

# CONTENTS

CONTENTS OF HOMEOSTASIS AND TOXICOLOGY OF NON-ESSENTIAL METALS, VOLUME 31B	xi
CONTRIBUTORS	xvii
PREFACE	xix

1. An Introduction to Metals in Fish Physiology and Toxicology: Basic Principles <i>Chris M. Wood</i>	
1. Background	2
2. Structure of the Book	6
3. Chemical Speciation in Freshwater and Seawater	7
4. Sources of Metals and Economic Importance	11
5. Environmental Situations of Concern	12
6. Acute and Chronic Ambient Water Quality Criteria	13
7. Mechanisms of Toxicity	18
8. Essentiality or Non-Essentiality of Metals	23
9. Potential for Bioconcentration and/or Biomagnification of Metals	24
10. Characterization of Uptake Routes	27
11. Characterization of Internal Handling	31
12. Characterization of Excretion Routes	36
13. Behavioral Effects of Metals	38
14. Molecular Characterization of Metal Transporters, Storage Proteins, and Chaperones	39
15. Genomic and Proteomic Studies	40
16. Interactions with Other Metals	40
2. Copper <i>Martin Grosell</i>	
1. Introduction	54
2. Chemical Speciation and Other Factors Affecting Toxicity in Freshwater and Seawater	55
3. Sources of Copper in the Environment and its Economic Importance	59
4. Environmental Situations of Concern	59

5.	Acute and Chronic Ambient Water Quality Criteria	60
6.	Mechanisms of Toxicity	62
7.	Essentiality of Copper	93
8.	Potential for Bioconcentration and Biomagnification of Copper	94
9.	Characterization of Uptake Routes	94
10.	Characterization of Internal Handling	103
11.	Characterization of Excretion Routes	107
12.	Behavioral Effects of Copper	108
13.	Molecular Characterization of Copper Transporters, Storage Proteins, and Chaperones	109
14.	Genomic and Proteomic Studies	109
15.	Interactions with Other Metals	109
16.	Knowledge Gaps and Future Directions	110
3.	<b>Zinc</b> <i>Christer Hogstrand</i>	
1.	Introduction	136
2.	Chemical Speciation of Zinc in Freshwater and Seawater	137
3.	Sources of Zinc and Economic Importance	138
4.	Environmental Situations of Concern	140
5.	Ambient Water Quality Criteria for Zinc in Various Jurisdictions	142
6.	Mechanisms of Toxicity	144
7.	Essentiality and Roles of Zinc in Biology	149
8.	Potential for Bioconcentration of Zinc	157
9.	Characterization of Uptake Routes	161
10.	Characterization of Internal Handling	172
11.	Characterization of Excretion Routes	176
12.	Behavioral Effects of Zinc	177
13.	Molecular Characterization of Zinc Transporters, Storage Proteins, and Chaperones	179
14.	Genomic and Proteomic Studies	179
15.	Interactions with Other Metals	180
16.	Knowledge Gaps and Future Directions	184
4.	<b>Iron</b> <i>Nicolas R. Bury, David Boyle and Christopher A. Cooper</i>	
1.	Chemical Speciation in Freshwater and Seawater	202
2.	Sources of Iron and Economic Importance	205
3.	Environmental Situations of Concern	206
4.	A Survey of Acute and Chronic Ambient Water Quality Criteria in Various Jurisdictions in Freshwater and Seawater	207
5.	Mechanisms of Toxicity	209
6.	Essentiality or Non-Essentiality of Iron: Evidence For and Against	212
7.	Potential for Bioconcentration and/or Biomagnification of Iron	212
8.	Characterization of Uptake Routes	215
9.	Characterization of Internal Handling	221
10.	Characterization of Excretion Routes	227
11.	Behavioral Effects of Iron	227

12.	Molecular Characterization of Epithelial Iron Transporters and Hepcidin	228
13.	Genomic and Proteomic Studies	234
14.	Interactions with Other Metals	234
15.	Knowledge Gaps and Future Directions	236
5.	Nickel	
	<i>Greg Pyle and Patrice Couture</i>	
1.	Nickel Speciation in Freshwater and Saltwater	254
2.	Nickel Sources and Economic Importance	256
3.	Environmental Situations of Concern	258
4.	Environmental Criteria	258
5.	Mechanisms of Toxicity	260
6.	Nickel Essentiality	269
7.	Potential for Biomagnification or Bioconcentration of Nickel	272
8.	Characterization of Uptake Routes	272
9.	Internal Handling of Nickel	272
10.	Characterization of Excretion Routes	277
11.	Chemosensory and Behavioral Effects	278
12.	Genomic, Proteomic, and Genotoxic Effects	280
13.	Nickel Interaction with Other Metals	280
14.	Knowledge Gaps and Future Directions	281
6.	Cobalt	
	<i>Ronny Blust</i>	
1.	Chemical Speciation in Freshwater and Seawater	292
2.	Sources (Natural and Anthropogenic) of Cobalt and Economic Importance	295
3.	Environmental Situations of Concern	296
4.	A Survey of Acute and Chronic Ambient Water Quality Criteria in Various Jurisdictions in Freshwater and Seawater	296
5.	Mechanisms of Toxicity	297
6.	Essentiality or Non-Essentiality of Cobalt: Evidence For and Against	300
7.	Potential for Bioconcentration and/or Biomagnification of Cobalt	304
8.	Characterization of Uptake Routes	307
9.	Characterization of Internal Handling	312
10.	Characterization of Excretion Routes	314
11.	Behavioral Effects of Cobalt	314
12.	Molecular Characterization of Cobalt Transporters, Storage Proteins, and Chaperones	315
13.	Genomic and Proteomic Studies	317
14.	Interactions with Other Metals	317
15.	Knowledge Gaps and Future Directions	318
7.	Selenium	
	<i>David M. Janz</i>	
1.	Introduction	329
2.	Chemical Speciation in Freshwater and Seawater	329

3.	Sources of Selenium and Economic Importance	332
4.	Environmental Situations of Concern	334
5.	Survey of Water Quality Guidelines	337
6.	Mechanisms of Toxicity	338
7.	Selenium Essentiality	344
8.	Potential for Bioaccumulation and Biomagnification of Selenium	348
9.	Characterization of Uptake Routes	351
10.	Characterization of Internal Handling	352
11.	Characterization of Excretion Routes	357
12.	Behavioral Effects of Selenium	358
13.	Molecular Characterization of Transporters, Storage Proteins, and Chaperones	359
14.	Genomic and Proteomic Studies	359
15.	Interactions with Other Metals	361
16.	Interactions with Water Temperature	363
17.	Knowledge Gaps and Future Directions	364
8.	Molybdenum and Chromium <i>Scott D. Reid</i>	
1.	Chemical Speciation in Freshwater and Seawater	376
2.	Sources (Natural and Anthropogenic) of Molybdenum and Chromium and Economic Importance	378
3.	Environmental Situations of Concern	379
4.	A Survey of Acute and Chronic Ambient Water Quality Criteria in Various Jurisdictions in Freshwater and Seawater	380
5.	Mechanisms of Toxicity	381
6.	Essentiality or Non-Essentiality of Molybdenum and Chromium: Evidence For and Against	389
7.	Potential for Bioconcentration and/or Biomagnification of Molybdenum and Chromium	390
8.	Characterization of Uptake Routes	393
9.	Characterization of Internal Handling	394
10.	Characterization of Excretion Routes	398
11.	Behavioral Effects of Molybdenum and Chromium	402
12.	Molecular Characterization of Molybdenum and Chromium Transporters, Storage Proteins, and Chaperones	403
13.	Genomic and Proteomic Studies	403
14.	Interactions with Other Metals	405
15.	Knowledge Gaps and Future Directions	406
9.	Field Studies on Metal Accumulation and Effects in Fish <i>Patrice Couture and Greg Pyle</i>	
1.	Historical Review of Natural and Anthropogenic Contamination of Aquatic Environments by Metals	418
2.	Relative Importance of Diet Versus Water as Metal Sources in Wild Fish	426
3.	Bioenergetic Effects of Metal Contamination in Wild Fish	434

CONTENTS

**ix**

4. Metal Effects on Behavior	446
5. Seasonal, Interannual, and Age-dependent Variations in Fish Condition and Contamination	450
6. Applying Predictive Models in Field Situations	458
7. Concluding Remarks	461

INDEX	475
-------	-----

OTHER VOLUMES IN THE FISH PHYSIOLOGY SERIES	495
---	-----

COLOR PLATE SECTION