

# Contents

<b>1</b>	<b>Evolution in the Dark: Introduction</b> . . . . .	1
	References . . . . .	2
<b>2</b>	<b>The Role of Rudimentation in Evolution</b> . . . . .	3
	References . . . . .	11
<b>3</b>	<b>Diversity and the Phylogenetic Age of Cave Species</b> . . . . .	13
3.1	Mexico and the Peri-Caribbean Islands: A Hot Spot of Aquatic Cave Species Diversity . . . . .	14
3.2	Strongly Eye-Reduced Cave Species . . . . .	16
3.3	Lesser and Variably Eye-Reduced Cave Species . . . . .	20
	References . . . . .	33
<b>4</b>	<b>Surface and Cave Populations of Mexican <i>Astyanax</i></b> . . . . .	37
4.1	<i>Astyanax</i> Surface Fish . . . . .	38
4.2	<i>Astyanax</i> Cave Fish . . . . .	38
4.3	Phylogeography and Speciation of Surface and Cave <i>Astyanax</i> . . . . .	44
4.3.1	Invasion of Surface <i>Astyanax</i> from South America and Origin of the Cave Forms . . . . .	44
4.3.2	Multiple Origin of Cave Forms . . . . .	48
4.3.3	Population Genetic Diversity of Cave Populations . . . . .	49
	References . . . . .	50
<b>5</b>	<b>Complexity of Interrelationship Between <i>Astyanax</i> Cave and Surface Fish</b> . . . . .	53
5.1	General Remarks . . . . .	54
5.2	Strongly Eye- and Pigment-Reduced Cave Populations . . . . .	54
5.2.1	Pachón Cave Fish . . . . .	55
5.2.2	Yerbaniz Cave Fish . . . . .	57
5.3	Variably Eye- and Pigment-Reduced (VEP) Cave Populations . . . . .	58
5.3.1	Micos Cave Fish . . . . .	58
5.3.2	Chica Cave Fish . . . . .	63
5.3.3	Caballo Moro Cave Fish . . . . .	66
5.3.4	Molino Cave Fish . . . . .	67
5.4	Role of Introgressive Hybridization . . . . .	68
5.5	Speciation and Taxonomy of <i>Astyanax</i> Surface and Cave Fish . . . . .	70
		vii

5.5.1	Surface Fish . . . . .	70
5.5.2	Cave Fish . . . . .	72
References . . . . .		74
<b>6</b>	<b>Regressive and Constructive Traits in <i>Astyanax</i> Surface and Cave Fish . . . . .</b>	<b>79</b>
6.1	General Remarks . . . . .	80
6.2	Reproductive Behaviour . . . . .	82
6.3	Sex Determination . . . . .	84
6.4	Auditory Capacities . . . . .	86
6.5	Lateral Line System . . . . .	86
6.6	Taste . . . . .	91
6.7	Olfaction . . . . .	94
6.8	Feeding Behaviour and Food Uptake . . . . .	94
6.9	Metabolic Adaptation to Permanent or Periodic Low Food Supply . . . . .	98
6.10	Overall Sleep and Activity Patterns . . . . .	102
6.11	Egg Yolk Content . . . . .	104
6.12	Aggressive Behavioural Patterns in <i>Astyanax</i> . . . . .	106
6.13	Dorsal Light Reaction . . . . .	112
6.14	Phototactic Behaviour . . . . .	114
6.15	Pineal Organ . . . . .	116
6.16	Circadian Rhythm . . . . .	118
6.17	Fright Reaction . . . . .	127
6.18	Schooling and Shoaling Behaviour . . . . .	129
6.19	Scales . . . . .	132
6.20	Pigmentation . . . . .	133
6.20.1	Melanophores . . . . .	133
6.20.2	Brown Gene ( <i>Mclr</i> ) . . . . .	134
6.20.3	Albino Gene ( <i>Oca2</i> ) . . . . .	137
6.20.4	Guanine and Carotinoids . . . . .	138
6.21	Eye . . . . .	140
6.21.1	Morphology and Histology of the Eyes of the Surface and the SEP <i>Astyanax</i> Cave Fish . . . . .	140
6.21.2	Visual Pigments . . . . .	142
6.21.3	Size and Histology of the Eye in the VEP Cave Fish and in the Crossings Between Surface and Cave Fish . . . . .	144
6.21.4	Ontogeny of Eye Development in the SEP Cave Fish . . . . .	148
6.21.5	Genetic Basis of Eye Development . . . . .	156
6.21.6	The Role of the Lens in Eye Development . . . . .	161
6.21.7	Ontogenetic Eye Regression and Head Formation . . . . .	162
6.21.8	Root Effect . . . . .	165
6.22	Brain . . . . .	166
6.23	Comparison of the Genetics of Complex Regressive and Constructive Traits . . . . .	169

6.23.1	Phenotypic Manifestation and Gene Expression . . . . .	169
6.23.2	Comparison of Phenotypic Manifestation . . . . .	173
6.23.3	Genetics of Phylogenetically Young VEP Cave Fish . . .	175
6.23.4	Significance of Unproportional Epistatic Gene Effect . . .	177
6.23.5	Nature of Genes Responsible for Complex Traits . . . . .	178
	References . . . . .	179
<b>7</b>	<b>Mechanisms of Regressive Evolution . . . . .</b>	<b>191</b>
7.1	Deleterious Risk . . . . .	192
7.2	Food Limitation and Energy Economy . . . . .	192
7.3	Quantitative Trait Loci Polarity Test for Selection (Orr's Sign Test) . . . . .	193
7.4	Pleiotropy . . . . .	194
7.4.1	Pleiotropy of Sonic Hedgehog ( <i>Shh</i> ) Genes . . . . .	194
7.4.2	Pleiotropy of Neuromodulation (Melanin-Catecholamine Trade-Off Hypothesis) . . . . .	195
7.4.3	Pleiotropy of Vibration Attraction Behaviour (VAB) and Superficial Neuromasts in the Cave Fish Orbit . . . . .	197
7.5	Independent Inheritance . . . . .	198
7.6	Evolutionary Rates of Regressive and Constructive Traits . . . . .	199
7.7	Reversibility of Regressive Evolution . . . . .	200
7.8	Variability and Loss: Neutral Mutation Theory . . . . .	201
7.8.1	Variability of Regressive Traits . . . . .	203
7.8.2	Loss of Behavioural Traits Not Performed in Darkness . . .	205
7.8.3	Genetic Studies . . . . .	205
7.9	Variability and Constructive (Darwin's) Gain . . . . .	207
7.10	Concluding Remarks . . . . .	211
	References . . . . .	211