<table>
<thead>
<tr>
<th>Brief contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full contents</strong> vii</td>
</tr>
<tr>
<td><strong>Preface to the second edition</strong> xi</td>
</tr>
<tr>
<td><strong>Preface to the first edition</strong> xii</td>
</tr>
<tr>
<td><strong>Phylogenetic relationships among living and extinct fish groups</strong> xv</td>
</tr>
</tbody>
</table>

**Part I Introduction** 1

1. The science of ichthyology 3
2. Systematic procedures 11

**Part II Form, function, and ontogeny** 21

3. Skeleton, skin, and scales 23
4. Soft anatomy 41
5. Oxygen, metabolism, and energetics 57
6. Sensory systems 75
7. Homeostasis 91
8. Functional morphology of locomotion and feeding 111
9. Early life history 129
10. Juveniles, adults, age, and growth 149

**Part III Taxonomy, phylogeny, and evolution** 167

11. “A history of fishes” 169
12. Chondrichthyes: sharks, skates, rays, and chimaeras 205
13. Living representatives of primitive fishes 231

14. Teleosts at last I: bonytongues through anglerfishes 261
15. Teleosts at last II: spiny-rayed fishes 291

**Part IV Zoogeography, genetics, and adaptations** 327

16. Zoogeography 329
17. Fish genetics 355
18. Special habitats and special adaptations 393

**Part V Behavior and ecology** 423

19. Fishes as predators 425
20. Fishes as prey 439
21. Fishes as social animals: reproduction 455
22. Fishes as social animals: aggregation, aggression, and cooperation 477
23. Cycles of activity and behavior 499
24. Individuals, populations, and assemblages 525
25. Communities, ecosystems, and the functional role of fishes 551

**Part VI The future of fishes** 583

26. Conservation 585

References 625
Index 693
CONTENTS

Preface to the second edition  xi
Preface to the first edition  xii
Phylogenetic relationships among living and extinct fish groups  xv

Part I  Introduction  1

1  The science of ichthyology  3
   What is a fish?  3
   Superlative fishes  5
   A brief history of ichthyology  6
   Additional sources of information  7
   Summary  9

2  Systematic procedures  11
   Species  11
   Taxonomy versus systematics  12
   Approaches to classification  12
   Taxonomic characters  14
   Vertebrate classes  15
   Units of classification  16
   International Code of Zoological Nomenclature  16
   PhyloCode  17
   Name changes  17

Collections  18
   Summary  19
   Supplementary reading  19

Part II  Form, function, and ontogeny  21

3  Skeleton, skin, and scales  23
   Skeleton  23
   Integumentary skeleton  36
   Summary  40
   Supplementary reading  40

4  Soft anatomy  41
   Muscles  41
   Cardiovascular system  45
   Alimentary canal  48
   Gas bladder  50
   Kidneys  52
   Gonads  52
   Nervous system  54
   Summary  56
   Supplementary reading  56
5 Oxygen, metabolism, and energetics 57
   Respiration and ventilation 57
   Gas transport 64
   Metabolic rate 66
   Energetics 68
   Summary 73
   Supplementary reading 73

6 Sensory systems 75
   Mechanoreception 75
   Electroreception 80
   Vision 84
   Chemoreception 87
   Magnetic reception 89
   Summary 89
   Supplementary reading 90

7 Homeostasis 91
   Coordination and control of regulation 91
   Temperature relationships 94
   Osmoregulation, excretion, ion and pH balance 100
   The immune system 105
   Stress 106
   Summary 108
   Supplementary reading 109

8 Functional morphology of locomotion and feeding 111
   Locomotion: movement and shape 111
   Feeding: biting, sucking, chewing, and swallowing 119
   Summary 127
   Supplementary reading 128

9 Early life history 129
   Complex life cycles and indeterminate growth 129
   Early life history: terminology 130
   Eggs and sperm 130
   Embryology 137
   Larvae 139
   Getting from here to there: larval transport mechanisms 145
   Summary 147
   Supplementary reading 148

10 Juveniles, adults, age, and growth 149
   Juveniles 149
   Adults 153
   Age and growth 157
   The ontogeny and evolution of growth 162
   Summary 164
   Supplementary reading 165

Part III Taxonomy, phylogeny, and evolution 167

11 “A history of fishes” 169
   Jawless fishes 170
   Gnathostomes: early jawed fishes 175
   Advanced jawed fishes I: teleostomes (Osteichthyes) 178
   Advanced jawed fishes II: Chondrichthyes 197
   A history of fishes: summary and overview 200
   Summary 203
   Supplementary reading 204

12 Chondrichthyes: sharks, skates, rays, and chimaeras 205
   Subclass Elasmobranchii 205
   Subclass Holocephali 227
   Summary 229
   Supplementary reading 230

13 Living representatives of primitive fishes 231
   Jawless fishes: lancelets, hagfishes, and lampreys 231
## Contents

**Primitive bony fishes** 241
**Conclusions** 258
Summary 258
Supplementary reading 259

### 14 Teleosts at last I: bonytongues through anglerfishes 261

Teleostean phylogeny 261
A survey of living teleostean fishes 263
Neognathi 280
Neoteleostei 281
Acanthomorpha: the spiny teleosts 284
Summary 289
Supplementary reading 290

### 15 Teleosts at last II: spiny-rayed fishes 291

Superorder Acanthopterygii: introduction 291
Series Mugilomorpha 292
Series Atherinomorpha 293
Series Percomorpha: basal orders 296
Series Percomorpha, Order Perciformes: the perchlike fishes 300
Series Percomorpha: advanced percomorph orders – flatfishes and twisted jaws 322
Summary 325
Supplementary reading 326

## Part IV Zoogeography, genetics, and adaptations 327

### 16 Zoogeography 329

Marine fishes 329
Freshwater fishes 339
Summary 354
Supplementary reading 354

### 17 Fish genetics 355

Fish genomics 355
Molecular ecology 360
Population genetics 365
Phylogeography 370
Molecular evolution 379
Conservation genetics 385
Summary 389
Supplementary reading 390

### 18 Special habitats and special adaptations 393

The deep sea 393
The open sea 401
Polar regions 405
Deserts and other seasonally arid habitats 410
Strong currents and turbulent water 415
Caves 417
Summary 420
Supplementary reading 421

## Part V Behavior and ecology 423

### 19 Fishes as predators 425

Search and detect 425
Pursuit 426
Attack and capture 429
Handling 433
Scavengers, detritivores, and herbivores 436
Optimally foraging fishes 437
Summary 437
Supplementary reading 438
20 Fishes as prey 439
  Avoiding detection 439
  Evading pursuit 446
  Preventing and deflecting attacks 447
  Discouraging capture and handling 448
  Balancing foraging against predatory threat 452
  Summary 453
  Supplementary reading 454

21 Fishes as social animals: reproduction 455
  Reproductive patterns among fishes 455
  Courtship and spawning 461
  Parental care 468
  Alternative mating systems and tactics 473
  Summary 475
  Supplementary reading 476

22 Fishes as social animals: aggregation, aggression, and cooperation 477
  Communication 477
  Agonistic interactions 485
  Aggregations 488
  Interspecific relations: symbioses 492
  Summary 496
  Supplementary reading 497

23 Cycles of activity and behavior 499
  Diel patterns 499
  Semilunar and lunar patterns 507
  Seasonal patterns 509
  Annual and supra-annual patterns: migrations 515
  Summary 522
  Supplementary reading 523

24 Individuals, populations, and assemblages 525
  Individuals 525

25 Communities, ecosystems, and the functional role of fishes 551
  Community-level interactions between fishes and other taxonomic groups 551
  The effects of fishes on plants 554
  The effects of fishes on invertebrate activity, distribution, and abundance 559
  Fishes in the ecosystem 563
  Influence of physical factors and disturbance 577
  Summary 580
  Supplementary reading 581

Part VI The future of fishes 583

26 Conservation 585
  Extinction and biodiversity loss 585
  General causes of biodiversity decline 589
  What can be done? 618
  Summary 621
  Supplementary reading 622

References 625
Index 693