

Contents

Preface	xxiii
Acknowledgments	xxv
Abbreviations	xxvii
1. The Spatial Basis of Biogeography	1
The Spatial Component of Evolution: Basic Concepts and Methods of Analysis	1
Species Concepts	1
Dispersal and Vicariance	2
An Example of Vicariance and Subsequent Dispersal: Psilotaceae	3
Two Different Concepts of "Dispersal"	4
"Normal" Dispersal: An Observed Ecological Process	4
Chance Dispersal: An Inferred Mode of Speciation	4
Some More on Normal, Observed Dispersal and Inferred Chance Dispersal	5
Dispersal and Rare or Unique Events	6
Founder Speciation	7
Origin of Distributional Overlap	8
Means of Dispersal, Observed Dispersal, and Inferred Dispersal: Some Case Studies	8
The Hawaiian Islands Biota and Metapopulations	8
Trans-Tasman Sea Affinities	10
Trans-Pacific Affinities	11
Observed Dispersal and Inferred Dispersal: A Case Study in a Group of Alpine Plants, the <i>Hebe</i> Complex	11
Danthonioid Grasses and Dispersal by Serendipity	12
New Analytical Methods (DIVA, DEC, and Others) Based on Old Concepts of Local Centers of Origin and Chance Dispersal	13
Do Basal Clades Occupy Centers of Origin?	13
Do Paraphyletic, Basal Grades Occupy Centers of Origin?	14
Interpretation of Basal Grades Restricted to Particular Regions: Examples from Plants	16
Interpretation of Basal Grades Restricted to Particular Regions: Examples from Animals	18
Coding the Areas Used in Ancestral Areas Programs	20
A Case Study from Liverworts	20
Summary on Ancestral Areas Programs	20
Ecological Speciation and Sympatric Speciation: A Critique	21
Sympatric Speciation and the Rarity of Sympatric Sister Species	22
Suggested Cases of Sympatric Sister Species	22
Niche Conservatism: Lack of Niche Divergence between Sister Clades	24
Niche Differences between Species That Have Not Resulted from Ecological Speciation	25
Conclusions on Ecological Differentiation	26
The Relationship between Biogeography and Ecology	26
Does Ecology Determine Geographic Distribution?	27
History of Ideas on Ecology and Distribution	28
Early Ideas on Ecology and Geographic Distribution	28
Taxonomic Biogeography Since Its Origin in the Sixteenth Century	28
Modern Ecological Biogeography and the Niche Theory of Distribution	29
The Chasm between Ecological and Systematic Biogeography	30
Climate and Distribution	30

Climate-Based SDMs Often Do Not Work.....	30
Niche Variation in Space and Time	31
Biotic Factors and Distribution	32
Historical Factors and Distribution	32
Formal Acknowledgment of Historical Factors in Distribution	33
Some Applications of Vicariance-Based Ecology	33
The Neutral Theory of Biodiversity	33
Ecology and Biogeography in New Zealand	33
The Concept of "Center of Origin" in Ecological Theory	34
The Ecological Center of Origin in Practice	35
General Conclusions on Biogeography and Ecology	35
The High Levels of Geographic Structure Observed in Clades	37
The High Levels of Geographic Structure and Repeated Distribution Patterns in Clades	37
Single, Monophyletic Groups of Good Dispersers in Island Regions: Long-Distance	
Dispersal Events That Occur Just Once in Geological Time.....	37
New Zealand Lizards	38
Tribe Sicyoeae (Cucurbitaceae) in Australasia	38
Reciprocal Monophyly of Island Clades and Diverse, Widespread Mainland Clades	39
The New Zealand Biota Is Not a Subset of the Australian Biota	39
Biogeographic Parallels between the Southwest Pacific and the Caribbean: More	
Islands with "Basal" Groups	40
Geographic Structure in Microorganisms, Spore Plants, Estuarine Groups, and Marine	
Groups: Toward a Trans-Realm Biogeography	41
Vicariance in Microorganisms	41
Vicariance in Spore Plants	42
Vicariance in Fungi	42
Vicariance in Ferns	42
Vicariance in Estuarine Groups	42
Vicariance in Marine Groups	43
Unexpected Levels of Geographic Structure in Marine Groups	43
Vicariance Models for Marine Groups	44
Local Endemism in Marine Animals: New Zealand Mollusks	45
Toward a Trans-Realm Biogeography	46
2. Analyzing the Timeline of Evolution	47
Interpreting the Fossil Record	47
Placing Fossils in a Phylogeny	48
Informal Transmogrification of Minimum (Fossil-Calibrated) Clade Ages into Maximum	
Clade Ages	49
Two Case Studies of Informal Transmogrification	49
Grammitid Ferns (Polypodiaceae)	49
Nothofagaceae	50
Transmogrification of Clade Ages in a Bayesian Framework: The Problem of the Priors	50
Examples of Bayesian Dating Studies	52
Monimiaceae	52
Winteraceae	52
Orchidaceae	53
Alstroemeriaceae	53
Haloragaceae	53
Malvaceae	53
Campanulaceae	54
Calceolariaceae	54
Goodeniaceae	54

Asteraceae	54
Other Widespread Plant Groups	55
Specifying Bayesian Priors and Their Parameters	55
Integrating Living and Fossil Records	55
Protecting Dispersal Theory from Falsification by Early New Zealand Fossils of Modern Groups	56
Protecting Dispersal Theory from Old New Zealand Endemics with No Extralimital Fossils	56
Biogeography and Extinction: Dealing with the Possible Extinction of a Clade in Areas Where It Has No Fossils	57
Is Evolution Clocklike?	58
Calibrating Phylogenies Using Tectonics and Vicariance	59
Tectonic Calibration and the Passerine Birds	60
Criticism of Tectonic Calibration	60
How Old Are Modern Species?	62
Assessing Analytical Methods in Biogeography: Do They Explain Classic Problems or Lead to New Ideas?	64
Analysis of Space and Time in Evolution	64
3. New Zealand Geology	67
The New Zealand Plateau or Zealandia	67
Terrane Accretion and Orogeny in Mesozoic New Zealand	72
Accretion of the Western Province Terranes	73
Emplacement of the Median Batholith	73
Accretion of the Eastern Province Terranes	74
Subduction Zones and Island Arcs	75
The Culmination of Convergence and the Switch to Extension at ~100 Ma	77
Arrival of a Spreading Ridge at the Gondwana-Pacific Subduction Zone	77
Slab Capture of Subducting Phoenix Plate Slabs by the Pacific Plate	78
Slab Window Formation	78
Arrival of the Hikurangi Plateau at the Chatham Rise	79
Orogenic Collapse	81
Changing Motions of the Australia and Pacific Plates at ~100 Ma	81
100–84 Ma: Predrift Rifting, Magmatism, and Metamorphism, Including Formation of Core Complexes	82
Predrift Rifting	82
Plutonism, Metamorphism, and Core Complex Emplacement	85
The Haast Schist	85
The Otago Schist as a Metamorphic Core Complex	86
Metamorphism Developing with Progressive Accretion and Underplating of the Torlesse Terrane	87
The Alpine Schist	88
Post-100 Ma Felsic (Silicic) Magmatism	88
Post-100 Ma Mafic (Mainly Alkaline) Volcanism	89
Possible Causes of the Intraplate Volcanism	89
Mantle Plumes	89
Extension and Thinning	90
Multiple, Small Lithospheric Detachments	90
Tectonic History in the Southwest Pacific Since 90 Ma	90
90 Ma (Late Cretaceous)	93
75 Ma (Late Cretaceous)	93
60 Ma (Paleocene)	93
50 Ma (Early Eocene)	93
45 Ma (Middle Eocene)	93

35 Ma (Late Eocene)	94
25 Ma (Oligocene)	94
15 Ma (Middle Miocene)	94
10 Ma (Late Miocene)	94
5 Ma (Pliocene)	94
Present	94
Slab Rollback and Extensional Opening of Backarc Basins	94
Backarc Rifting as a Mode of Vicariance in Arc Biotas	95
The Waipounamu Erosion Surface	96
Oligocene Flooding	96
Amuri Limestone and the Marshall Paraconformity	97
Cenozoic Deformation	98
Kaikoura Orogeny	98
Taupo Volcanic Zone	98
4. Introduction to the New Zealand Biota and Its Geography	99
The History of Ideas on New Zealand Biogeography	99
Dispersal Models for the New Zealand Biota	99
The "Paleozealandic Element" in Dispersal Theory	100
Problems with the Dispersal Model: Paradox and Perversity in the New Zealand Biota	102
A Vicariance Model of New Zealand Biogeography	103
The New Zealand Biota and Its Global Significance	104
Globally Basal Endemics in New Zealand	104
Flora	105
Fauna	106
Interpretation of the Globally Basal Groups	108
Intercontinental Affinities of the New Zealand Biota	109
Simple Allopatry: The Mite Harvestmen (Opiliones, Suborder Cyphophthalmi)	109
Global Allopatry and Local Overlap: New Zealand Shags (Phalacrocoracidae)	111
Distribution Straddling the Ocean Basins and Their Spreading Centers	113
Indian Ocean Groups: Examples from Ratites, Ducks, Beetles, and Plants	113
Tethyan Groups	114
Distribution around the Tasman Sea	115
Phylogenetic/Biogeographic Breaks in the Tasman Basin: An Example from	
Cuckoos	115
A Break around the Tasman Region Plus Secondary Overlap There: Stylidiaceae	116
Overlap around the Tasman in Liliales: Colchicaceae and Alstroemeriaceae	117
Overlap around the Tasman in a Clade of Thymelaeaceae	119
Trans-South Pacific Disjunctions: Examples from New Zealand Hymenoptera	120
Some Gondwanan Pseudoscorpions	122
Panaustral + Central Pacific Distribution	122
The Schefflera Group (Araliaceae)	122
Metrosidereae (Myrtaceae)	123
Panaustral + Central Pacific Distribution, and the New Zealand "Star" Pattern: The Case	
of Asteliaceae	124
Origin of Asteliaceae	124
Differentiation in Asteliaceae	125
The New Zealand "Star" Pattern	126
Another Pacific Group: <i>Coprosma</i> (Rubiaceae)	129
<i>Muehlenbeckia</i> (Polygonaceae): Another "Star Pattern"	130
The "Home Advantage" or "Founder-Takes-All" Model of Biogeography	131
New Zealand Groups with Pacific, Not Gondwanan, Affinities: The Basal Frogs	132
Summary of the Intercontinental Affinities of New Zealand Biota	132

5. Biogeography of Northern New Zealand: The Offshore Islands, the Northland-East Coast Allochthon, and the Taupo Volcanic Zone	135
New Zealand—New Caledonia Connections	135
Examples from Weevils	135
Differences between New Caledonia and New Zealand	137
Lord Howe Island and Norfolk Island	137
The Skinks of Lord Howe Island, Norfolk Island, and New Zealand	138
The Islands off Northland	139
Endemism on the Northeastern Islands	141
"Horstian" Distribution off Eastern Northland and Auckland	141
Connections of the "Horstian" Distributions with the Norfolk Ridge and Other Regions	143
Three Kings Islands and the Mount Camel Terrane	143
Three Kings Islands and the Mount Camel Terrane: Geology	144
Three Kings Islands and the Mount Camel Terrane: Biota	145
Relationships of the Three Kings Biota outside New Zealand	145
Relationships between the Three Kings Islands and Mainland New Zealand	147
Other Mount Camel Terrane Endemism	148
The Vening Meinesz Transform Margin and the Northland Plateau	149
Regional Geology	149
The Three Kings and Poor Knights Islands: Biology	150
Three Kings—Poor Knights Disjunction	151
Another Mount Camel Terrane—Poor Knights Distribution	152
The Northland and East Coast Allochthons	152
Biology of Northland—East Coast	153
Northland and East Coast Allochthons: Geology	155
Emplacement of the Ophiolite at the East-Dipping New Caledonia Subduction Zone	156
Ages of the Ophiolite	156
Did the Northland—East Coast Ophiolite Form in a Backarc or a Forearc?	157
Have Old Endemics on the Ophiolite "Floated" onto It from the Basement during Obduction?	157
Northland Miocene Volcanism	158
Alternative Geological Models for Northland	158
The Northland Basaltic Ocean Floor Terrane: A Poya Terrane Analogue?	159
Subduction between New Caledonia and New Guinea	159
Responses to the Whattam et al. Model	160
The Taupo Volcanic Zone	160
Endemism on the Volcanoes	161
Kermadec Islands	162
A Trans-Tropical Pacific Group in Northern New Zealand: <i>Sicyos</i> (Cucurbitaceae)	163
6. Biogeography of New Zealand's Subantarctic Islands and the Chatham Islands	167
Campbell Plateau and New Zealand's Subantarctic Islands	167
Endemism and Absence in the Subantarctic Region	167
Geology of the Campbell Plateau: A Submerged Block of Continental Crust	169
The Campbell Plateau and Antarctica	170
Rifting in the Great South Basin and the Bounty Trough, and Seafloor Spreading between the Chatham Rise and Antarctica	171
Penguins	172
Eared Seals: Otariidae	173
The <i>Pleurophyllum</i> Group (Asteraceae)	174
Subantarctic and Mainland Clades: Examples from New Zealand <i>Poa</i> (Poaceae)	175
Albatrosses	177

The Snares.....	177
Bounty and Antipodes Islands.....	178
<i>Pseudhelops</i> (Coleoptera, Tenebrionidae).....	178
<i>Cyanoramphus</i> Parrots (Psittacidae).....	178
A Basal Kelp in the Antipodes Islands: <i>Durvillaea</i> "Species A".....	180
Connections between the Subantarctic Islands and the Chatham Islands.....	180
Sedges (Cyperaceae).....	180
<i>Puccinellia</i> (Poaceae).....	180
Mollymawks (<i>Thalassarche</i> , Diomedidae).....	181
Subantarctic Pipits (<i>Anthus</i> , Motacillidae).....	181
Affinities between Campbell Plateau and Areas outside New Zealand.....	182
Tasmania, Patagonia, and the North Pacific.....	182
Abalone (<i>Haliotis</i> , Gastropoda): Campbell Plateau Differentiation in an Indian Ocean Group.....	182
Tectonic Extension on the Campbell Plateau and the Origins of the Endemism There.....	183
The Great South Basin and "Sliver" Distributions on the Mainland.....	183
Chatham Islands.....	183
Geographic Affinities of Chatham Islands Endemics.....	184
Chatham Islands Endemics with Sister Groups That Are Diverse and Widespread on the New Zealand Mainland.....	185
Absences from the Chatham Islands.....	186
Molecular Clock Dates of Chatham Islands Groups: Old Taxa Endemic to the Young Chatham Islands.....	186
Geology of the Chatham Islands, Chatham Rise, and Hikurangi Plateau.....	187
Volcanism.....	187
Tectonism in and around the Chatham Islands.....	188
Chatham Islands and the Hikurangi Plateau.....	188
Summary on Vicariance and the Chatham Islands.....	189
Affinities of the Chatham Islands Biota with Northern and Southern Parts of Mainland New Zealand.....	189
An Example of Character Geography: The Conspicuous Development of Tree Architecture and the Paucity of Divaricate Shrubs in the Chatham Islands Flora.....	190
Aspects of the Chatham Islands Fauna.....	191
Larger Size of Chatham Islands Birds.....	191
Differentiation within the Chatham Islands Region.....	192
Is Mainland New Zealand a Center of Origin for the Offshore Island Biota?.....	193
<i>Hemiphysa</i> (Columbidae).....	193
New Zealand Cicadas (Hemiptera, Auchenorrhyncha, Cicadidae).....	195
Outer Arcs on the New Zealand Plateau: Albatrosses and Insects.....	196
A "Star Pattern" in Zealandia: A Group of Filmy Ferns.....	196
7. Biogeography of Stewart Island and the Southern South Island: Mesozoic–Paleogene	
Geology	199
New Zealand Basement Terranes and Their Origin.....	199
Western Province Terranes.....	200
Western Province—Australia Affinities.....	202
A Distinctive Nelson Beetle, <i>Orthoglymma</i> (Carabidae).....	202
Western Distribution in Disjunct "Outer Arcs".....	203
The Boundary between Western and Eastern Provinces and Mid-Cretaceous Activity There.....	204
<i>Coprosma talbrockiei</i> and the Western Province Terranes of Northwest Nelson.....	205
Western Province and Eastern Province Differentiation in <i>Lyperobius</i> Weevils.....	207
Stewart Island.....	207
Eastern Fiordland as Part of the Eastern Province.....	210
Paparoa Range and Papahaua Range.....	211

Murihiku Terrane and the Southland Syncline.....	215
The Otago Schist.....	216
Moonlight Tectonic Zone.....	216
<i>Pontodrilus</i> (Annelida, Megascolecidae).....	218
<i>Maoricicada campbelli</i> (Hemiptera, Cicadidae).....	219
Calibrating Clocks in <i>Maoricicada</i> Using the Age of Habitats: "Mountain Age" and "Island Age" Methods.....	221
Other Northeast-Trending Features in Otago.....	222
Nevis-Cardrona Fault System.....	222
Titri-Leith-Waitati Fault Zone and Dunedin Endemism.....	222
The Little Blue Penguin <i>Eudyptula</i>	224
The Penguins <i>Megadyptes</i> and <i>Eudyptes</i>	224
Gore-Rock and Pillar Range-Kyeburn.....	225
Waihemo Fault Zone.....	225
The Aoraki Node.....	226
Westland Endemism around the Fox and Franz Josef Glaciers.....	229
8. Biogeography of the Northern South Island, and Its Mesozoic-Paleogene Geology	231
The Torlesse Node.....	231
The Kaikoura Node, Southern Marlborough.....	237
Distribution in an Inland Strip: Central Otago-Southern Marlborough.....	240
Is Distribution in the South Island Central Strip and around the Moonlight Tectonic Zone Caused by Current Climate?.....	240
Central Strip Distribution Hitting the Coast in Marlborough.....	241
Geology of the Kaikoura Region, Southern Marlborough.....	242
Events Following the End of Subduction in the Albian.....	242
Normal Faulting and Basin Formation.....	243
Volcanism.....	244
Intrusion.....	245
Uplift.....	245
Latest Cretaceous and Paleogene Subsidence.....	246
The Cook Strait Node.....	246
Breaks at Cook Strait and the Alpine Fault, Incomplete Lineage Sorting, and Microrefugia: The Case of <i>Pseudopanax ferox</i> (Araliaceae).....	249
Oligocene Marine Transgression.....	250
Tectonic Evidence for Oligocene Land.....	251
Lithological Evidence for Oligocene Land.....	251
Paleontological Evidence for Oligocene Land.....	252
High Diversity and Endemism in Early Miocene Fossil Assemblages, Soon after Maximum Flooding.....	252
Lack of Biotic Turnover between Pre- and Postinundation Fossil Biotas.....	254
Biological Evidence for Survival of New Zealand-Endemic Clades through the Oligocene.....	255
Absences of Old, Widespread Groups in the New Zealand Biota.....	256
Pre-Oligocene Molecular Clock Dates for New Zealand-Endemic Clades.....	256
A Case Study: <i>Agathis</i> and Its Possible Survival through the Oligocene Flooding.....	257
Does Accepting Mid-Oligocene Land Depend on a Circular Argument?.....	258
Equivocation in Claims for Complete Submergence.....	258
Current Views on the Total Submersion Model.....	259
Survival of Clades through the Oligocene as Dynamic Metapopulations.....	259
Evolution in the Oligocene.....	260
The Last, Great Modernization of the New Zealand Biota Was Pre-Miocene.....	260
Conclusions on the Total Submersion Theory.....	260

9. Biogeography and Neogene Geology of Mainland New Zealand: Alpine Fault Strike-Slip, Kaikoura Orogeny, and Pleistocene Glaciation

Strike-Slip, Kaikoura Orogeny, and Pleistocene Glaciation	263
Cenozoic Deformation in New Zealand	263
The Emerald Fracture Zone and Extensional Deformation in the Paleogene	263
Transpressional Deformation in the Neogene, the Alpine Fault, and the Orocline	265
Northland and East Cape to Cook Strait and Kaikoura	267
Northland to Cook Strait/Kaikoura and the Chatham Islands	267
Biogeography at the Alpine Fault: Boundaries and Disjunctions at a Transform Fault, with Distributions Preserved in Multiple Microrefugia	268
Geological and Biological Offset along the Alpine Fault	269
Alpine Fault Disjunction in Animals	269
Alpine Fault Disjunction in Plants	270
Alpine Fault Disjunctions in Alpine <i>Celmisias</i>	272
Other Aspects of Strike-Slip Displacement on the Alpine Fault	273
A Small Number of Macrorefugia or Multiple Microrefugia?	275
Groups in Which the Westland Biotic Gap Is Filled by a Sister Group	276
Disjunction across Fiordland and Stewart Island in Dolphins	278
Alpine Fault Disjunction and Transoceanic Disjunction	279
Could the Westland Gap Have Been Caused by Glaciation?	281
Criticism of Strike-Slip Displacement in Living Communities	281
Case Studies of Groups at the Alpine Fault	282
New Zealand Gentians (<i>Gentianella</i> : Gentianaceae)	282
Freshwater Snails	282
Onychophora	282
Pettalid Harvestmen (Opiliones): Nodes at Aoraki, Moonlight Tectonic Zone, Waihemo Fault Zone, and Alpine Fault	283
Plecoptera (Stoneflies)	285
Grasshoppers and Wetas (Orthoptera)	286
Zizina Butterflies (Lycaenidae)	287
New Zealand Frogs	287
Skinks	287
Kiwis (Ratitae: <i>Apteryx</i>)	287
Megalapteryx Moas (Ratitae)	289
The New Zealand Wrens, Acanthisittidae	291
Alpine Fault Distributions Other Than Simple Disjunction	291
Alpine Fault Disruption of a Southern Boundary: Groups Present in Nelson and Fiordland, Absent in Westland and Stewart Island	292
Alpine Fault Disruption of a Northern Boundary: Groups Present in the Southwestern and Southeastern South Island and through Westland	294
The Alpine Fault as an East/West Boundary: The <i>Lobelia ionantha</i> Group (Campanulaceae)	294
The Alpine Fault and Community Ecology	295
Distributions Mapped on a 27 Ma Reconstruction	295
Distributions That Coincide with the Alpine Fault Rather Than Rainfall Differences	299
The Kaikoura Orogeny and the New Zealand Alpine Biota	300
Traditional Ideas on the Alpine Biota: Young Taxa on Young Mountains	300
Alternative Ideas on the Alpine Biota: Old Taxa on Young Mountains	301
Adaptation and Preadaptation in Alpine Groups	302
Tectonic Uplift of Communities and the Origin of the Alpine Biota	303
Birds of Paradox: Seabirds Nesting in Mountains	305
Another Seabird Paradox: Mobile Birds with Localized, Philopatric Populations	306
Kaikoura Orogeny Uplift and Associated Deposition of Gravels	307

Pleistocene Refugium Theory in New Zealand: Glaciation and Centers of Origin, or Metapopulations in Multiple Microrefugia?	307
Survival of Groups as Metapopulations in Multiple Microrefugia	308
Differentiation in the Alpine Scree Weta (<i>Deinacrida connectens</i> : Anostostomatidae): Pleistocene or Pre-Pleistocene?	309
10. Case Studies of New Zealand Plants	311
<i>Wahlenbergia</i> (Campanulaceae)	311
The Two Main Clades of <i>Wahlenbergia</i> in New Zealand	311
Onagraceae in New Zealand	313
<i>Fuchsia</i> (Onagraceae) and Its Global Affinities	313
Differentiation within <i>Fuchsia</i>	315
Differentiation in <i>Fuchsia</i> Section <i>Skinnera</i>	316
Differentiation in <i>Epilobium</i>	318
The Australasian Clade of <i>Epilobium</i>	318
Biogeography in the Australasian Clade of <i>Epilobium</i>	319
Architecture in the Australasian Clade of <i>Epilobium</i>	319
New Zealand Asteraceae (1): The Tribe Anthemideae and Its Genus <i>Leptinella</i>	320
The Age of Asteraceae	320
The Center of Origin of Asteraceae	321
Tribe Anthemideae	321
<i>Leptinella</i> : A Southern Hemisphere Genus That Is Diverse through New Zealand	322
Phylogeny in <i>Leptinella</i>	322
<i>Leptinella</i> Clade 1	323
<i>Leptinella</i> Clade 2: <i>Leptinella goyenii</i>	323
<i>Leptinella</i> Clades 3–8	324
New Zealand Asteraceae (2): <i>Solenogyne</i> and <i>Lagenophora</i> (Asteraceae)	325
<i>Lagenophora</i> "New Zealand Clade"	326
<i>Lagenophora</i> "South American Clade"	327
New Zealand Asteraceae (3): Pre- and Postdrift Tectonics and Evolution in <i>Abrotanella</i> (Senecioneae)	327
Timing Evolution in <i>Abrotanella</i>	328
Implicit Conversion of Fossil-Calibrated, Minimum Clade Ages into Maximum Clade Ages	328
Transmogrifying Divergence Dates for <i>Abrotanella</i> in a Bayesian Framework	328
Using Island-Age Calibrations to Corroborate Bayesian Transmogrification	329
Spatial Evolution in <i>Abrotanella</i> : Tectonics and Biogeographic Breaks	329
Differentiation between <i>Abrotanella</i> and Its Sister Group	330
Differentiation of the Three Main Clades in <i>Abrotanella</i>	331
Differentiation within the Widespread Tasman Group of <i>Abrotanella</i> (Clade II)	332
Evolution in <i>Abrotanella</i> : A Synthesis	334
Reconstructions of <i>Abrotanella</i> before Neogene Deformation	334
Allopatry and Overlap in <i>Abrotanella</i>	334
The New Zealand Clades of <i>Abrotanella</i>	336
Differences between South Pacific Groups: <i>Abrotanella</i> and the <i>Hebe</i> Complex	336
Regional Tectonic History and Phylogeny in <i>Abrotanella</i>	336
The Case of <i>Abrotanella</i> : Some Implications for Biogeographic Methods	337
Is Evolution Clocklike?	338
Estimating Sampling Error in the Fossil Record	338
<i>Abrotanella</i> and Tectonic–Vicariance Calibration	338
Predrift Rifting and Austrochiloid Spiders: Australia–New Zealand; Tasmania–South America	339

11. Some More Case Studies of New Zealand Plants	341
Ranunculaceae in New Zealand.....	341
<i>Caltha</i>	341
<i>Anemone</i> and Possible Differentiation between East and West Antarctica.....	342
<i>Clematis</i>	343
<i>Ceratocephala</i>	344
<i>Myosurus</i> and Central Otago Halophytes.....	344
<i>Ranunculus</i>	345
The New Zealand Alpine Ranunculi: <i>Ranunculus</i> Sect. <i>Pseudadonis</i>	346
The New Zealand Brooms: <i>Carmichaelia</i> (Fabaceae) and Allies.....	348
The <i>Carmichaelia</i> Group of Genera (<i>Carmichaeliinae</i>).....	352
<i>Carmichaelia</i>	353
<i>Carmichaelia</i> Subgenus <i>Kirkiella</i>	353
<i>Carmichaelia</i> Subgenus <i>Suterella</i>	354
<i>Carmichaelia</i> Subgenus <i>Monroella</i>	355
<i>Carmichaelia</i> Subgenus <i>Huttonella</i>	357
<i>Carmichaelia</i> Subgenus <i>Carmichaelia</i>	357
<i>Carmichaelia</i> Subgenus <i>Enysiella</i>	360
<i>Carmichaelia</i> Clade: "Notoxanthium Group" and "Corallospartium Group".....	360
Ecology of <i>Carmichaelia</i>	362
Summary of the <i>Carmichaelia</i> Group + <i>Swainsona</i>	362
Apiaceae in New Zealand.....	362
Subfamily Mackinlayoideae.....	363
Subfamily Saniculoideae.....	363
Subfamily Azorelloideae.....	364
Subfamily Apioideae (Carrots, Celery, and Relatives).....	364
<i>Lilaeopsis</i>	365
Tribe Aciphyllae: <i>Anisotome</i> and <i>Aciphylla</i>	365
<i>Oreomyrrhis</i> (<i>Chaerophyllum</i> Clade).....	366
<i>Apium</i>	368
<i>Daucus</i>	368
Brassicaceae in New Zealand.....	368
The Age of Brassicaceae.....	368
Biogeography of Brassicaceae.....	369
<i>Notothlaspi</i>	370
<i>Lepidium</i>	370
<i>Cardamine</i>	373
<i>Rorippa</i>	374
<i>Pachycladon</i> (Including <i>Cheesemania</i> and <i>Ischnocarpus</i>).....	374
Summary: <i>Pachycladon</i> and Brassicaceae.....	381
12. Case Studies of New Zealand Animals	383
Onychophora, Freshwater Mollusks, and Predrift Differentiation.....	383
Predrift Vicariance in Onychophorans.....	383
Predrift Vicariance in Freshwater Bivalves.....	384
New Zealand Oribatid Mites: Intercontinental Affinities and Local Distributions.....	384
Some More New Zealand Cicadas: Overlap in the North Island, Traces of Allopatry, and	
Niche Models.....	385
Niche Models for the Cicadas.....	387
Forest Beetles, the Aoraki Node, and the Alpine Fault.....	388
The New Zealand Satyrines and the Waiheke Fault Zone.....	389

New Zealand Freshwater Fishes	390
Diadromy in the New Zealand Fish Fauna and the Problem of Ancestral Habitat	390
Lampreys (Geotriidae: Petromyzontiformes).....	392
Freshwater Eels (Anguillidae: Anguilliformes).....	392
Galaxiidae (Galaxiiformes).....	393
Galaxiid Phylogeny	394
The <i>Neochanna</i> Clade of <i>Galaxias</i>	394
<i>Galaxias maculatus</i> and Allies.....	395
The Species-Rich Clade of <i>Galaxias</i>	396
Summary on Galaxiids	400
Retropinnidae (Osmeriformes).....	400
Pleuronectidae (Pleuronectiformes).....	401
Cheimarrichthyidae (Perciformes).....	401
Eleotridae (Perciformes: Gobioidae).....	402
A Notable Absence in the New Zealand Fish Fauna: Otophysi.....	403
The Tuatara, <i>Sphenodon</i> (Rhynchocephalia).....	404
The Restriction of Extant Rhynchocephalia to New Zealand and the Paucity of Its	
Sister Group There	405
New Zealand Skinks	405
New Zealand Geckos	411
Central Otago as a Center of Endemism and a Phylogenetic Boundary	413
Differentiation around Nuclear Central Otago	414
Ecology in Central Otago	415
Summary	415
13. Structural Evolution and Ecology	417
The Modern Synthesis View: Structural Evolution Is Determined by Extrinsic Needs.....	417
Teleological Models of Evolution: The Origin and Evolutionary Development of a	
Structure Are Explained by an End Result.....	419
The Panadaptationist Position: Selection Is the Only Force Directing Evolution	420
Mutation-Driven Evolution: Intrinsic Genetic Factors Cause Evolutionary Direction and	
Evolutionary Trends	421
Selection, Mutation, and the Modern Synthesis	422
The Geneticists: Mendelian and Mutationist	422
Internal Genetic Causes of Evolutionary Direction: The Significance of Available	
Variation and Mutation	423
Mutation-Driven Evolution: Evolution as "Climbing Mount Probable"	423
Aspects of Genetics Consistent with Mutation-Driven Evolution	424
Nonrandom Mutation.....	424
Biased Gene Conversion	424
Evolution of Structural Complexity	424
Evolution of Diversity and Evolvability	425
Evolution of Gene Regulatory Networks	426
Long-Term Genetic Conservation	426
Evolution of the Genetic Code	426
Genome Reduction	426
Masatoshi Nei (2013) and Mutation-Driven Evolution	426
Toward a Postmodern Synthesis in Evolution.....	428
Summary on Mutation-Driven Evolution: Modern Critique of Teleological	
Explanation in Biology.....	428

Trends in Morphological Evolution: Some General Aspects.....	429
Trends and Ecology.....	430
Trends and Parallelism.....	430
Trends Seen in the Fossil Record, and "Orthoselection".....	431
Trends and Extinction: Evolutionary Constraint and Maladaptation.....	431
Methods of Inferring Ancestral Morphology.....	432
Some Examples of Trends in Morphology.....	433
Example of a Trend: Reduction.....	434
Example of a Trend: The Origin of Curved Structure by Fusion.....	434
Example of a Trend: Paedomorphosis/Neoteny.....	435
Trends in the Evolution of Symmetry: Plant Shoots and Vertebrate Limbs.....	436
14. Case Studies of a Trend: Morphological Reduction and Fusion Series	439
Case Studies of Reduction Series in Plants.....	439
Suppression of Runners, Rhizomes, and Roots.....	439
"Inflorescence Plants" with Divaricate, Ericoid, and Broom Architecture: Reduction by	
Suppression and Sterilization.....	440
Architecture of Divaricate Shrubs.....	440
Architecture of Ericoid Shrubs and Trees, Including Cushion	
Plants and "Whipcords".....	442
Whipcord Architecture in Other New Zealand Groups.....	443
Architecture in Monocots That Can Be Interpreted as "Inflorescence Plants".....	446
Brooms in <i>Carmichaelia</i> (Fabaceae): Another Group of Reduced	
"Inflorescence Plants".....	446
Morphological Differentiation of "Inflorescence Plants".....	447
Biogeography of Divaricate Plants.....	449
Biogeography of "Inflorescence Plants".....	450
New Zealand Alpine Plants and Their Morphology.....	450
Angiosperm Flowers and Anemophily.....	451
Reduction in the Flowers of Viscaceae.....	452
Flowers and Peloria.....	452
Cleistogamy.....	452
Flowers: Glands as Reduced Organs.....	453
Hygrochastic Capsules: The Result of Purposeful Strategy or Prior Trends?.....	454
Ecological Interaction as the Result of Intersecting Trends in Plant and Animal	
Evolution.....	454
Case Studies of Reduction Series in Animals.....	455
Reduction in Crustaceans.....	455
Reduction of the Gills in New Zealand Gastropods and the Transition from Sea to Land.....	455
Reductions in Moths and Weevils of the Three Kings and Poor Knights Islands.....	456
Reduction and Bilateral Symmetry in Vertebrates.....	456
Remnants of Spiral Symmetry in Vertebrates.....	456
Asymmetry in Bilateria and in Vertebrates.....	457
Asymmetry in Agnatha.....	458
Asymmetry in Fishes, with Special Reference to Flatfishes.....	458
Asymmetry in Squamates.....	460
Asymmetry in Birds.....	460
Asymmetry in Mammals.....	460
Ontogeny and Phylogeny of Symmetry in Vertebrates.....	461
Reduction in Vertebrates.....	462
Limbs.....	462
Reduction at the Posterior End of Bilaterian Animals.....	463

Reduction in the Vertebrate Head.....	463
Comparative Lack of Reduction in Some Features of the Vertebrate Head.....	464
Changes in Symmetry Accompanying Reduction and Fusion in the Skull.....	464
Ears.....	465
Eyes.....	465
The Third Eye of the Tuatara: More Evidence for Reduction.....	466
The Vomeronasal Organ.....	467
Reduction in the Head of Invertebrates.....	467
15. Biogeography and Evolution in New Zealand Birds.....	469
Bird Morphology: Extreme Reduction and Fusion.....	469
Reduction in the Limbs of Birds.....	470
Extreme Reduction in Forelimbs Leading to Loss of Flight.....	470
Ventral Reduction.....	471
Feeding.....	471
Kiwis and Moas (Ratites).....	471
Flightlessness.....	473
Feathers.....	473
Bill Structure and the Tactile Sense.....	473
The Bill-Tip Organ.....	474
Olfaction.....	475
The Kiwi Visual System.....	475
Nocturnality in Ratites.....	476
Regressive Evolution in the Kiwi Visual System.....	476
Another Feature of the Kiwi Visual System: The Pecten.....	477
The Auditory System in Ratites: Further Evidence of Reduction.....	477
The Kiwi Brain.....	477
Encephalization and Brain Evolution in Moas and Kiwis.....	478
Kiwis and Their "Remarkable Path of Evolution" as Mammal Equivalents.....	479
Summary of Kiwi Evolution.....	480
Quails (Galliformes).....	480
Ducks (Anseriformes).....	481
The Blue Duck (<i>Hymenolaimus malacorhynchus</i>).....	481
Specializations in the Blue Duck's Binocular Field.....	482
Pigeons (Columbiformes).....	483
Owlet-Nightjars (Aegotheliformes).....	483
Rails (Ralliformes).....	483
Porphyrio Species: Takahe and Pukeko.....	484
Gallirallus: Wekas and Their Relatives.....	484
Neoteny and Other Trends in the Weka.....	486
An Extinct Chatham Islands Rail, " <i>Cabalus</i> ".....	486
Another Extinct Rail, <i>Diaphorapteryx</i>	486
Penguins (Sphenisciformes).....	486
Albatrosses and Their Allies (Procellariiformes).....	487
Gannets and Shags (Suliformes).....	487
Spoonbills (Threskiornithidae: Pelecaniformes s.lat.).....	488
Waders (Charadriiformes).....	488
Haematopodidae (Oystercatchers).....	488
Charadriidae (Plovers and Others).....	488
Scolopacidae (Snipe).....	489
Eagles and Hawks (Accipitriformes).....	490
Owls (Strigiformes).....	490

Kingfishers (Coraciiformes).....	490
Falcons (Falconiformes).....	491
Parrots (Psittaciformes).....	491
Morphology of Parrots.....	492
The Kakapo (<i>Strigops habroptilus</i> : Strigopidae).....	493
The Kea (<i>Nestor notabilis</i> : Nestoridae).....	495
Perching Birds: Passeriformes.....	496
The Timeline of Evolution in New Zealand Birds.....	497
Acanthisittidae.....	498
Meliphagidae and Acanthizidae.....	498
Callaeidae and Notiomystidae.....	499
Petroicidae.....	500
Zosteropidae.....	501
Motacillidae.....	502
Locustellidae.....	502
Mohouidae.....	503
Oriolidae.....	504
Rhipiduridae.....	504
Corvidae.....	505
The New Zealand Passerines as a Relict Fauna.....	505
16. Biogeography and Evolution in New Zealand Bats.....	507
The New Zealand Mammal Fauna.....	507
Evolution and Biogeography in Bats.....	508
The Long-Tailed Bat, <i>Chalinolobus</i> (Vespertilionidae).....	509
The Snout and Mouth in <i>Chalinolobus</i>	510
The Short-Tailed Bat, <i>Mystacina</i> (Mystacinidae).....	511
Biogeography of Mystacinidae.....	512
<i>Mystacinobia</i> , a Bat Fly Associated with <i>Mystacina</i>	513
<i>Zealandofannia</i> , Another Bat Fly Associated with <i>Mystacina</i>	513
<i>Chirophagoides</i> , a Mite Associated with <i>Mystacina</i>	514
Did <i>Mystacina</i> Disperse to New Zealand or Did It Evolve There from a Widespread Proto-Noctilionoid Ancestor? The Significance of the Fossil <i>Icarops</i>	514
Did <i>Mystacina</i> Develop Its Distinctive Features as Adaptations to the New Zealand Environment?.....	515
Terrestrial Behavior in <i>Mystacina</i>	515
Explanations for Terrestrial Behavior in <i>Mystacina</i>	515
Reduction in the Vertebrate Face.....	516
The Snout in <i>Mystacina</i>	517
Reduction in the Bat Snout and Its Implications.....	518
The Noseleaf and Echolocation.....	519
Evolution of the Noseleaf.....	520
Ears in Bats.....	521
Feeding in New Zealand Bats.....	522
17. Conclusions.....	525
Tectonics and Biogeography.....	525
Centers of Origin, Dispersal, and Adaptation: The CODA Model of Evolution.....	526
Comparative Study in Biology and the Phylogenetic Context.....	527
The Wedge Model of Evolution.....	527
Centers of Origin in Biogeography.....	528
Centers of Origin in Ecology.....	528
Centers of Origin in Morphology.....	528

Evolution by Radiation (Center of Origin–Dispersal–Adaptation)	528
New Zealand Groups as Unique Wonders of Nature	529
Summary of the CODA Model and an Alternative	529
Some Practical Implications of Biogeographic Studies	530
Biogeography and Conservation in New Zealand	531
Description and Interpretation in Conservation	531
Biogeographic Theory and Conservation in New Zealand	531
The Penguin <i>Megadyptes</i> (Spheniscidae): A Case Study	531
Conservation and the Globally Basal Endemics	533
Conservation and Translocation	533
Ensuring That the Main Aims of Conservation Are Met	534
Glossary of Geological Terms	535
References	537
Index	615

