma</i>	558
<i>Calathospermum</i>	558
<i>Gnetopsis</i>	559
<i>Megatheca</i>	559
Other Lyginopterids: Pollen Organs	560
<i>Incertae Sedis</i>	563
Lyginopterid Evolution	565
Medullosales	566
Stems	566
<i>Medullosa</i>	566
Other Stem Taxa	569
Leaves (Fronds)	570
Roots	572
Growth Habit	572
Seeds	573
Pollen organs	581
Pollen	590
Medullosan Evolution	591
Callistophytales	593
Vegetative Organs	594
Reproductive Structures	595
Callistophytalean Evolution	598
Glossopteridales	598
Leaves	599
<i>Glossopteris</i>	599
<i>Gangamopteris</i>	603
Other Leaf Types	603
Stems and Roots	605
Ovulate Reproductive Structures	606
Permineralized Forms	606
Impression–Compression Specimens	609
What is the Glossopterid Ovulate Structure?	614
Pollen Organs	616
<i>Glossopteris</i> Habit and Habitat	618
Phylogenetic Position	618

CHAPTER 15

Mesozoic Seed Ferns 621

Caytoniales	622
<i>Sagenopteris</i>	622
<i>Caytonanthus</i>	623
<i>Caytonia</i>	624
<i>Rufflorinia</i> and <i>Ktalenia</i>	626
Corystospermales	627
Foliage	627
Stems	630

Pollen Organs	631
Ovulate Structures	634
Petriellales	637
Peltaspermales	639
Foliage	639
Reproductive Organs and Whole-Plant	
Concepts	643
Conclusions	648

CHAPTER 16

Late Paleozoic and Mesozoic Foliage 651

Late Paleozoic Foliage	652
<i>Adiantites</i>	655
<i>Alethopteris</i>	656
<i>Aneimites</i>	657
<i>Aphlebia</i>	658
<i>Alloiopteris</i>	658
<i>Botrychiopsis</i>	659
<i>Callipteridium</i>	659
<i>Cardiopteridium</i>	660
<i>Cardiopteris</i> (<i>Fryopsis</i>)	660
<i>Charlea</i>	660
<i>Cyclopteris</i>	661
<i>Dicksoniites</i>	662
<i>Discopteris</i>	664
<i>Eremopteris</i>	664
<i>Ginkgophytopsis</i>	664
<i>Kankakea</i>	665
<i>Kariopteris</i> , <i>Mariopteris</i> , and <i>Pseudomariopteris</i>	665
<i>Lesleya</i>	669
<i>Linopteris</i> , <i>Reticulopteris</i> , and <i>Barthelopteris</i>	669
<i>Lobatopteris</i>	671
<i>Lonchopteridium</i> and <i>Lonchopteris</i>	672
<i>Megalopteris</i>	672
<i>Neuropteris sensu lato</i>	673
<i>Laveinopteris</i>	674
<i>Macroneuropteris</i>	674
<i>Margaritopteris</i>	674
<i>Neuraethopteris</i>	674
<i>Neurocallipteris</i>	675
<i>Neurodontopteris</i>	675
<i>Neuropteris sensu stricto</i>	675
<i>Paripteris</i>	675
<i>Sphenoneuropteris</i>	676
<i>Neuropterid Growth Habit</i>	676
<i>Blanziopteris</i>	676
<i>Nothorhacopteris</i>	677
<i>Odontopteris</i> and <i>Lescuropteris</i>	677
<i>Pecopteris</i>	679

<i>Rhodea</i> (= <i>Rhodeopteridium</i>)	680
<i>Sphenopteris</i>	680
<i>Sphenopteris sensu stricto</i>	682
<i>Eusphenopteris</i>	682
<i>Spiropteris</i>	683
<i>Taeniopteris</i>	683
<i>Tinsleya</i>	685
<i>Triphyllopteris</i> , <i>Genselia</i> , and <i>Charbeckia</i>	685
Mesozoic Foliage	685
<i>Anomozamites</i>	687
<i>Cladophlebis</i>	687
<i>Coniopteris</i>	688
<i>Ctenis</i>	689
<i>Deltolepis</i> and <i>Cycadolepis</i>	689
<i>Dictyophyllum</i>	689
<i>Dictyozamites</i>	689
<i>Doratophyllum</i>	690
<i>Macrotaeniopteris</i>	690
<i>Matonidium</i>	690
<i>Mesodescolea</i>	690
<i>Nilssonia</i>	690
<i>Nilssoniopteris</i>	691
<i>Otozamites</i>	693
<i>Pachypteris</i> , <i>Komlopteris</i> , and <i>Thinnfeldia</i>	695
<i>Phlebopteris</i>	696
<i>Pseudoctenis</i>	696
<i>Pseudocycas</i>	697
<i>Pterophyllum</i>	697
<i>Ptilophyllum</i>	698
<i>Ptilozamites</i>	699
<i>Ruflofinia</i>	699
<i>Taeniozamites</i>	700
<i>Ticoa</i>	700
<i>Wingatea</i>	700
<i>Yabeiella</i>	700
<i>Zamites</i>	701

CHAPTER 17

Cycadophytes 703

Cycadales	703
Leaves and Petioles	706
Stems	707
Paleozoic Reproductive Structures	709
Triassic Cycads	715
Jurassic Cycads	718
Pollination Biology	721
Discussion: Cycad Evolution	721
Bennettitales	722
Cycadeoidaceae	725

Stem Anatomy	725	Roots	794
Reproductive Structures	728	Reproductive Features	795
Development	730	Reproductive Organs	795
Williamsoniaceae	732	Seeds	798
Ovulate Structures	734	Angaran Cordaites	801
Pollen Organs	738	Phylogenetic Position and Origin of the Cordaites	803
Discussion: Bennettitales	739		
CHAPTER 18		CHAPTER 21	
Ginkgophytes 743		Conifers 805	
Paleozoic Record	744	Early Conifers	806
Ginkgophyte Wood	747	Voltziales	807
Ginkgophyte Foliage	747	Utrechtiaceae	808
Pollen-Producing Structures	750	<i>Utrechtia</i>	809
Ginkgophyte Plants	750	<i>Ernestiodendron</i>	809
Ginkgoaceae	750	<i>Ortiseia</i>	809
Karkeniaceae	752	<i>Otovicia</i>	810
Umaltolepidiaceae	752	<i>Moyliostrobus</i>	811
Yimaiceae	752	Other Taxa	811
Schmeissneriaceae	753	Thucydiaceae	814
Taxa with Uncertain Affinities	754	Emporiaceae	815
Conclusions	755	Majonicaceae	816
		Ullmanniaceae	819
CHAPTER 19		Bartheliaceae	820
Gymnosperms with Obscure Affinities 757		Other Voltziales	820
Gigantopteridales	758	Ferugliocladaceae	823
Vegetative Remains	758	Buriadiaceae	826
Reproductive Organs	762	Pollen Cones	826
Vojnovskyales	763	Summary Discussion: Voltziales	828
Czekanowskiales	765	Coniferales	830
Iraniales	768	Palissyaceae	830
Pentoxylales	768	Cheirolepidiaceae	831
Hermanophytales	773	Summary Discussion: Cheirolepidiaceae	837
Gnetales	775	Podocarpaceae	838
Extant Genera	776	Summary Discussion: Podocarpaceae	843
<i>Ephedra</i>	776	Araucariaceae	843
<i>Gnetum</i>	776	Summary Discussion: Araucariaceae	848
<i>Welwitschia</i>	776	Cupressaceae	849
Extant Reproductive Structures	777	Cunninghamioideae	850
Fossil Gnetophyte Pollen	777	Taiwanoideae	851
Gnetophyte Megafossils	778	Athrotaxoideae	851
Putative Gnetophytes	781	Sequoioideae	852
Dirhopalostachyaceae	785	Taxodioideae	854
		Cupressoideae	857
CHAPTER 20		Cupressaceous Wood	859
Cordaitales 787		Summary Discussion: Cupressaceae	859
Vegetative Features	788	Sciadopityaceae	860
Stems	788	Pararaucariaceae	861
Foliage	791	Pinaceae	861
		Pinoideae	863

Genus <i>Pinus</i>	864	Nymphaeaceae	901
<i>Pinus</i> Wood	866	Austrobaileyales	902
<i>Larix</i>	866	Austrobaileyaceae	902
Piceoideae	867	Illiciaceae	902
Abietoideae	867	Schisandraceae	903
Summary Discussion: Pinaceae	868	Ceratophyllales	904
Cephalotaxaceae	868	Ceratophyllaceae	904
Taxaceae	869	Magnoliids	904
Summary Discussion: Cephalotaxaceae and		Canellales	904
Taxaceae	869	Winteraceae	904
Conclusions	870	Laurales	906
		Calycanthaceae	906
		Lauraceae	906
		Magnoliales	908
		Annonaceae	908
		Magnoliaceae	909
		Myristicaceae	914
		Piperales	915
		Lactoridaceae	915
		Saururaceae	915
		Monocotyledons	917
		Alismatales	917
		Alismataceae	917
		Araceae	917
		Hydrocharitaceae	917
		Zosteraceae (Seagrasses)	920
		Asparagales	921
		Agapanthaceae	921
		Hemerocallidaceae	921
		Orchidaceae	921
		Dioscoreales	922
		Dioscoreaceae	922
		Liliales	922
		Petermanniaceae	922
		Pandanales	923
		Pandanaceae	923
		Triuridaceae	923
		Commelinids	923
		Arecales	923
		Arecaceae (=Palmae)	923
		Commelinales	925
		Commelinaceae	925
		Poales	925
		Cyperaceae	925
		Poaceae (Gramineae)	926
		Zingiberales	928
		Musaceae	928
		Zingiberaceae	929
		Eudicots	929

CHAPTER 22

Flowering Plants 873

Angiosperm Origins	876
Origin of the Flower	877
Pseudanthial Theory	877
Euanthial Theory	878
Microsporangial Theories	878
Transitional-Combination Theory	878
Habit	879
Ecological Considerations	879
Site of Origin	880
Pre-Cretaceous Fossil Evidence	880
<i>Sanmiguelia</i>	881
<i>Furcula</i>	882
<i>Prolemnospermum</i>	883
Pre-Cretaceous Pollen	883
Dispersed Pollen	884
Early Angiosperm Evidence	885
Pollen	885
Pollen Evolution	889
Evidence from Leaves	889
Angiosperm Ancestors	893
Caytoniales	894
Czekanowskiales	895
Glossopteridales	895
Bennettitales	895
Pentoxylales	895
Gigantopteridales	895
Phylogenetic Analyses and Angiosperm Origins	895
Selected Angiosperm Families	897
Basal Angiosperms	898
Amborellaceae	898
Hydatellaceae	898
Archaeofractaceae	898
Chloranthaceae	899
Nymphaeales	901

Buxaceae	930	Ulmaceae	973
Trochodendraceae	931	Eurosids II (Malvids)	976
Proteales	933	Brassicales	976
Nelumbonaceae	933	Capparaceae	976
Proteaceae	935	Malvales	976
Platanaceae	937	Tiliaceae	976
Ranunculales	940	Sapindales	977
Berberidaceae	940	Anacardiaceae	977
Ranunculaceae	940	Meliaceae	978
Core Eudicots	941	Rutaceae	978
Gunnerales	941	Sapindaceae	979
Gunneraceae	941	Asterids	981
Caryophyllales	941	Cornales	981
Phytolaccaceae	941	Cornaceae	981
Saxifragales	942	Curtisiaceae	984
Cercidiphyllaceae	942	Hydrangeaceae	984
Haloragaceae	943	Ericales	985
Hamamelidaceae	945	Ebenaceae	985
Iteaceae	945	Ericaceae	985
Saxifragaceae	946	Theaceae	985
Rosids	946	Euasterids I (Lamiids)	986
Vitaceae	947	Icacinaceae	986
Myrtales	948	Garryales	987
Lythraceae	948	Eucommiaceae	987
Trapaceae	948	Gentianales	987
Myrtaceae	948	Gentianaceae	987
Onagraceae	950	Rubiaceae	987
Eurosids I (Fabids)	950	Lamiales	988
Fabales	950	Avicenniaceae	988
Fabaceae (=Leguminosae)	950	Byblidaceae	988
Fagales	953	Lentibulariaceae	988
Betulaceae	953	Oleaceae	988
Casuarinaceae	955	Solanales	988
Fagaceae	956	Solanaceae	988
Juglandaceae	961	Euasterids II (Campanulids)	988
Myricaceae	966	Bruniaceae	988
Nothofagaceae	966	Quintiniaceae	988
Malpighiales	967	Apiales	989
Clusiaceae	967	Araliaceae	989
Euphorbiaceae	968	Aquifoliales	989
Salicaceae	970	Aquifoliaceae	989
Malpighiaceae	970	Asterales	990
Oxalidales	971	Asteraceae (=Compositae)	990
Cunoniaceae	971	Menyanthaceae	991
Elaeocarpaceae	971	Dipsacales	991
Rosales	971	Caprifoliaceae	991
Moraceae	971	Cenozoic Floras	991
Rhamnaceae	971	Conclusions	996
Rosaceae	971		

CHAPTER 23

Interactions Between Plants and Animals 999

Early Terrestrial Ecosystem Associations	1001
Animals on Land	1001
Early Plant-Animal Associations	1001
Herbivory	1003
Defenses Against Herbivory	1004
Mechanical Protection	1005
Chemical Defenses	1006
Fossil Evidence of Herbivory	1007
Coprolites	1007
Gut Contents	1011
Marginal Feeding	1011
Defoliation	1013
Leaf Miners	1013
Wound Tissue	1015

Interactions with Vertebrates	1016
Herbivory	1016
Dentition	1018
Coprolites and Stomach Contents	1018
Dispersal	1018
Plants as Habitat	1019
Other Plant-Animal Interactions	1021
Mimicry	1021
Pollination	1022
Conclusions	1024
Appendix 1: Classification of Organisms	1027
Glossary	1031
References	1049
Index	1199