

Index

Note: Page numbers followed by *b* indicate boxes, *f* indicate figures, and *t* indicate tables.

A

Adaptive evolution, 221
 Adaptive traits, 145–146
Agastoschizomus lucifer, 35, 65
 Aggressiveness
 CF, 348, 349–350
 heterosis effect, 346
 innate behavior, 346
 losses, 344–346, 344*f*
 neural circuits, 346–347
 nonaggressive behavior, 346
 SF, 348–349
 stickleback males, 344
 AIM. *See* Astyanax International Meeting (AIM)
 Albinism, 102–104, 158, 166*f*, 167–168
AlphaA-crystallin (cryaa), 181–182
Anelpistina quinterensis, 66, 72
 Arroyo Lagartos, 42
 Arroyo Seco, 42
Astyanax community
 AIM, 394–395, 395*f*
 El Abra region, 41
 linking phenotype to genotype, 129
 QTL, 394
Astyanax International Meeting (AIM), 394–395, 395*f*
Astyanax mexicanus, 14*t*, 43
 adult dentition, 210–212, 210*f*, 214, 214*f*
 adults vs. larvae, 299–300
 aggressiveness, 344–350, 344*f*
 allelic variation (*see* Quantitative trait locus (QTL))
 behavioral and electrophysiological proper-ties (*see* Sleep)
 cave populations, 298, 299*f*
 constructive traits, 209
 craniofacial (*see* Craniofacial evolution)
 craniofacial alterations, 194, 195*t*
 depigmentation (*see* Depigmentation)
 development, 313–314
 DNA repair system, 325
 environment/geographic isolation event, 137–139, 142–145, 146, 147–148
 eye degeneration mechanism (*see* Eye degeneration)

 feeding behavior (*see* Blind cavefish)
 genetic analysis, 203, 204*f*
 genetic variation (*see* Standing genetic variation)
 invasion by lineages, 85–87
 locomotor activity, 317–318
 Meckel's cartilage, 212–213, 213*f*
 metabolism, 319*f*, 320–321
 nervous system patterning (*see* Neural development and evolution)
 perpetual darkness (*see* Spatial mapping)
 phenotype (*see* Phenotypic evolution)
 Phreatichthys andruzzii, 325–326
 pigmentation (*see* Pigment regression)
 QTL mapping, 298
 recording systems, 297–298, 297*f*
 reduced sleep, 300–301
 regressive (*see* Regressive evolution)
 retinomotor movements, 321
 rudimental eye, 175
 sensory adaptation (*see* Sensory system)
 Sierra de El Abra region (*see* Sierra de El Abra region)
 sleep, 318, 319*f*
 social behavior, 335–343, 337*f*, 339*f*, 342*f*
 surface-cave hybrids, 298
 tastebud, 216, 216*f*
 taxonomy (*see* Taxonomy)

B

Balitorid cavefishes, 95–97
 Base excision repair (BER), 325
 Basic helix-loop-helix (bHLH), 310
 Bats, 63, 64*t*
 Bee Cave (Sótano de las Colmenas), 28
 β -adrenergic receptors, 302
 Biodiversity
 cave communities, 59
 nacimientos, 61
 Sierra de Guatemala subregion, 60
 Sotanochactas elliotti, 60, 60*f*
 Blind cavefish
 apelin, 278–279
 appetite-related peptides, 271, 272*t*, 274*f*
 CART, 275–276

Blind cavefish (*Continued*)

- CCK, 277–278
- feeding behavior, 269–270
- ghrelin, 278
- metabolism and responses, fasting, 270–271
- monoamine neurotransmitters, 279–280
- orexins, 271–275
- PYY, 276–277
- TOR, 281
- tyrosine hydroxylase, 279–280

Brown phenotype, 104

CCanalization, 137–139, 138*b*, 140–141*Carassius auratus*, 271CART. *See* Cocaine-and amphetamine-regulated transcript (CART)

Cartography methods, 22, 24–25

Cave adaptation

- inner ear sensory system, 259–260
- pineal light-sensing organs, 260–261
- tactile sensing, 260–261

Cave-adapted fish (CF)

- foraging, 348
- hierarchy, 343
- locomotor activity, 336
- loss of aggressiveness, 349–350
- reproduction, 337–338, 337*f*
- restored eyes and restored visual function, 345–346
- schooling behavior, 339–340
- seasonal flooding, changes, 336
- zigzag swimming, 341, 342*f*

Cave ecology

- bats, 63
- cavefish food, 62–63
- crustaceans, 63–65
- hazards, 61–62
- temperature, 62

Cave exploration and mapping

- AMCS work, 19
- Anoptichthys jordani*, 18
- bioreserves, 17–18
- cartography methods, 22, 24–25
- Cueva Chica, 18
- El Abra range, 20
- fieldwork, 18
- Micos area, 19–20
- Nacimiento del Río Choy, 21, 24*f*
- Nacimiento del Río Mante, 21, 24*f*
- Robert W. Mitchell's research group, 19, 20*f*
- Sótano del Tigre, 20–21, 21*f*, 22*f*

Sótano de Venadito, 20–21, 23*f*

Western Hemisphere, 20

CCK. *See* Cholecystokinin (CCK)CF. *See* Cave-adapted fish (CF)

Chamal-Ocampo area, 28

Channelrhodopsin-2 (ChR2), 386

Characiformes, 77, 78*f*

Chemosensation, 236–238

Cholecystokinin (CCK)

- apelin, 279
- brain expression, 277–278
- CART, 275–276
- peripheral injections, 277
- TOR, 281
- tyrosine hydroxylase, 279

Circadian clocks

- advantage, 309
- cave animals, 311–313, 312*t*
- cave model (*see* *Astyanax mexicanus*)
- DNA repair, 322–325, 324*f*
- field studies, 327
- light and dark cycle, 309
- melatonin, 321–322
- pineal gland, 321–322
- rhythmic conditions, laboratory, 314–316, 315*f*
- wild cavefish, 315*f*, 316–317
- zebrafish, 310–311

Cocaine-and amphetamine-regulated transcript (CART), 275–276

Compensatory plasticity, 370

Convergent evolution

- feeding-associated sensory processes, 300–301
- lineages, 85
- sleep loss, 297–298, 297*f*, 299*f*

Craniofacial evolution

- circumorbital bone, 193, 194, 194*f*, 195*t*
- coordinated changes, 201–202
- cranial neural crest, 204–205
- demography, 196
- genetic analyses, 202–203, 204*f*
- geographically-and evolutionarily-distinct populations, 193–194, 194*f*, 196
- mechanisms, 199–201
- morphological changes, 198–199
- SO3 fragmentation, 193, 194*f*
- suborbital bone fusion, 196–198, 197*f*
- trogloform, 196

Cryptic variation, 137–141, 138*b*Cryptochrome (*cry*), 310*Ctenopharyngodon idellus*, 276Cueva Chica, 37. *See also* La Cueva Chica

Cueva de El Pachón, 28
 Cueva de la Curva, 37
 Cueva del Lienzo, 37
 Cueva de los Sabinos, 36, 70–72
 Cueva del Río Subterráneo, 37
 Cueva de Otates, 37
 Cupula, 253–254
Cyprinus carpio, 275–276

D

De novo mutation, 137–140, 138*b*, 138*f*
 Dentition
 caudal teeth, 210*f*, 211, 213–214
 early tooth development, 214, 214*f*
 ethmoid cartilage, 213
 intraosseus tooth development, 214–215
 mandibular symphysis, 210*f*, 211
 maxillary bone, 210*f*, 212
 Meckel's cartilage, 212–213, 213*f*
 multicuspid, 210–211, 210*f*, 213–214
 ossification, 212–213, 213*f*
 palatoquadrate cartilage, 213
 premaxillary bone, 210*f*, 211, 212
 Depigmentation
 CAT-dependent processes, 169–170
 direct/indirect natural selection, 168, 169
 genetic basis, 164–168, 165*t*
 lateral stripe/diamond-shaped spot, 157*f*, 158
 melanogenic substrate assay, 163–164, 163*f*
 neural crest cells, 162, 163, 163*f*
 neutral mutation/genetic drift, 168–169
 RPE pigmentation, 162
Dicentrarchus labrax, 277
 Diphtheria toxin A-subunit (DTA), 385–386
 Direct natural selection, 168, 169
Drosophila melanogaster, 140

E

Epinephelus coioides, 271–275
 Evolutionary developmental biology
 (EvoDevo), 361–362
 Expression QTL (eQTL), 128–129
 Eye degeneration, 183
 ciliary marginal zone, 176–178, 176*f*, 179
 crystalline lens, 175–176, 176*f*
 differentiation phase, 176–179,
 176*f*, 177*f*
 energy conservation hypothesis, 187–189
 growth-maintenance phase, 176–178, 176*f*,
 177*f*, 179
 lens PCD, 177*f*, 178–179, 180, 181–182

 natural selection, 183
 neutral mutation, 183, 185–186, 188–189
 outgrowth phase, 176–178, 176*f*, 179
 Pax6 protein, 175–176, 177*f*, 178
 photoreceptor cells, 175–176, 178–179
 Phreatichthys andruzzii, 184–185
 reversed transplantation, 180–181
 Rhamdia, 183–184
 RPE, 175–176
 Sinocyclocheilus, 184
 specification phase, 176–178, 176*f*, 177*f*, 179
 teleosts, 175, 176*f*
 trade-off hypothesis, 186–187, 188–189
 Eye regression, 258–259, 261, 262*f*

F

5-hydroxytryptamine (5-HT), 347

G

Gadus morhua, 271–275
 Gene flow, 148–149
 Genetically encoded calcium indicators
 (GECIs), 386
 Genetic assimilation, 137–139, 138*b*
 Genetic drift, 168–169, 185–186
 Geographic information system (GIS), 25–26
 Gómez Farías area. *See* Sierra de Guatemala
 Green fluorescent protein (GFP), 381–382

H

Heat shock protein 90 (HSP90)
 capacitor of evolution, 141–142
 cavefish evolution, 142–145, 144*f*
 definition, 137–139, 138*b*
 Hedgehog (*Hh*) signaling, 261, 262*f*
Hoplobunus boneti, 72
 Hydrogeology of caves
 Astyanax, 57
 dating, 49, 50
 drainage divide, 54, 55
 erosion, 49–50
 features, 51*t*
 Galápagos tortoises, 53–54
 geology, 46–47
 limestone, chemical erosion, 47, 48
 molecular clocks, 48
 Pachón cave, 53
 rivers of El Abra region, 41, 44*f*
 Soyate cave entrance, 50
 surface rivers, 50–53, 52*f*
 tectonic folding, 56

Hydrogeology of caves (*Continued*)

- underground drainages, 45–46
- uplift, 49

Hypocretin (*Hcrt*), 296–297

Hypothalamus, 347

Hypotheses test

- eyes regression, 95–100
- hallmarks of selection, 95, 100–102
- polarity differences, patterns, 95
- tighter eye size QTL, 95, 100–102

I*Ictalurus punctatus*, 275–276

Indirect natural selection, 168, 169

Invasion, 85–87

Iridophores, 156–158

L

La Cueva Chica, 66–70

Lienzo caves, 45

Light input pathway

- DNA repair, 322–325, 324f
- melatonin, 321–322
- pineal gland, 321–322

Lineages, 82–84, 83f, 85–87

Los Cuates, 37

MMAO. *See* Monoamine oxidase (MAO)

Mechanosensory lateral line, 236–237, 238–239

- American Amblyopsid cavefish, 250–252
- canal neuromasts, 251f, 252–253
- neural tracing and neurophysiological studies, 254
- superficial neuromasts, 251f, 252–254

Meckel's cartilage, 212–213, 213f

Melanocortin 1 receptor (mc1r) gene, 161f, 166–167, 166f

Melanogenesis, 160–162, 161f

Melanophores, 156–158, 157f, 158b, 159t

Messenger RNA (mRNA) expression, 271–275

Micos area valley, 37, 46

Microphthalmia-related transcription factor (*mitf*), 160–161, 161f

Mirror test, 344–345, 344f

Mitochondrial information, 85

Modularity evolution, 221

Molecular clocks, 48

Monoamine oxidase (MAO), 239, 240, 347

Multiple interval mapping (MIM), 106

Mutations, 137

N

Nacimiento del Río Coy, 43–45, 44f

Nacimiento de San Rafael de los Castros, 46

Nasal epithelium, 255f, 258

Natural selection, 183, 220

Neural crest cells, 162, 163, 163f, 200–201

Neural development and evolution

- adult brain anatomy and networks, 229–231, 229f
- brain neurochemistry, 228, 239–240
- chemosensation, 236–238
- early embryonic development, 233–235, 234f
- larval brain development, 235–236
- mechanosensation, 236–237, 238–239
- morphological differences, 227–228
- quantitative variations, 228
- visual system degeneration, 231–233, 232f

Neural plate patterning, 233–234, 234f

Neuromasts, 201

- canal neuromasts, 251f, 252–253
- superficial neuromasts, 251f, 252–254
- transparent extracellular mucus structure, 253–254

Neutral mutation, 168–169, 183, 185–186

Newportia sabina Chamberlin, 66

Noradrenergic signaling, 303

OOcular and cutaneous albinism-2 (*Oca2*), 239–240

Olfactory system, 257

Oncorhynchus mykiss, 277

Oral jaws

- adaptive evolution, 221
- adult dentition and jaw bones (*see* Dentition)
- constructive traits, 209
- limited food resources, 209
- modularity evolution, 221
- natural selection, 220
- regressive and constructive changes, 217
- tastebuds, 215–216, 216f
- teeth, 217–219
- teeth-eye linkages, 219–220
- tooth-tastebud linkages, 219

Orbital bones, 142–145, 144f

Oreochromis mossambicus, 276

Orexins (OXs), 271–275

Ossification, 212–213, 213f

P

Pachón population, 42

Paired box 6 (*Pax6*) protein, 175–176

Paradoxical sleep, 291
 Peptide YY (PYY), 276–277
 Per-arnt-sim (PAS) domain transcription factors, 310
 Phenotypic evolution
 advantages, 2
 cave environment, 3
 evolutionary genetics, 2–3
 free-swimming ancestral surface, 4
 geology, ecology, and biodiversity, 4–5
 intense selection pressure, 3
 molecular and genetic tools, 1–2
 morphological/behavioral changes, 1
 regressive evolution, 4
 Photoreceptor cells, 175–176, 321
Phreatichthys andruzzii, 184–185
 Pigment regression, 156, 157*f*, 170
 albinism, *oca2* gene, 158, 166*f*, 167–168
 iridophores, 156–158
 mclr gene, 161*f*, 166–167, 166*f*
 melanogenesis, 160–162, 161*f*
 melanophores differentiation, 156–158, 157*f*, 158*b*, 159*t*, 160, 161*f*
 teleosts, 160
 troglomorphy, 155–156
 xanthophores, 156–158, 157*f*
 Pleiotropic trade-off hypothesis, 177*f*, 186–187
 Programmed cell death (PCD), 177*f*, 178–179, 180, 181–182
 Promoters of period (*per*), 310
 Propranolol, 302
Proteus anguinus, 95–97
Pseudosinella petrustrinatii Christiansen, 66
Pygocentrus nattereri, 271

Q

QTN. *See* Quantitative trait nucleotide (QTN)
 Quantitative trait locus (QTL), 121–123, 394
 accuracy and precision, 124–126
 CF and SF, 115–119, 116*t*, 126–127
 chemical sensors, 258
 craniofacial phenotypes, 203
 cryaa, 181–182
 Danio genomes, 120
 definition, 112, 137–139, 138*b*, 145, 146
 depigmentation, 164–165
 eQTL, 128–129
 eye size, 255–256, 261, 262*f*
 F₂ hybrids, 255–256
 genome scans, 126, 127–128
 genotype-to-phenotype-to-fitness, 129
 Mendelian vs. quantitative traits, 112–115, 113*f*

multiple behavioral/morphological traits, 255–256
 multiple genomic loci, 254, 255*f*
 pleiotropic genes, 186, 187
 population scans, 126
 sampling, 126–128
 troglomorphy in *Astyanax*, 114*f*
 Quantitative trait nucleotide (QTN)
 accuracy and precision, 124–125
 albinism, 122
 alleles identification, 121–122
 brown pigmentation, 122–123
 eye size/lens degeneration, 123
 genome scans, 127–128
 laboratory-based mapping, 124
 signaling factors, 123

R

Raphe nucleus, 343, 349
 Rapid eye movement (REM) sleep, 291
 Regressive evolution
 albinism, 102–104
 brown phenotype, 104
 hypotheses test (*see* Hypotheses test)
 mapping and QTL analysis, 106
 oca2 and *mclr*, 104–105
 pigmentation, 106–107
 Tinaja/surface cross, 106
 Restriction site associated DNA sequencing (RADseq), 303
 Retinal pigmented epithelium (RPE), 104, 175–178, 176*f*, 321
Rhamdia, 183–184
 Río Boquillas, 42, 45
 Río Choy, 42
 Río Comandante, 42
 Río Coy, 43–45, 44*f*
 Río Frío, 42
 Río Gallinas, 43
 Río Mante, 42
 Río Naranjo, 43
 Río Puerco, 43
 Río Santa Clara, 42
 Río Santa María, 43
 Río Subterráneo, 45
 Río Tampaón, 43
 Río Tantoán, 42
 Río Valles, 43

S

Sabinos area, 35
Salmo salar, 276

- Salmo trutta*, 278
- San Rafael de los Castros, 42, 46
- Schistura jaruthannini*, 97–98
- Schistura kaysoniae*, 97–98
- Schizothorax davidi*, 278
- Sensory system
- chemical sensory system, 255*f*, 257–258
 - chemosensation, 236–238
 - detecting vibrations (*see* Mechanosensory lateral line)
 - foraging behavior (*see* Vibration attraction behavior (VAB))
 - hh signaling, 261, 262*f*
 - inner ear, 259–260
 - mechanosensation, 236–237, 238–239
 - pineal light-sensing organs, 260–261
 - tactile sensing, 260–261
 - visual system, 258–259
- Serotonin, 347
- Sierra Cucararas, 28
- Sierra de El Abra region, 9–10, 10*f*, 45–46
- Astyanax* caves, 14*t*
 - cave exploration and mapping (*see* Cave exploration and mapping)
 - Cretaceous period, 11
 - GIS, 25–26
 - Huastecan Province, 10
 - hydrogeology of caves (*see* Hydrogeology of caves)
 - karst, 11
 - limestone, 16–17
 - map, 12*f*, 13*f*
 - Nacimientos (springs), 16*t*
 - Prietella lundbergi, 17
 - Sierra de Guatemala, 26–37
- Sierra de Guatemala, 45
- Agastoschizomus lucifer*, 35
 - AMCS cave map symbols, 32*f*
 - Chamal-Ocampo area, 28
 - Micos area, 37
 - Sabinos area, 35
 - Sótano (Resumidero) de Jineo, 26, 27*f*
 - Sótano de Molino, 26–27
 - Sótano de Yerbániz, 29, 30*f*, 31*f*, 33–34, 33*f*
 - Sótano Escondido's, 27–28
 - Southern El Abra, 37
 - subregion, 60
- Sierra Tamalave, 28
- Single-nucleotide polymorphism (SNP), 147–148
- Sinocyclocheilus*, 184
- Sleep
- Danio rerio* (*see* Zebrafish)
 - electrophysiological methods, 291–292
 - genetically amenable model systems, 292
 - pharmacological interrogation, 301–303
 - REM sleep, 291
 - sleep duration and architecture, 292
 - sleep loss (*see* *Astyanax mexicanus*)
- SNP. *See* Single-nucleotide polymorphism (SNP)
- Social behavior
- alarm reaction, 341–342, 342*f*
 - reproductive behavior, 335–338, 337*f*
 - schooling behavior, 338–340, 339*f*
 - shoaling, 340
 - territoriality and hierarchy, 342–343
- Sotanito de Montecillos, 36
- Sotanochactas elliotti*, 60, 60*f*, 65
- Sótano de Japonés, 35
- Sótano (Resumidero) de Jineo, 26, 27*f*
- Sótano de Jos, 36
- Sótano de la Palma Seca, 36–37
- Sótano de la Roca, 36
- Sótano del Arroyo, 36
- Sótano de Las Piedras, 36
- Sótano de la Tinaja, 36
- Sótano del Caballo Moro, 28
- Sótano del Toro, 37
- Sótano de Matapalma, 35
- Sótano de Molino, 26–27
- Sótano de Pichijumo, 36
- Sótano de Soyate, 36, 72–74
- Sótano de Vasquez, 28
- Sótano de Venadito, 28
- Sótano de Yerbániz, 28–35, 30*f*, 31*f*, 33*f*, 65–66
- Sótano Escondido's, 27–28
- Sound localization, 259–260
- Southern El Abra, 37
- Spatial mapping
- absence of vision, 368–370
 - active nonvisual sensing, 366
 - Bronze corydoras, 366–368
 - computer-generated model, 364–365
 - EvoDevo, 361–362
 - eyesight loss, humans, 371
 - habituation period, 364–365
 - human sensory deprivation, 370
 - mammals, 362–363
 - Maze designs, 364, 365*f*
 - space mapping, 370
 - swimming velocity and wall-hugging behavior, 366, 367*f*
 - tastebuds, 368

- vertical and horizontal movements, 365*f*, 366–368
- Zebrafish, 363–364
- Speocirolana bolivari*, 63–65, 65*f*
- Speocirolana pelaezi*, 65
- Sphaeromicola cirolanae* Rioja, 71
- Standing genetic variation
- adaptive trait, 145–146
 - Astyanax mexicanus*, 147–148, 149
 - canalization, 140–141
 - cryptic variation, 140–141
 - vs. *de novo* mutation, 137–140, 138*b*, 138*f*
 - detection, 146–147
 - gene flow, 148–149
 - heritable adaptations, 137
 - HSP90, 141–145, 144*f*
 - mutations, 137
- Surface fish (SF)
- aggressiveness, 348–349
 - hierarchy, 343
 - hybrids, 346
 - lens enucleation, 339
 - locomotor activity, 336
 - predation pressure, 340
 - substrates, 336
 - swim isolation, 338, 339*f*
 - territoriality, 342–343
 - visual cues, 337–338, 337*f*
- T**
- Target of rapamycin (TOR), 281
- Tastebud system, 251*f*, 257–258
- Taxonomy, 79
- A. aeneus*, 80–82, 81*f*, 82*f*
 - delimitation of species, 80, 81*f*
 - genomic islands, 80
 - interbreeding, 79–80
 - lineages, 82–84, 83*f*
 - phylogenetic structure, 84
 - sensu* (Rosen), 84
 - troglobite populations, 78–79, 84
- Teleosts, 160, 175, 176*f*
- Thalassoma pavo*, 271
- Transgenesis
- development and anatomy, 381–383
 - genetic causality, 383–384
 - gene transfer experiments, 379–380
 - homologous recombination, 380
 - low efficiency, 380
 - neuronal activity, monitoring, 384–386
- Trogglomorphs, 155–156, 196, 199. *See also* Quantitative trait locus (QTL)
- Tyrosine hydroxylase (TH), 279–280
- U**
- Ultraviolet (UV) light, 323–325
- V**
- Ventrolateral preoptic (VLPO) area, 295–296, 296*f*
- Vibration attraction behavior (VAB), 187
- adults vs. larvae cavefish, 299–300
 - Astyanax* cavefish population, 248–250, 249*f*
 - genetics, 251*f*, 254–257
 - laboratory setting, 248–250, 249*f*
 - standing variation, 248–250, 249*f*
 - surface fish, 248–250, 249*f*
 - tuning, 250, 251*f*
- W**
- “Waddington’s widget”, 140–141
- X**
- Xanthophores, 156–158, 157*f*
- Z**
- Zebrafish
- arousal threshold, 294
 - behavioral quiescence, 293–294
 - developmental mechanisms, 2
 - developmental stages, 295
 - genetic and transgenic tools, 293
 - sensory stimuli, 293–294, 295
 - sleep systems, 295–297, 296*f*
 - spatial mapping, 363–364