

TABLE OF CONTENTS

Epigenetics in Aquaculture

List of Contributors

Preface

Acknowledgments

Part I Theoretical and Practical Bases of Epigenetics in Aquaculture 1

1 The Potential Role of Epigenetics in Aquaculture: Insights from Different Taxa to Diverse Teleosts 3

Han-Ping Wang and Zhi-Gang Shen

1.1 Introduction 3

1.2 Key Players of Epigenetics 4

1.3 Divergent Epigenetic Mechanisms from Different Taxa to Diverse Teleosts 10

1.4 The Roles and Applications of Epigenetics 11

1.5 Conclusion and Perspectives 25

2 Transcriptional Epigenetic Mechanisms in Aquatic Species 45

Laia Navarro-Martín, Jan A. Mennigen, and Jana Asselman

2.1 Epigenetic Mechanisms as Modulators of Transcription 45

2.2 Transcriptional Epigenetic Mechanisms in Aquatic Species 51

2.3 Modulation of Biological Functions by Transcriptional Epigenetic Mechanisms in Aquaculture Species of Interest 54

2.4 Conclusions and Perspectives 57

3 Epigenetic Regulation of Gene Expression by Noncoding RNAs 65

Elena Sarropoulou and Ignacio Fernández

3.1 General Introduction 65

3.2 Major Types of ncRNAs 65

3.3 Roles of ncRNA in Key Processes of Teleosts 76

3.4 ncRNAs as Biomarkers and Future Perspectives 84

4 Epigenetic Inheritance in Aquatic Organisms 95

Ramji K. Bhandari

4.1 Introduction 95

4.2	Epigenetic Reprogramming of Embryo and Germline Cells	101
4.3	Heritable Effects of Environmental Stress	104
4.4	Past Exposure and Future Phenotypic Consequences in Aquatic Species	108
4.5	Conclusions and Perspectives	114
5	Environmental Epigenetics in Fish: Response to Climate Change Stressors	127
	<i>Zhi-Gang Shen, Yue Yu, and Han-Ping Wang</i>	
5.1	Overview of Climate Change and Environmental Stressors	127
5.2	Epigenetic Response to Climate Change	129
5.3	Conclusions and Future Perspectives	137
6	Analytical Methods and Tools to Study the Epigenome	149
	<i>Oscar Ortega-Recalde and Timothy A. Hore</i>	
6.1	Introduction	149
6.2	Recommendations for Choosing a Method to Study the Epigenome	150
6.3	Methods and Tools to Analyze Epigenetic Modifications	150
6.4	Bioinformatics Analysis	165
6.5	Databases and Other Public Resources	166
6.6	Conclusions and Outlook	166
Part II	Epigenetics Insights from Major Aquatic Groups	175
7	Epigenetics in Sexual Maturation and Gametes of Fish	177
	<i>Marta Lombó Alonso, Audrey Laurent, María Paz Herráez, and Catherine Labbé</i>	
7.1	Introduction	177
7.2	Epigenetics During Spermatogenesis and Oogenesis	177
7.3	Epigenetic Changes in the Gametes Triggered by Environmental Constraints	181
7.4	Conclusion	186
8	Epigenetics in Sex Determination and Differentiation of Fish	193
	<i>Qian Wang, Qian Liu, Xiaona Zhao, Wenxiu Ma, Lili Tang, Bo Feng, and Changwei Shao</i>	
8.1	Introduction	193
8.2	Epigenetics and Sex Chromosome Evolution	195
8.3	Epigenetics and Sex Determination	198
8.4	Epigenetic Regulation of Sex Differentiation in Gonochoristic Species and Sex Change in Hermaphrodites	199
8.5	Transgenerational Epigenetic Sex Reversal	201
8.6	Conclusions and Future Perspectives	203

9 Epigenetics in Fish Growth 209

Jorge M.O. Fernandes, Artem V. Nedoluzhko, Ioannis Konstantinidis, and Paulo Gavaia

9.1 Myogenesis in Teleosts 209

9.2 Skeletogenesis in Teleosts 213

9.3 Epigenetic Regulation of Sexually Dimorphic Growth 215

9.4 Epigenetic Control of the Skeleton in Teleosts 218

9.5 Mitochondrial Epigenetics 219

9.6 Conclusion 221

10 Epigenetics in Fish Nutritional Programming 231

Kaja H. Skjærven, Anne-Catrin Adam, Takaya Saito, Rune Waagbø, and Marit Espe

10.1 Epigenetic Basis of Nutritional Programming 231

10.2 Nutritional Programming 233

10.3 Key Nutrients and Metabolites for Epigenetic Mechanisms 235

10.4 Case Examples 237

10.5 Conclusions and Perspectives for Nutritional Programming in Aquaculture 239

11 Microbiome, Epigenetics, and Fish Health Interactions in Aquaculture 245

Sofia Consuegra, Tamsyn Uren Webster, and Ishrat Anka

11.1 Introduction 245

11.2 The Fish Microbiome in Aquaculture 245

11.3 Microbiome-Epigenome Interactions 252

11.4 Gaps in Knowledge and Future Research Avenues 255

11.5 Conclusions 255

12 Epigenetics of Stress in Farmed Fish: An Appraisal 263

Bruno Guinand and Athanasios Samaras

12.1 Introduction 263

12.2 Stress and Stress Response 264

12.3 Is There an Epigenetics of Stress in Cultured Fish? 267

12.4 The Neuroepigenetics of Stress: Fishing with Mammalian Models 269

12.5 Epigenetic Biomonitoring of Stress 273

12.6 Conclusions 274

13 Epigenetics in Hybridization and Polyploidization of Aquatic Animals 287

Li Zhou and Jian-Fang Gui

13.1 Hybridizing and Hybridization 287

13.2 Polyploidy and Polyploidization 287

13.3 Epigenetic Changes and Effects During Hybridization and Polyploidization in Aquatic Animals 289

13.4 Association of Epigenetic Changes with Heterosis 292

13.5 Conclusions and Future Perspectives 293

14 Epigenetics in Aquatic Toxicology 301

Sara J. Hutton and Susanne M. Brander

14.1 Introduction 301

14.2 Epigenetic Endpoints in Aquatic Toxicology Studies 303

14.3 Epigenetics During Early Development Related to Toxicology 310

14.4 Multigenerational and Transgenerational Toxicology 311

14.5 Epigenetics in Ecological Risk Assessment 313

14.6 Rapid Evolution 314

14.7 Epigenetics in Aquaculture 315

14.8 Conclusion and Perspectives 316

15 Epigenetics in Mollusks 325

Manon Fallet

15.1 Introduction 325

15.2 DNA Modifications in Mollusk Species 328

15.3 Chromatin Conformation and Histone Modifications/Variants in Mollusks 330

15.4 Noncoding RNAs in Mollusks 331

15.5 Epigenetic Responses to Environmental Fluctuations in Mollusks 336

15.6 Mechanisms of Meiotic Epigenetic Inheritance in Mollusks and Their Impact in Evolution 340

15.7 Perspectives 345

15.8 General Conclusions 346

16 Epigenetics in Crustaceans 355

Günter Vogt

16.1 Introduction 355

16.2 Epigenetics Research with Brine Shrimps and Copepods 356

16.3 Epigenetics Research with Water Fleas 359

16.4 Epigenetics Research with Amphipods 363

16.5 Epigenetics Research with Freshwater Crayfish 363

16.6 Epigenetics Research with Shrimps and Crabs 371

16.7 State of the Art of Epigenetics in Crustaceans 373

16.8 Potential Application of Epigenetics in Crustacean Aquaculture 374

17 Epigenetics in Algae 383

Christina R. Steadman

17.1 Introduction: What Are Algae 383

17.2 Algae Epigenetics 388

17.3 Environmental Stress Alters Microalgae Epigenomes 404

17.4 Conclusions and Perspectives 405

Part III Implementation of Epigenetics in Aquaculture 413

18 Development of Epigenetic Biomarkers in Aquatic Organisms 415

Dafni Anastasiadi and Anne Beemelmans

18.1 Biomarkers 415

18.2 Epigenetic Biomarkers 415

18.3 Development of Epigenetic Biomarkers 417

18.4 Epigenetic Biomarkers in Aquatic Organisms and their Applications in Aquaculture 425

18.5 Future Perspectives 431

18.6 Concluding Remarks 432

19 Genetics and Epigenetics in Aquaculture Breeding 439

Shokouh Makvandi-Nejad and Hooman Moghadam

19.1 Overview 439

19.2 Breeding in Aquaculture and Evolution of Genetic Markers 440

19.3 Epigenetics and Missing Heritability 442

19.4 Transgenerational Inheritance of Epigenetic Marks 444

19.5 Epigenetic Marks — Possible Biomarkers to Improve Breeding 444

19.6 Association Analysis and Search for Epigenetic Biomarkers 445

19.7 Concluding Remarks 446

20 Epigenetics in Aquaculture: Knowledge Gaps, Challenges, and Future Prospects 451

Francesc Piferrer

20.1 Introduction 451

20.2 Knowledge Gaps 452

20.3 Challenges 456

20.4 Prospects 458

Acknowledgments 461

References 461

.../...

Index-Species 465

Index-Subjects 469.