

Contents

<i>Preface</i>	xiii
<i>Acknowledgements</i>	xv
<i>List of figures</i>	xvii
<i>List of tables</i>	xxiii

1 A history of molecular ecology

Introduction	1
An evolutionary perspective for molecular ecology	2
Systematics, phylogenetics, and the species concept	2
Variation within species	4
The origins of modern genetics	6
The modern synthesis	6
The neutral theory of molecular evolution	8
Behavioural ecology	8
Genetics in ecology	9
Ecological genetics	9
Genotype, phenotype, and phenotypic plasticity	12
What is a molecular marker?	13
Milestones in molecular ecology	15
Early days of molecular ecology	16
Allozyme electrophoresis	16
Restriction fragment length polymorphism	17
Minisatellite DNA fingerprinting	19
The polymerase chain reaction	20
PCR-based molecular markers	22
DNA sequencing	24
Molecular ecology today	25
SUMMARY	26

2 Molecular biology for ecologists

Introduction	27
Nucleic acids and the common origin of life	28
The structures of DNA and RNA	29

Primary structure of nucleic acids	29
Secondary structure of nucleic acids	31
DNA replication	33
Protein structure	35
Basic immunology	38
The genetic code and gene expression	39
Genome structure: an overview	41
Non-coding DNA	43
Functional (coding) DNA	47
Ribosomal DNA	47
Nuclear structural (protein-coding) genes	48
Mitochondrial DNA	49
Chloroplast DNA	51
Plasmids and genetic manipulation in molecular ecology	52
Mutation	54
Somatic mutations	54
Germline mutations	54
DNA point mutations	55
Other types of mutation	57
Evolution and the mutation rate	57
SUMMARY	58

3 Molecular identification: species, individuals, and sex

Introduction	61
The species question	62
Defining distinctiveness	62
Hybrids	65
Dealing with individuals	69
Basic identification	69
Competition between toads	69
Woodland succession	70
Identification of prey in predator guts	70
Identification of disease vectors	71
Forensic investigations	72
Sex	73
Bits of individuals	75
Molecular identification methods: an appraisal	78
Protein analysis	78
DNA analysis	78
SUMMARY	80

4 Behavioural ecology

Introduction	81
From monogamy to promiscuity	82
Animal mating systems	82
Determining unknown mating systems	84
Male reproductive success	86
Sexual dimorphism	86
Lekking	87
Female reproductive success	88
Sperm competition	88
Why is female promiscuity adaptive?	90
Mate choice and the MHC	92
Sexual conflict	94
Sex ratio biases in offspring	95
Cooperative behaviour	96
Cooperative breeding in birds	96
Social insects	97
Cheating tactics	99
Interspecific brood parasitism	99
Intraspecific brood parasitism	100
Foraging and dispersal	101
Foraging	101
Dispersal	102
Behaviourally mediated speciation	104
SUMMARY	108

5 Population genetics

Introduction	111
Genetic diversity in natural populations	112
Some basic concepts	112
Population size and genetic diversity	113
Mammalian examples of population size and genetic diversity estimates	115
Population structure	117
Assessing where subdivisions occur	117
Statistical tests for population subdivision	118
Marker selection for the study of population subdivision	119
The genetics of metapopulations	122
Metapopulations	122

Testing whether metapopulations exist	123
Distinguishing different types of metapopulations	125
Gene flow and migration rates	127
Genetic estimation of gene flow and migration rates	127
Isolation by distance	129
Maximum likelihood methods for estimating migration rates	131
Identification of immigrants	132
Effective population size	133
Genetic estimators of effective population size	133
Determination of effective population size using allele frequency variation between generations	134
Alternative methods for N_e determination	136
Population bottlenecks	137
The significance of population bottlenecks	137
Genetic tests for population bottlenecks	138
Molecular markers for population genetics: an appraisal	140
The basis for choice	140
Fundamental tests	141
SUMMARY	142

6 Molecular and adaptive variation

Introduction	145
Neutral markers that are not really neutral	148
Allozymes	148
Nuclear DNA markers	150
Mitochondrial DNA	152
Heterozygosity and fitness	152
Background	152
Allozyme studies	153
DNA markers	155
Molecular approaches to understanding adaptive variation	157
Comparisons of neutral and adaptive variation	157
Variation at specific loci	158
Gene mapping	160
Quantitative traits and adaptive variation	161
Genomics and the study of adaptive variation	163
SUMMARY	164

7 Phylogeography

Introduction	165
Molecular markers in phylogeography	166
Early phylogeography	166
MtDNA as the standard phylogeographic tool	166
Alternatives to mtDNA	168
Genealogies and the coalescent process	169
Genetic variation in space	170
Geographic patterns in single populations	170
Vicariance and dispersal	173
Divergence between populations: Drift versus gene flow	174
Gene flow between species	175
Genetic consequences of the Pleistocene Ice Ages	176
Phylogeography and coevolution	179
Nested clade analysis	179
Genetic variation in time	181
Geological events and molecular divergence rates	181
Measuring lineage divergence in real time	183
Applied phylogeography	185
Taxonomic decisions	185
Determining a species natural range	187
Finding the source populations of introduced species	191
Phylogeography and adaptive traits	194
SUMMARY	196

8 Conservation genetics

Introduction	199
The state of the biosphere	200
Molecular genetics in conservation biology	202
Genetic diversity as a conservation issue	203
Inbreeding and genetic load	205
The basis of inbreeding effects	205
Inbreeding depression and genetic load in the wild	206
Purging of genetic load	208
Outbreeding depression	209
Genetic restoration	210
Desperate measures	211
Plant conservation	212

Animal conservation	214
Wildlife forensics	217
Genetics in conservation biology—a wider role	217
Systematics and conservation genetics	218
Phylogeography and conservation genetics	219
Globally important areas of genetic diversity	221
Molecular markers in conservation genetics	222
SUMMARY	222

9 Microbial ecology

Introduction	225
Outstanding issues in microbial ecology	227
The role of microbial communities in nature	227
Problems for molecular microbiology	230
Immunological approaches to microbial ecology	232
Immunological methods	232
Use of antibody identification in microbial ecology	233
Ribosomal genes and microbial ecology	236
Structure and usefulness of ribosomal genes	236
Identification: the use of sequence-specific oligonucleotide probes in microbial ecology	238
New developments, problems, and alternative approaches with probes	240
Ribosomal gene sequencing and community studies	242
Genetic profiling of microbial communities	244
Alternatives to ribosomal genes in profiling approaches	247
Genome analysis and microbial ecology	250
Sequence complexity and microbial diversity	250
Microarrays and microbial ecology	251
Other genomic approaches in microbial ecology	252
Whole genome separation and viral diversity	253
Overview of microbial molecular ecology	254
Molecular markers for microbial ecology: an appraisal	255
Protein methods	255
Nucleic acid methods	255
SUMMARY	256

10 Molecular ecology and genetically modified organisms

Introduction	259
Environmental risks from GMOs	261

The role of molecular ecology in GMO research	262
Horizontal gene transfer in nature	263
Conjugation	264
Transduction	266
Transformation	266
Effects of GMOs on natural communities	267
Transfer of genes from GMOs to other organisms	269
Vertical gene transfer	269
Horizontal gene transfer	271
Effects of introduced genes on other species	273
Future GMO research and molecular markers	276
SUMMARY	277

Appendix 1: Practical aspects of molecular ecology

Sampling and sample treatment	279
Sampling	279
Protein and DNA extraction	280
Protein-based methods	280
Allozyme analysis and protein polymorphism	280
Protein profiling	282
Immunological methods	282
DNA-based methods	284
Oligonucleotides for cell identification	284
Polymerase chain reaction	284
Restriction fragment length polymorphism (RFLP)	284
Multilocus minisatellite DNA fingerprinting	286
RAPD and AFLP analyses	287
Microsatellite analysis	287
DNA sequencing	288
Denaturing gradient gel electrophoresis (DGGE), thermal gradient gel electrophoresis (TGGE) and single strand conformation polymorphism (SSCP)	289
Primers for PCR-based analyses	290
Special circumstances: museum material and non-invasive sampling	293
DNA microarrays	293

Appendix 2: Analytical methods in molecular ecology

Individual identification and family relationships	297
Use of multilocus fingerprints	297
Use of single locus profiling	298

Assigning individuals to populations	300
Population diversity and structure	301
Marker properties	301
Diversity estimates	301
Population structure	302
Population size and history	304
Phylogeography	305
Phylogeographic trees	305
Correlation with geography	306
Microbial ecology	307
<i>Glossary</i>	309
<i>References</i>	315
<i>Index</i>	335