## Contents

1	The evolutionary record and methods of reconstruction				
	1.1	Introduction			
	1.2	The geological timescale			
	1.3	Methods of reconstruction			
	1.4	Phylogenetic trees	20		
	1.5	Dating methods	20		
	Sun	nmary MATCAT-DISCRETE	2		
2	Ear	liest forms of plant life	27		
	2.1	The earliest environments	27		
	2.2	Accumulation of organic material and formation of the first cell	3		
	2.3	The first prokaryotes: the geological evidence	33		
	2.4	Evolution of photosynthesis	39		
	2.5	Evolution of the eukaryotes	4		
	2.6	Possible triggering mechanisms of eukaryotic evolution	50		
	Sun	nmary BM Negrot A automate Division	53		
3	The	colonization of land	55		
	3.1	Environmental changes during the Cambrian and Ordovician (541–443 Ma)	55		
	3.2	Fossil evidence for plant terrestrialization	61		
	3.3	Examples of earliest land plants in the fossil record	72		
	3.4	Evolutionary trends: green algae to land plants	77		
	3.5	Evolutionary trends in land plants: non-vascular to vascular	83		
	3.6	Biogeographical distribution of the earliest land plants in the late Silurian and early Devonian (~430–390 Ma)	86		
	3.7	The influence of land-dwelling plants on the Earth system	87		
	Summary				
4	The first forests				
	4.1	Environmental changes spanning the mid Devonian to end Carboniferous (~394–299 Ma)	92		
	4.2	Major changes and innovations in the plant fossil record during the mid Devonian to end Carboniferous (~394–299 Ma)	98		
	4.3	Evidence of further plant adaptations to land dwelling between mid Devonian and end Carboniferous (~394–299 Ma)	99		
	4.4	Further adaptations to the plant life cycle	104		

	4.5	Earliest trees in the fossil record	113	
	4.6	Biogeographical distribution of global vegetation during the early	135	
-	P	(~359-342 Ma) and late Carboniferous (~318-299 Ma)	144	
	Sun	mary	144	
5	Ma	jor emergence of the seed plants	146	
	5.1	Environmental changes during the Permian (299–252 Ma)	146	
	5.2	Evolution of cycads, bennettites, ginkgos, glossopterids, and gnetales	149	
	5.3	Biogeographical distribution of global vegetation during the middle Permian (270-260 Ma)	164	
	5.4	Major radiation of the conifers and other seed plant lineages	167	
	5.5	Biogeographical distribution of global vegetation during the early Jurassic (201–182 Ma)	173	
	Summary			
6	Flowering plant origins			
	6.1	Evidence for the first angiosperms	179	
	6.2	Nature and distribution of the earliest angiosperms	196	
	6.3	Why so late?	202	
	6.4	Evolutionary trends: gymnosperms to angiosperms	214	
	6.5	Biogeographical distribution of global vegetation during the late Cretaceous (~100-66 Ma)	217	
	Summary		223	
7	The past 66 million years			
	7.1	Environmental changes over the past 66 million years (Cenozoic)	225	
	7.2	Biogeographical distribution of global vegetation between ~60 and 50 Ma (late Palaeocene to early Eocene)	231	
	7.3	The evolution of grasses	239	
	7.4	Decline of the forests and spread of aridland vegetation	243	
	7.5	Biogeographical distribution of global vegetation between 34-23 Ma (Oligocene)	246	
	7.6	The evolution of plants using the C4 and CAM photosynthetic pathways	251	
	7.7	Biogeographical distribution of global vegetation by 11.6-5.3 Ma (late Miocene)	254	
	Sun	nmary	263	
8	Mass extinctions and persistent populations			
	8.1	Definition of mass extinction	265	
	8.2	Evidence in the geological record: plants versus animals	266	
	8.3	Why no mass extinction in the plant fossil record?	287	
	8.4	Evidence for persistence in the plant fossil record	288	
	8.5	Adaptations of plants for persistence through intervals of environmental change	290	
	Sun	omary	296	

## CONTENTS

9	Evolutionary theories and the plant fossil record			
	9.1	Evolutionary theories	298	
	9.2	Patterns of evolutionary change in the plant fossil record	301	
	9.3	The mechanisms driving evolutionary change	307	
	Con	iclusions	331	
Bib	liogra	phy	333	
Glo	378			
Ind	ex		385	