INDEX

Abnormal neural crest cell patterning, 22
Abnormal root development, candidate genes linked to, 169–170
Abramyan, John, ix, 135
Absorbable collagen sponge (ACS), for periodontal bioengineering, 503
Acellular cementum, 154, 155–156, 162
formation of, 160–162
Acellular muscle matrix transplantation, 401
Acinar cell repopulation, by intercalated progenitors, 274
Acinar cells, 271, 272, 274
loss in irradiated glands, 272–273
Acquired disorders, of the temporomandibular joint, 72
Acquired immunogenicity, of iPSCs, 386
Actin, 229
Activating transcription factor 4 (ATF4), 59
Acute–chronic model, 420–421
Acute defect models, 418
Adaptive cementum, 154–157
Additive fabrication methods, 352
Adeno-associated viruses, 403
Adenohypophyseal placode, 11
Adenoviral vectors, 516
Adipogenesis, 247
regulation of, 309
Adipose-derived cells. See also Adipose tissue–derived stromal and stem cells (ASCs); Stromal vascular fraction (SVF) cells
future directions of, 249
harvesting, 241
Adipose-derived cells/tissues, clinical applications of, 248–249
Adipose-derived stem cells (ADSCs), 66. See also Adipose stem cells (ASCs); Adipose tissue–derived stem cells
Adipose-derived stromal cells (ASCs), 383–385. See also Adipose stem cells (ASCs); Adipose tissue–derived stem cells
Adipose MSCs, transplantation of, 472. See also Mesenchymal stem cells (MSCs)
Adipose stem cells (ASCs), 350
Adipose tissue evaluating utility of, 245
as a source of stem cells, 241
Adipose tissue–derived stem cells, regeneration potential of, 241–245
Adipose tissue–derived stromal and stem cells (ASCs), 241, 242–243
characterization of, 242–245
differentiation potential of, 243

Edited by George T.-J. Huang, Irma Thesleff.
Adipose tissue–derived stromal and stem cells (ASCs) (Continued)

DPSCs vs., 247
future directions of, 249
isolation of, 242
odontogenic differentiation ability of, 247
regenerative capacity of, 244
for repairing critical-sized cranial defects, 245
in soft tissue reconstruction, 247–248
for tooth regeneration, 246–247

Adipose tissue harvesting, isolation methods for, 242
Adult bone marrow mononuclear cells, 227
Adult brain, major compartments of, 7
Adult human bone marrow CFU-F, pure populations of, 227. See also Colony-forming units–fibroblastic (CFU-F)
Adult skeletal muscle stem cells, 95
Adult stem cells, 206, 315
Adult tissues, homeostasis of, 315
Aged persons, pulp regeneration for, 470–472
Aging, markers of, 472
Aglossia, 42
Aldehyde 3 (Aldh3) activator, 279
Alk2-lacking mice, 36
Alkaline phosphatase osteoblast-related marker, 229
Allogeneic ASCs, 244. See also Adipose-derived stromal cells (ASCs)
Allogeneic dental pulp stem cells (DPSCs), 488, 489
transplantation of, 492
Allogeneic materials, 380
Allogeneic mesenchymal stem cells, for tooth root engineering, 487–488
Allogeneic PDLSC sheets, 514. See also Periodontal ligament stem cells (PDLSCs)
Allogeneic stem cell transplantation, 474
Allogeneic tissue regeneration, 230
Alloplastic materials, 380
α-smooth muscle actin, 229
Alveolar bone, 155–156, 171
development of, 163–164
functions of, 157
Alveolar bone osteoblasts, 164
Alveolar cleft defects, 231
Alveolar extraction sockets model, 423
Ato6 expression, 16
Ameloblast cell layer, enamel matrix formation and, 121
Ameloblast development, failure of, 332
Ameloblast differentiation, 119, 120, 323
Ameloblast morphology, 120
Ameloblasts, 110, 118, 119–121, 333, 438, 441, 442, 448
ectopic, 441
Ameloblast–stratum intermedium complex, 436
Amelogenesis, 120
Amniotes, tooth regeneration in, 135–136. See also Basal amniotes
Amyotrophic lateral sclerosis (ALS), 215
Anatomical shape/architecture, reconstructing, 342
Angiogenesis, 17–18, 372
chemotaxis-induced, 375
as a prerequisite for pulp regeneration, 465–466
Angiogenesis promotion, 244
Angiogenic cytokine expression, 244
Angiogenic factors, 347
Animal bone defect models, 231
Animal models. See also Ectopic model: Mouse (mice) models; Orthotopic model; Rat models
Animals, fenestration defect studies in, 419–420. See also Amniotes; Basal amniotes; Chickens; Dog(s); Gecko stem cells; Goat(s); Large-animal entries; Mammalian entries; Mammals; Mice; Monkeys; Mouse entries; Rabbit entries; Reptile entries; Rodent entries; Sheep; Shiba goat(s); Squamate entries; Swine entries; Vertebrate entries; Zebrafish
Anterior cranial mesoderm, 87
Anterior–posterior axis, CNCC-derived palatal mesenchyme patterning along, 32–35
Anterior somites, 87
Anterior visceral endoderm (AVE) formation, 9
Anti-inflammatory factors, gene delivery of, 516–517
Apc deletion, 125
Apc loss of function, 193
Apexification, 462
Apexogenesis, 462
Apical bud, 317
Apical bud cells (ABCs), 304
Apical MSC niche, 335
Apical niche, 330–333
Apical papilla, 292–293
Apical papilla tissue, 486
Apoptosis, 305–306. See also Cell death of MES cells, 34
radiation-induced, 279
in rudimentary lamina, 141
in the successional lamina, 124
AP patterning of palatal CNCC-derived mesenchyme, 34
of palatal epithelium, 34
INDEX

Arch-derived muscles, 100
Arch morphogenesis, 92
Arch muscle development, 100, 101–102
Arginine–glycine–aspartic acid (RGD) peptides, 354, 476
for periodontal bioengineering, 504
Artificial niches, in periodontal endogenous regeneration, 513
Artificial tooth germ, 450
Asc13 transcription factor, 275
ASC delivery, timing of, 245. See also Adipose-derived stromal cells (ASCs); Adipose tissue–derived stromal and stem cells (ASCs)
ASC differentiation potential, 243
ASC immunosuppressive properties, 244
ASC layer formation, 247
ASC research, advances in, 384
ASC-surface markers, 384
Asymmetric self-renewal, of satellite cells, 262
Autogenous tissue derivation, patient-specific, 386
Autoimmune diseases, 305
Autologous bone grafts, 379–382
Autologous iPSCs, 386. See also Induced pluripotent stem cells (iPSCs)
Autologous stem cells, 517
Autologous stem cell sources, 246
AVE-mediated WNT signaling, 9
Avian neural induction, 6
Axial craniofacial skeletal muscles, 15
Axial groups, neural crest cell, 11
Axial mesoderm, 15
Axin2 expression, 142
Axis patterning, 38
Axon guidance molecule families, 19
Basal amniotes, tooth replacement in, 136–137
Basal lamina, 262–263
Basic fibroblast growth factors (bFGFs), 307, 467, 469, 508
BATGAL reporter mice, 322
BA underdevelopment, 37. See also Branchial arches (BAs)
BCL-6 co-repressor, 308
Bell stage, 448
in squamate teeth, 140
in tooth formation, 110–111
β-catenin, 55, 124
β-catenin expression, 115. See also Wnt/β-catenin signal pathway
β-catenin gain of function, 193
β-galactosidase (LacZ+), 334–335, 337
β-TCP scaffolds, 506. See also TCP scaffolds;
Tricalcium phosphate (TCP)
β-tricalcium phosphate (β-TCP), 248, 384
for periodontal bioengineering, 505, 506
Bicortical defect in the mandible model, 424
Bioactive glasses, for periodontal bioengineering, 505, 506–507
Bioactive proteins, in dentin, 475
“Bioactive” scaffolds, 425
Bioartificial organs, 449
Bioceramics, for periodontal bioengineering, 505–506
Biodegradable polymers, for periodontal bioengineering, 505
Biodegradable scaffolds, bioengineered tooth germ production using, 450
Bioengineered bone scaffolds, degradation rate of, 345
Bioengineered cell aggregates, transplantation of, 450, 451
Bioengineered craniofacial bone, clinical performance of, 358
Bioengineered teeth, 127
nerve fiber innervation of, 455
neuronal perceptive potential of, 454–455
response to mechanical stress, 454
Bioengineered tooth germ production, using a biodegradable scaffold, 450
Bioengineered tooth germs, 450–452
Bioengineered tooth germ/tooth unit, transplantation of, 452–454
Bioengineering. See also Craniofacial tissue bioengineering/regeneration; Stem cell–based bioengineering
mandible, 357
of craniofacial bones, 357
of functional teeth, 447–459
periodontal, 502–503
of tooth roots and periodontal tissues, 485–499
via cell aggregation method, 450–452
Bioengineering technologies, 448
Bioglass, 506–507
Biological processes, translation into regenerative medicine approaches, 278–279
Biological regeneration, 517
Biological tooth root, 293
Biology, of early tooth development, 179–202
Biomaterial design, 507–508
Biomaterial modification, 507
Biomaterials
development of, 508
as growth factor carriers, 410
for periodontal bioengineering, 503–508
smart, 425
three-dimensional matrices from, 402
Biomaterials-based approach, to regenerate dental pulp, 511–512
Biomaterial scaffolds, 231, 232, 247–248, 341–342, 517. See also Three-dimensional (3D) scaffold;
Treated dentin matrix (TDM) scaffolds
Biomaterial surfaces, 346
Biomechanical force, 81
Biomechanical scaffolds, 342–346, 398, 409. See also Biomaterial scaffolds; Biomimetic scaffold; Bioscaffolds; Decellularized tissue scaffold
alginate, 401–402
bone bioengineering applications of, 354–358
cellular interaction of, 346
in dental tissue engineering, 410–412, 413–414
of extracellular matrix, 475–476
future perspectives of, 412
properties of, 342–345
surface properties and topographical cues of, 346
in tooth regeneration, 371, 372
in total pulp regeneration, 469
Biomimetic peptides, for bone bioengineering, 354
Biomimetic proteins, 475
Biomimetic scaffold, 381
Biomimeralized tissue formation, 290
Bio-Oss collagen, 509
Biophysical stimuli, for bone bioengineering, 353
Bioractors, 353
Bioroot engineering, 486–488, 489, 490
Bioroot regeneration schematic, 489
Bioroots, regenerated, 488, 489, 490
Bioscaffolds, 310. See also Biomechanical scaffolds
Biosynthetic biomaterials, in dental tissue engineering, 410
Biphasic calcium phosphate (HA/TCP), in dental tissue engineering, 411, 515. See also HA/TCP entries; Tricalcium phosphate (TCP); β-Tricalcium phosphate (β-TCP)
BITE-IT tooth gene expression database, 185, 190
Blast colony–forming cell (BL-CFC), 18
Blastema stage, of TMJ development, 72, 73
Blastopore lip, 6
Bmp2 expression, 34. See also Bone morphogenetic protein 2 (BMP2); Bone morphogenetic proteins (BMPs)
Bmp2 marker, 139
BMP2 maxillary sinus augmentation, 357
BMP4/7 activity, 9
Bmp4 expression, 6, 37, 113, 114, 182–183, 190–191
in the tooth system, 181
Bmp4 transcription factor, 38–39
Bmp4 transgene, 33
Bmp7 expression, 7. See also Bone morphogenetic protein 7 (BMP7)
BMP-associated Smads, 35
Bmp expression, 39
cross-regulation of, 189
in odontogenic mesenchyme, 143
BMP inhibitors, 7, 43, 93
BMP mediators, 35
Bmp pathway, 142, 189
Bmpr1a deficiency, 39
Bmpr1a inactivation, 36
BMP-responsive genes, 39
Bmps. See also Bone morphogenetic proteins (BMPs)
in odontoblast differentiation, 119
role in ameloblast differentiation, 119
Wnt activity regulation by, 143
Bmp (BMP) signaling, 7, 12–13, 36, 115
in early odontogenesis, 182–183
neural crest cell induction and, 9
taste bud maintenance and, 44
BMP signals, 33
Bone, formation of, 5. See also Ossification entries; Osteo-entries; Skelet-entries
Bone autografts, 231
Bone bioengineering, 341–366
clinical applications of, 356, 357–358
craniofacial, 357
elements of, 380
future considerations in, 358
maxillofacial, 357
Bone defect models, for large animals, 231
Bone degradation, 60
Bone deposition/resorption, cellular coordination of, 60–61
Bone development/regeneration, 51–70
Bone flap, 384
Bone formation, improving, 388
Bone formation/destruction, 60
Bone formation induction, 294
Bone grafts, 379
autologous, 379–382
Bone graft substitutes, 506
Bone growth, modeling, remodeling, suture formation, and function, 61–64. See also Osteoinductive growth
Bone integration, 452–454
Bone maintenance, cell-scaffold constructs for, 423
Bone marrow cells, mixed with dental epithelial cells, 437–438
Bone marrow cell subpopulations, 439
Bone marrow CFU-F, 227. See also Colony-forming units–fibroblastic (CFU-F)
Bone marrow-derived cells (BMDCs), 436, 439
Bone marrow-derived mesenchymal stem cells (BMSCs, BMMSCs), 66, 206, 223–239, 244, 503, 515. See also Bone marrow-derived MSCs; Bone marrow MSC entries; Bone marrow stem cells (BMSCs); Bone marrow stromal stem cells (BMSSCs)
ASC osteogenic differentiation and, 243
Bone marrow-derived mesenchymal stromal cells (BMMSCs), 382. See also Mesenchymal stromal cells (MSCs); Bone marrow stromal stem cells (BMSSCs)
drawbacks of, 383
multipotent capacity of, 381–382
Bone marrow-derived MSCs, 350
Bone marrow extracts, 382
Bone marrow MSC-based therapies, for treating craniofacial defects, 231–233. See also Mesenchymal stem cells (MSCs); Mesenchymal stromal cells (MSCs)
Bone marrow MSC purification strategies, 226
Bone marrow MSCs. See also Bone marrow-derived mesenchymal stem cells (BMSCs, BMMSCs) characterization of, 226–228
Bone marrow stem cells (BMSCs), differentiation capabilities of, 246, 247
Bone marrow stromal cell lineages, 223
Bone marrow stromal cells (BMSSCs), 304
Bone marrow stromal system, 224–226, 232
diagram of, 225
Bone matrix–forming osteoblasts, from mouse iPSCs, 386–387
Bone matrix vesicles, 59
Bone morphogenetic protein 2 (BMP2), 245, 385
Bone morphogenetic protein 7 (BMP7), 469, 516
Bone morphogenetic proteins (BMPs), 6, 37, 260, 348. See also BMP entries
Calcification, of pulp space, 464
Calcium phosphate (CaP) cement scaffold, for periodontal bioengineering, 505. See also CaP biomaterials
Calcium phosphate (CaP) ceramics, in dental tissue engineering, 411–412
Calvaria, osteoclasts in, 59
Calvaria-defect models, bone bioengineering and, 355. See also Calvarial defect model
Calvarial (intramembranous) bone phenotypes, human gene mutations resulting in, 57–59
Calvarial bone growth, regulation of, 62
Calvarial bones, 52
Calvarial defect model, 388–389
Calvarial defects, repair of, 249
Calvarial (intramembranous) bone phenotypes, human gene mutations resulting in, 57–59
Calvarial bone growth, regulation of, 62
Capillary density, 18
Capillary network, associated with skeletal muscle, 18
Cap stage in mouse odontogenesis, 181–182
in tooth formation, 110
Capsulin, 94, 96
Cardiac α-myosin heavy chain, 97
Cardiac neural crest cells, 11
Cardiac outflow tract development, 97
Cardiac progenitor cells, 96–97, 99
branchiomeric skeletal muscles and, 88
Cardiac transcription factor NKK2–5, 97, 99
Cardiofacio-branchial development, 97
Cartilage, formation of, 5. See also Cartilages; Chondro-entries; Condylar cartilage entries
Cartilage development, 74
Cartilages, origin from chondrogenic condensations, 53
INDEX

β-Catenin, 55, 124. See also β-catenin entries
Caudal arch–derived muscles, 94
Causal regulatory information, 186
Cavitation, 72, 73, 74
CCAAT-enhancer-binding proteins (C/EBPs), 308, 309
CD31+ side population (SP) cells, 466, 467, 468, 469, 476, 477
transplantation of, 473
CD34 glycoprotein, 290, 399
CD105+ cells, 466, 468, 469, 471, 472, 474, 476, 477
CD105/endoglin, 466
CD105 expression, 384–385
CD106 cell-associated antigen, 491
CD106 glycoprotein, 228
CD133+ cells, 401
CD146 molecule, 228, 291
CD295 leptin receptor, 472
CD markers, 290
Cell adhesion molecules, 54
Cell aggregation method, tooth germ bioengineering via, 450–452
Cell-assisted lipotransfer, 249
Cell-based therapies, 399–401
for treating muscular dystrophy, 403
Cell-based tissue regeneration, cell sources for, 477
Cell biology issues, 233
Cell–cell adhesion molecules, 120
Cell–cell contact mechanism, 230
Cell death, 439. See also Apoptosis programmed, 141
Cell delivery approaches, 370–371
Cell differentiation, mechanisms of, 296–297
Cell differentiation gradients, 432
Cell-fate decisions, insights into, 196
Cell fates. See also Genetic-fate mapping experiments
directing specific, 214
modulating, 441
Cell heterogeneity, changes in, 439
Cell homing, 332–333, 367, 368, 469
to injured tissue, 368
orthotopic tooth regeneration by, 373
regeneration by, 370–375
by stem cells, 368
in tissue regeneration, 371
Cell homing approaches, 371–375
Cell homing models, 370
Cell kinetic parameters, 436
Cell labeling, 330
Cell lineage–specific differentiation, 65
Cell manipulation, 206
three-dimensional, 450, 451
Cell manipulation technology, 449
Cell marker expression patterns, 304
Cell methylation profile, 213
Cell microenvironment, 440
Cell migration, 470
Cell migration/recruitment, 367–369
Cell origin, in craniofacial bone development, 52
Cell phenotypes, changes in, 440
Cell plasticity, in craniofacial bone development, 52
Cell proliferation control of, 332, 333
rapid, 73
Cell proliferation assays, 330, 331
Cell reassociations, 439
Cell reconstitution, 370
Cell reprogramming, 206, 209–211
Cells maintaining in vitro odontogenic potential of, 439–441
with tooth-forming capacity, 128
Cell–scaffold constructs, for bone maintenance, 423
Cell self-organization, 215
Cell sheet engineering, 514
Cell sheets, for periodontal regeneration, 495–496
Cell sources. See also Mesenchymal cell sources for cell-based tissue regeneration, 477
for dental tissue engineering, 434
for dentin regeneration, 476
for enamel organ engineering, 435–436
identification of, 455–456
odontogenic potential of, 438
Cell-surface markers, 262, 286, 383, 440
identification of, 385
Cell therapy, 389
muscular dystrophies and, 395–396
Cell-to-cell communication, 60
Cell transplantation in orofacial regeneration, 370–371
tooth regeneration by, 371
Cellular cementum, 154–157, 162, 165
formation of, 163
Cellular components, 380
Cellular heterogeneity, during odontogenesis, 432
Cellular junctions, 120
Cellular microenvironment, 443
Cementoblasts, 117, 118, 165, 170
in acellular cementum formation, 162
origin and nature of, 160
Cementocytes, 165
in cellular cementum formation, 163
Cementogenesis, 163
Hertwig’s epithelial root sheath and, 170
Cementum, 154–157, 165, 464. See also Acellular cementum; Cellular cementum
PDLSC–generated, 291
Cementum–dentin junction (CDJ), in acellular cementum formation, 162
Cementum–enamel junction (CEJ), 164
Central nervous system (CNS), development of, 5
Ceramics in dental tissue engineering, 411–412
for periodontal bioengineering, 505–506
Ceramic scaffolds, in dental tissue engineering, 411–412
Cervical loops (CLs), 145, 147, 317. See also Labial CL; Lingual CL; Molar CLs root formation and, 158
CFU-F clonal cell lines, developmental capacity of, 224–225. See also Colony-forming units–fibroblastic (CFU-F)
CFU-F clones, 224
CFU-F location, in bone marrow, 229
CFU-F population, strategies to purify, 229
CG methylation, 212–213
Chai, Yang, ix, 31
Chemokine receptor expression, 369
Chemokines, in regulating rolling and adhesion processes, 368–369
Chemokine secretion, in tooth eruption, 163
Chemokine superfamily, 369
Chemotactic effects, on pulp regeneration, 494
Chemotaxis-induced angiogenesis, 375
Chen, Fa-Ming, ix, 501
Chen, Mo, ix, 367
Chen, YiPing, ix, 71
Chickens, tooth induction in, 115
Chitosan, for periodontal bioengineering, 504
Chitosan-based gel-like scaffolds, 410
Chitosan–collagen composite scaffold, 516
Cho, Choko, ix, 367
Chondrocyte differentiation, 54. See also Cartilage entries
Chondrocyte proliferation, 80
Chondrogenesis, 78
Chondrogenic condensations, 53
formation of, 54
Chronic defect models, 418
Chung, Michael T., x, 379
*Chiona intestinalis*, 98–99
Circumpulpal dentin, 160
Circumvallate lingual papillae, 44
Cleft lip and/or palate (CLP), 396
Cleft palate, 32–33, 34, 35, 36, 37
Cleft palate defects, 249
Cleft palate, 32–33
Cleft palate, 34
Cleft palate, 35
Cleft palate, 36
Cleft palate, 37
Cleft palate defects, 249
Cleft palate, 396
Cleft palate, 397
Cleft palate, 398
Cleft palate, 399
Congenital defects, of the head and face, 3
Congenital heart defects, 96
Congenital malformations, of the temporomandibular joint, 72
Congenital muscular dystrophies (CMDs), 402–403

CNCC-derived mesenchyme patterning, during tooth initiation, 37–38
CNCC-derived palatal mesenchyme patterning along the anterior–posterior axis, 32–35
along the oral–nasal axis, 35–36
CNCC-derived tongue mesenchyme, influence on gustatory papillae development, 44–45
CNCC functions, 45
CNCC/myogenic cell interactions, 40–41
Collagen, for periodontal bioengineering, 503–504
Collagenase digestion, 242
Collagen binding, 475–476
Collagen composite scaffolds, for periodontal bioengineering, 503
Collagen disk, 401
Collagen disorders, 173
Collagen gel, 416
Collagens, 76–77, 157, 158
Collagen scaffolds, 410
Colony-forming cells, 494
Colony-forming units–fibroblastic (CFU-F), 224. See also CFU-F entries
in bone marrow aspirates, 226
perivascular origin of, 229
purification steps to increase, 228
Combination materials, for periodontal bioengineering, 504
Commercial ceramics, in dental tissue engineering, 411
Communication mode, between epithelium and mesenchyme, 183
Compensatory bone growth, 64
Complete pulp regeneration, with pulp stem and progenitor cells, 468–470
Completion stage, of TMJ development, 72
Complex organs, reconstructing, 448–449
Composite hybrid polymeric scaffolds, 515
Compressive forces, condylar growth and, 81
Computation topology design (CTD), 352
Computed tomography, 352, 353
Condensation formation, cellular processes of, 53
Condylar blastema, of the temporomandibular joint, 73
Condylar cartilage, 76–78
Condylar cartilage development, 79
Condylar primordial cells, 77–78
Condylar primordium, 73, 74. See also Condyle primordium
Condylar development, tissue interactions and, 78–79
Condyle dysplasia, 79
Condyle growth, compressive forces and, 81
Condyle primordium, of the temporomandibular joint, 72. See also Condylar primordium
Congenital defects, of the head and face, 3
Congenital heart defects, 96
Congenital malformations, of the temporomandibular joint, 72
Congenital muscular dystrophies (CMDs), 402–403
Constitutive epithelial Wnt activation, 194
Contaminated pluripotent cells, 217
Continuously erupting mouse incisors, fibroblast growth factors and, 147
Continuously growing teeth, 316–317, 322, 329–330 evolution of, 318
Continuous tooth replacement, 121 in reptiles, 135
Controlled mechanical loading, in dental tissue engineering, 416
Copolymers, glycolic/lactic acid, 345
Copula, 40
Core-binding factor A-1 (CBFA-1), 308. See also Runx2 entries
Core mesoderm, signal exchange between crest cells and, 101
Coronal dentin regeneration, 474–476
Coronal follicle, in tooth eruption, 163
cpG methylation, 212
Cranial defect repair, animal model for, 246
Cranial defects, 231
Cranial mesoderm, 15, 87, 90–91, 92, 101
Cranial muscle development, neural crest cells in regulating, 16–17
Cranial myogenesis inhibitors, 93
Cranial nerves, 3
Cranial neural crest (CNC), 11, 101
role of, 102
Cranial neural crest cells (CNCCs), 99, 100. See also CNCC entries: Crest cells in craniofacial bone development, 52 dental stem cells and, 39–40 maxillary and mandibular, 32 migration of, 31 TGFβ signaling in postmigratory, 36–37 in tissues and organs, 31–49 tongue connective tissue derived from, 40–41 tooth morphogenesis and, 38–39 tooth root formation and, 158 Cranial neural crest development defects, 16–17 Cranial neural crest patterns, 99–102 Cranial placode formation, 13 Cranial placode patterning, regulation of, 13–14 Cranial specializations, 3, 4 Craniofacial anomalies, 17 minimizing or preventing, 21 Craniofacial bone stem cell–based bioengineering of, 379–394 stem cell regeneration of, 388 Craniofacial bone bioengineering, 341–366 Craniofacial bone development, initial stages of, 52–54 Craniofacial bone formation, reproducible, 384 Craniofacial bone niches, differences in, 380 Craniofacial bone patterning, 52 Craniofacial bone reconstruction, 341 Craniofacial bone regeneration, 64 Craniofacial bones bioengineering of, 357 roles of, 51 Craniofacial defects, 36, 94 bone marrow MSC–based therapies for, 231–233 Craniofacial deformity, 64 Craniofacial development, 21, 31. See also Craniofacial morphogenesis/development analyses of, 22 during gastrulation, 4 Craniofacial intramembranous bone development/regeneration, 51–70 Craniofacial intramembranous bone growth, 62 Craniofacial malformations, 22, 36 Craniofacial microsoma, 101 Craniofacial morphogenesis, vascular system and, 17 Craniofacial morphogenesis/development, molecular blueprint for, 3–29 Craniofacial muscle development, 87–107 Craniofacial muscles diversity of, 102 limb muscles vs., 266–267 origin of, 99 Craniofacial myogenesis, 100 Dlx5/6 expression and, 42 in zebrafish, 96 Craniofacial organ development, control of, 45 Craniofacial preclinical animal models, findings from, 245–249 Craniofacial reconstruction, 64, 379 Craniofacial reconstruction procedures, 348 Craniofacial region areas, stages of development in, 63 Craniofacial repair, 248–249 Craniofacial skeletal muscles, 15 functions controlled by, 87 Craniofacial skeletal engineering, rhBMP application in, 388 Craniofacial structures, 352 Craniofacial tissue bioengineering/regeneration, by endogenous stem cells, 367–378 Craniosynostosis, 22, 62, 63 in craniofacial bone development, 52 Craniosynostosis syndrome, 125 Craniosynostotic suture, 64 Cre recombinase, 93 Crest cells. See also Cranial neural crest cells (CNCCs) role in FGF signaling, 100 signal exchange between core mesoderm and, 101 Crest–mesodermal interactions, key role of, 102 Critical-sized cranial defects, ASCs for repairing, 245 Critical-sized defect (CSD), 422 Critical-sized supraalveolar defect model, 421 Cross-regulation, of Wnt and Bmp expression, 189 Cross-regulatory control, of signaling molecule genes, 189 Crown dentin, 160
Crown formation, signaling pathways involved in, 171
Crown morphogenesis, root formation and, 158
Crown-to-root transition, 158–160
stem cell loss and, 323
Cryopreserved human PDL, 491
Cultured bone marrow MSCs, 227
Cultured satellite cells, 400
Current good manufacture practice (cGMP) facilities, 477
Current periodontal therapies, 489–490
CXCR4, 369
Cytodifferentiation, 277
Cytokine delivery, effect on pulp regeneration, 374
Cytokine inhibition, 305
Cytokines, 244
Cytotactic ligand/receptor cascade, 368
Decellularized tissue scaffold, 358
Deciduous teeth, 112
Deciduous tooth germs, 123
Decorin, 397, 403
Degradable polymers, 345
del22q11.2 syndrome, 94, 98
Delamination, of neural crest cells, 10–11
Demineralized bone matrix (DBM), 348
De novo tooth formation, 113
dermal cell lineages, 110, 455. See also Teeth; Tooth entries
differentiation among, 117–121
Dental cells, from embryonic mouse molars, 438
Dental CNCC-derived mesenchyme, 37. See also Cranial neural crest cells (CNCCs)
Dental development, mouse model for, 136–137
Dental ecto-mesenchymal cells, 439
Dental ectomesenchymal stem cells, 291
Dental epithelial cells, bone marrow cells mixed with, 437–438
Dental epithelial stem cell growth, promoting in reptiles, 147
Dental epithelial stem cells, 40
Dental epithelium, 53, 118
derivation of, 110
ectoderm-derived, 37
gene expression changes in, 189
stem cells in, 144–145
in tooth formation, 110–111
Dental features, dysmorphic, 173
Dental follicle, 294–298
in tooth eruption, 163
tooth root formation and, 158
Dental follicle cells (DFCs), 111, 295–297
biological function of, 297
osteogenic differentiation potential of, 296
for periodontal bioengineering, 511
as periodontal precursor cells, 297
Dental follicle cell sheets, for tooth root engineering, 487
Dental follicle progenitor cells (DFPCs), for periodontal bioengineering, 510
Dental follicle stem cells (DFSCs), 245
Dental hard tissues, 450
Dental implants, 485. See also Implants
Dental lamina, 110, 123, 124, 448
gene expression patterns of, 142–143
in squamates, 138
invagination of, 137
Dental lamina cells, 127
Dental lamina epithelium, 121
Dental lamina formation, 113, 114
Dental lamina gene expression patterns, successional lamina and, 142–143
Dental mesenchymal cells, 448
dissociated, 439
embryonic, 439
primary enamel knot induction and, 441–442
Dental mesenchymal stem cell differentiation
epigeneic regulation of, 309
molecular regulation of, 306–308
physical factors in, 310
transcriptional regulation of, 308–309
Dental mesenchymal stem cells, 303–314
differentiation potential of, 303, 304
origin of, 437–438
regulation of, 303
Dental mesenchymal tissues, 292
Dental mesenchyme, 113, 287, 437
gene expression changes in, 189
Pax9 and Mx1 function in, 191, 192
Dental neural crest—derived progenitor cells (dNC-PCs), 293–294
SCAPs and, 294
Dental papilla, 110, 292–293, 448, 486
tooth root formation and, 158
vascularization of, 434
Dental papilla cells, origin of, 432
Dental papilla–derived SCAPs, 294. See also Stem cells from apical papilla (SCAPs)
immunoregulatory properties of, 305
Dental/peridental mesenchymal stem cells, 436, 437–438
Dental placodes, 110, 115–117
as signaling centers, 116
Dental problems, biological solutions for, 409
Dental pulp, 287–290
diseased, 372
three-dimensional environment in, 416
Dental pulp cells, 410
Dental pulp–dentin complex, 292
Dental pulp/dentin-like complex, 293
Dental pulp–like tissue regeneration, 372
Dental pulp progenitor cells, in dentin regeneration, 476
Dental pulp regeneration, biomaterials-based approach to, 511–512
Dental pulp stem cells (DPSCs), 40, 212, 306
allogeneic, 488, 489
ASCs vs., 247
in dentin regeneration, 476
immature, 290
immunoregulatory properties of postnatal, 305
in nondental tissue regeneration, 289
for periodontal bioengineering, 510
postnatal, 286, 287–290
SCAP/dNC-PCs and postnatal, 294, 295
Dental root fragment model, 418
Dental signaling centers, regulation of, 112, 115–117
Dental stem cell differentiation, signaling regulation of, 307
Dental stem cells, 285–286, 287
CNCC and, 39–40
implanted, 289
isolated from dental pulp, 287
potential of, 289–290
tooth renewal/regeneration and, 126–127
Dental stem cell types, 288
Dental tissue, stem and progenitor cells from, 285–302
Dental tissue–derived stem cells, 245
features of, 298–299
Dental tissue differentiation, Wnt activation in restoring, 193–194
Dental tissue engineering, 409–428
animal models in, 412–415
progress in, 412
scaffolds in, 410–414
in vitro models in, 415–417
in vivo models in, 417–425
Dental tissue engineering models, 412–425
Dental tissues, regenerating lost, 409
Dentin, 118–119, 154, 155–156, 165.
See also Root dentin formation
bioactive proteins in, 475
Dentin–enamel junction, 432
Dentin extracellular matrix proteins, 475
Dentin formation induction, 474–475
Dentin matrix, 119
Dentin matrix protein 1 (DMP1), 157, 310, 475
Dentinogenesis, 39, 160
reparative, 438
Dentinogenic cells, isolation of, 287
Dentinogenic differentiation, 486
Dentinogenic markers, 486
Dentin phosphoprotein, 119, 157
Dentin production, 160
Dentin-pulp cell culture, 416
Dentin-pulp complex, regenerating, 290
Dentin-pulp-like complex, 288
Dentin regeneration, 288, 461–484
advances in, 462
cell sources for, 476
future perspectives on, 477
Dentin sialophosphoprotein (Dspp), 119
Dentin sialoprotein (DSP), 157
Dentition patterning, 38
Dermal bone differentiation, 21
Dermal fibroblasts (DFs), 211
Desmosomes, 120
Developing condyles, gene expression in, 78
Developmental capacity, reactivation of, 115
Developmental errors, of the forebrain, 8
Developmental mechanisms, understanding, 19–20
Developmental programs, during early embryogenesis, 20
Developmental signaling families, 57
DFC differentiation, 295–296. See also Dental follicle cells (DFCs)
Diabetes, 216
Diastema teeth, vestigial, 144
Diastema tooth buds, 144
Dicer1 deletion, 322
Dickkopf-1 (Dkk1), 61, 182
Dickkopf-related protein 1 (DKK1), 170
Differentially methylated regions (DMRs), 212, 213
Differentially regulated genes (DRGs), 184
in Pax9 and Msx1 mutants, 192–193
Differentiation potential. See also MSC differentiation potential; Odontogenic cell differentiation potential; Osteogenic differentiation potential of ASCs, 243
of dental mesenchymal stem cells, 303, 304
of mesenchymal cells, 443
Diffusible signaling molecules, 180–181, 184–185
DiGeorge syndrome, 94
Digit joint formation, 80
Ding, Gang, x, 485
Dinosaurs, tooth replacement rates in, 140
Directed cell migration, toward tissue damage, 333–334
Direct tissue resection, 242
Diseased dental pulp, 372
Disease modeling, 217
Disease-specific induced pluripotent stem cells, 217
Dissociated dental mesenchymal cells, 439
Distal-less homeobox (Dlx) code, 31
Distal-less homeobox-containing (Dlx) transcription factors, face patterning and, 52
Diverse tooth phenotypes, 117
Distal-less homeobox (Dlx) function, 38
Dlx5/6 expression, craniofacial myogenesis and, 42
Dlx5 Dlx6 double-mutant embryos, 102
Dlx5 inactivation, 35
Dlx code, 38
Dlx genes, in tongue development, 42
DNA encapsulation, 516
INDEX

DNA methylation, 212–213
DNase-seq data, 196
Dog(s)
  bicortical defect in the mandible studies in, 424
  as bone regeneration model, 422
  fenestration defect studies in, 419–420
Dog periodontal regeneration model, 495
Double tissue recombination experiment, 183
DPSC marker expression, 287–288. See also Dental pulp stem cells (DPSCs)
DPSC population, 289–290
*Drosophila*, skeletal muscle development in, 95
Drug compounds, large-scale screening of, 217
Drug delivery systems (DDSs), 505, 509–510
Duchenne muscular dystrophy (DMD), 395–396, 397–399, 402–403, 404
Dura mater (DM) cells, 385
Dyskeratosis congenita (DC), 211
Dysmorphic dental features, 173
Dystrophin, 399, 402
E3 ubiquitin ligase activity, 332
Early dental lamina, gene expression patterns of, 142–143
Early embryonic dental lamina, stem cells in, 123
Early odontogenesis
  E–M signaling in, 180–182
  sequential and reciprocal E–M signaling in, 180–182
  systems biology of E–M signaling dynamics during, 184–194
  Wnt and Bmp signaling in, 182–183
Early-stage jaw epithelium, 439
Early tooth development, systems biology of, 179–202
E-cadherin, 10. See also M-cadherin; N-cadherin expression
Ectoderm, 3, 4
  mandibular, 37
  neural crest cells and, 9–11
  neural induction and, 6–7
  neurulation and, 8
  placodes and, 11–14
Ectodermal differentiation, 214
Ectodermal dysplasia syndromes, 116
Ectodermal expression domains, 100
Ectodermal organs, 110
  development of, 116
  generating, 449
Ectoderm-derived dental epithelium, 37
Ectoderm/ neural crest cells/mesoderm relationships, 21–22
Ectodysplasin (Eda), in successional lamina reformation/survival, 143–144
Ectodysplasin (Eda) signaling pathway, 195
  ED progenitors, 274. See also Excretory ducts (EDs)
  Effector genes, 80
  *Edh1* expression, 32
  Elderly patients, pulp regeneration for, 470–472
  Electrical “short circuit,” 193
  Electrospraying, 353
  Embree, Mildred C., x, 367
  Embryo-derived hemangioblasts, 18
  Embryoid body (EB) formation, 209, 213
  Embryonic blood vessels, 19
  Embryonic dental cells, 434
    whole-tooth organ engineering using, 432–435
  Embryonic dental lamina, stem cells in, 123
  Embryonic dental mesenchymal cells, 439
  Embryonic development, tissue interaction roles in, 78–79
  Embryonic gut, 21
  Embryonic induction concept, 180
  Embryonic mouse molars, dental cells from, 438
  Embryonic muscle, 261–262
  Embryonic myogenesis, 260–262
    model of, 264
  Embryonic patterning, role of endothelial dells in, 19
  Embryonic skeletal muscles, 260
  Embryonic stem (ES) cells (ESCs), 196, 206, 208–209, 297–298, 322. See also ESC entries
    induced pluripotent stem cells vs., 212
    iPSCs vs., 386
    pluripotency of, 371
    similarity to iPSCs, 211–212
    for treating diseases, 208–209
  Embryonic sutures, 62
  Embryonic tooth germ cells, 371
  Embryos, mutant, 37
  E–M compartments, genome-wide gene expression changes across, 184, 185
  Emdogain, 358, 506, 508
  E–M interaction mediation, by extracellular signaling molecules, 185. See also Epithelial–mesenchymal (E–M) entries
  E–M signaling dynamics. See also
    Epithelial–mesenchymal (E–M) signaling systems approach for, 183
    systems biology of, 184–194
  E–M signaling interaction, 196–198

Ectomesenchymal progenitor cells, 293–294
Ectomesenchyme, tooth root formation and, 158
Ectopic ameloblasts, 441
Ectopic bone flap, 384
Ectopic model, of pulp–dentin engineering/regeneration, 464–465
Eda activity, during tooth replacement, 144.
  *See also* Ectodysplasin (Eda) entries
  Eda overexpression mouse, 144
  Edar expression, 144
  Eda signaling, 116–117
  Eda signaling pathway, 195
  ED progenitors, 274. See also Excretory ducts (EDs)
  Effector genes, 80
  *Edh1* expression, 32
  Elderly patients, pulp regeneration for, 470–472
  Electrical “short circuit,” 193
  Electrospraying, 353
  Embree, Mildred C., x, 367
  Embryo-derived hemangioblasts, 18
  Embryoid body (EB) formation, 209, 213
  Embryonic blood vessels, 19
  Embryonic dental cells, 434
    whole-tooth organ engineering using, 432–435
  Embryonic dental lamina, stem cells in, 123
  Embryonic dental mesenchymal cells, 439
  Embryonic development, tissue interaction roles in, 78–79
  Embryonic gut, 21
  Embryonic induction concept, 180
  Embryonic mouse molars, dental cells from, 438
  Embryonic muscle, 261–262
  Embryonic myogenesis, 260–262
    model of, 264
  Embryonic patterning, role of endothelial dells in, 19
  Embryonic skeletal muscles, 260
  Embryonic stem (ES) cells (ESCs), 196, 206, 208–209, 297–298, 322. See also ESC entries
    induced pluripotent stem cells vs., 212
    iPSCs vs., 386
    pluripotency of, 371
    similarity to iPSCs, 211–212
    for treating diseases, 208–209
  Embryonic sutures, 62
  Embryonic tooth germ cells, 371
  Embryos, mutant, 37
  E–M compartments, genome-wide gene expression changes across, 184, 185
  Emdogain, 358, 506, 508
  E–M interaction mediation, by extracellular signaling molecules, 185. See also Epithelial–mesenchymal (E–M) entries
  E–M signaling dynamics. See also
    Epithelial–mesenchymal (E–M) signaling systems approach for, 183
    systems biology of, 184–194
  E–M signaling interaction, 196–198
E–M tissues, transcriptional coupling of, 184–185
En2 expression, 96
Enabling technologies, for bone bioengineering, 351, 352–354
Enamel, 119–121
Enamel epithelial bulge, 139–140
Enamel epithelium, 112
Enamel knot(s), 110, 114, 115–117, 139, 448
 in mouse odontogenesis, 181–182
 secondary, 140
 as transient epithelial signaling centers, 117
Enamel knot formation, 441–442
Enamel knot signaling, 117
Enamel matrix, 119, 121
Enamel matrix derivative (EMD), 508–509, 513
Enamel matrix proteins (EMPs), 170, 508
Enamel organ, 110, 119
Enamel organ engineering, cell sources for, 435–436
Encapsulation, of DNA, 516
Endochondral ossification, 51, 78
Endocranial posterior frontal suture fusion, 53
Endoderm, 3, 4–6. See also Anterior visceral endoderm (AVE) formation
 contribution to head development, 20
 oral cavity and, 20
 pharyngeal, 20
 signal(s) arising from, 21
Endodontically treated teeth, 372
Endogenous axon guidance, 289
Endogenous orofacial regeneration, 375
Endogenous regeneration, facilitated, 512–513
Endogenous stem cells, craniofacial tissue bioengineering/regeneration by, 367–378
Endogenous tissue engineering, 513
Endothelial cell migration, 20
Endothelial cell networks, role of, 20
Endothelial cell/neural crest cell interdependency, 20
Endothelial cells
 mesoderm and, 17–20
 neurogenesis and, 19
 role in embryonic patterning/organ differentiation, 19
 role in vascular development phases, 18
Endothelial–epithelial interactions, 278
Endothelial signaling, in neural development, 19
Engineered skin, 215
Entity theory, 207
Environmental niche, 385
Ephrin–Eph binding, 61
Epibranchial placodes, 12
Epigenetic memory, 213
Epigenetic regulation, of dental mesenchymal stem cell differentiation, 309
Epigenetic reprogramming, 212
Epigenetics, reprogramming and, 212–213
Epithelial bud stage, in squamate teeth, 139
Epithelial cell rests of Malassez (ERM), 111, 118
Epithelial cell sources, in tissue recombination experiments, 443
Epithelial–mesenchymal (E–M) GRNs, 186–189, 197, 198. See also E–M entries; Gene regulatory networks (GRNs)
Epithelial–mesenchymal (E–M) interactions, 34, 137, 179–180, 450, 451
 reciprocal signaling dynamics in, 189
 self-sustaining, 197
 signaling requirements in, 182
 systems approach to understanding, 183–184
 for tooth morphogenesis, 112–113, 114
Epithelial–mesenchymal interface, 431
Epithelial–mesenchymal junction, specification of, 438–439
Epithelial–mesenchymal (E–M) signaling. See also E–M signaling entries
 in early odontogenesis, 180–182
 in tooth root development, 168
Epithelial–mesenchymal transition (EMT), 324
Epithelial morphogenesis, 116
Epithelial–neuronal communication, 277–278
Epithelial progenitor–niche communication, 276–278
Epithelial progenitor pool, expanding, 278–279
Epithelial progenitor cells, in teeth, 123
Epithelial signaling centers, 115–116, 448
 enamel knots as, 117
Epithelial somites, 88
Epithelial stem cell niche, in the mouse incisor, 317–323
Epithelial stem cells, 121, 127, 272
 localization in the incisor, 317
 nature of, 324
Epithelial Wnt activation, in restoring dental tissue differentiation, 193–194
Epithelial Wnt signaling, constitutive activation of, 193, 194
Epithelium
 mesenchymal condensations and, 53
 odontogenic potential induction in, 112–115
ESC differentiation, 213. See also Embryonic stem (ES) cells (ESCs)
 ESC lines, 207
 ESC pluripotency, verification of, 209
 E-selectin, 369
Ethylenediaminetetraacetic acid–soluble tooth proteins (ESTPs), 475
European Commission (EC), on dental tissue engineering models, 412
Ever-growing teeth, 316–317. See also Continuously growing teeth
 evolution of, 316–317
Evolution
 head muscle, 99
 reptile, 135–136
 vertebrate, 99
Evolutionarily conserved stem cells, 137
Evolutionary diversity, in jaw muscle morphology, 16
Excretory ducts (EDs), 272. See also ED progenitors
"Exogenous" cells, 432
Expanded cells, in periodontal endogenous
regeneration, 511
Expanded human bone marrow CFU-F, 225. See also
Colony-forming units–fibroblastic (CFU-F)
Extracellular environment, importance of, 513
Extracellular matrix composition, 157–158
Extracellular matrix/matrices (ECM/ECMs), 228,
263, 310, 354, 440, 507, 508, 513–514
growth factors in, 264
TMJ development regulation by, 81
Extracellular matrix (ECM) production, 35
Extracellular matrix proteins, 217, 467
in acellular cementum formation, 162
Extracellular matrix scaffolds, 475–476
in soft tissue reconstruction, 247–248
Extraocular muscle development, genetic control of,
91–92
Extraocular muscle morphogenesis defects, 92
Extraocular muscle patterning, 91
Extraocular muscles (EoMs), 15, 87, 91
Extraocular myogenesis, 92
Extraocular myotubes/myoblasts, 91
Extrinsic neural crest cell specification, 11
Ex vivo–expanded adult human CFU-F, 225. See also
Colony-forming units–fibroblastic (CFU-F)
Ex vivo–expanded bone marrow CFU-F, 225
Ex vivo–expanded bone marrow MSCs, 224. See also
Mesenchymal stem cells (MSCs)
efficacy of employing, 233
Ex vivo–expanded CFU-F, 224. See also
Colony-forming units–fibroblastic (CFU-F)
Eya1/2 gene expression, 13
Eya1 (EYA1) function, 96, 97
Eye muscles, 91
Face
building blocks of, 6
congenital defects of, 3
Face patterning, distal-less homeobox-containing
transcription factors and, 52
Facial expression muscles, 93
Facial lipoatrophy, 249
Facial prominences, blueprint of, 21
Facilitated endogenous regeneration, 512–513
Familial adenomatous polyposis (FAP), 125
Fas receptor, 306
Feeding mechanism, 42
Fenestration defect model, 419–420
Feng, Jifen, x, 329
Ferret tooth replacement, 123
Fetal SMG Kit+ cell population, 276. See also
Submandibular glands (SMGs)
Fgf3 expression, 321, 332. See also Fibroblast
growth factor entries
Fgf4 induction, 117
FGF6 function, 43–44. See also Fibroblast growth
factor 6 (FGF6)
Fgf7 postradiation treatment, 279
Fgf8 expression, 37, 113
FGF8 expression, 100
Fgf8 function, 115
FGF8 signal, 38
Fgf9 expression, 36
FGF10, taste papilla development and, 44. See also
Mesenchymal FGF10
Fgf10 expression, 35, 36, 43, 321, 332
FGF10 function, 43
Fgf10 modulation, 323
Fgf activity, 332
FGF functions, 43
Fgfr2b function, 195
Fgfr2b function, 321
Fgfr2c expression, 195
Fgfr2 expression, 115, 323
Fgf signaling, 12, 13
FGF signaling, 9, 16, 93, 96, 348
neural crest cell formation and, 9–10
role of crest cells in, 100
FGF signaling pathway, 90
significance of, 43–44
Fgf signaling pathways, 321
Fgf signals, 119
Fibrin degradation, 514–515
Fibrin scaffolds, 475
Fibroblast growth factor 2 (FGF2), 245, 264, 266,
347, 382, 397, 401, 467, 509. See also FGF
Fibroblast growth factor 3 (FGF3), 245, 264, 266.
See also FGF6 function
Fibroblast growth factor 23 (FGF23), 171
Fibroblast growth factor (FGF) family signals,
expression during odontogenesis, 144
Fibroblast growth factors (FGFs), 37, 307
continuously erupting mouse incisors and, 147
in successional lamina reformation/survival,
143–144
Fibroblasts, 264
induced pluripotent stem cells reprogrammed from
senescent, 216
Fibronectin, 354
Fibrosis, 259, 403
Fibrotic tissue, formation of, 396–397
FLICE-like inhibitory protein (FLIP), 306
Fluorescence resonance energy transfer sensors,
440
Foliate lingual papillae, 44
Follicle cells, in acellular cementum formation, 162
Follicle-derived embryonic neural crest (FENC) stem cells, 297–298, 299
Follistatin-BMP7 regulatory circuit, 44
Follistatin (Fst) expression, 321
Follistatin overexpression, 125
Follistatin overexpression/deletion, 117
Forebrain, 7, 8
developmental errors of, 8
Foster, Brian L., x, 153
Foxc1 transcription factor, 62
Fra1. See OS-related antigen 1 (Fra1)
Fractionated pulp stem cells, 470
“Fringe fibers,” in acellular cementum formation, 162
Frontonasal prominence, 32
Functional teeth, bioengineering of, 447–459
Functional tissues, regeneration of, 477
Fungiform lingual papillae, 44
Furcation defect model, 421
β-Galactosidase (LacZ+), 334–335, 337
Ganglion coalescence, loss of, 14
Garlick, Jonathan A., x, 205
Gastrulation, 3, 260
craniofacial development during, 4
Gecko stem cells, 145, 147–148
Gene-activated matrix (GAM), 516
Gene coexpression, 333
Gene delivery, of anti-inflammatory factors, 516–517
Gene expression, in the developing condyle and primary cartilages, 78
Gene expression alteration/changes in dental epithelium and mesenchyme, 189
via gene therapy, 388
Gene expression pattern compendium, 190
Gene expression patterns of early dental lamina, 142–143
in progenitor cell populations, 97
Gene mutations, related to craniosynostosis, 64
Gene promoters, 213
Gene regulation, 198
Gene regulatory circuits, 102
Gene regulatory networks (GRNs), 180, 183–184
for organ development, 195–196
reconstructing for odontogenic E–M interactions, 186–190
signaling-based, 187–188
in tooth development, 112
Gene-related mineralization, 247
Genes linked to abnormal tooth development, 169–170
molecular roles of, 186
regulating tooth development, 109–110
as signaling pathway targets, 141–142
Gene-targeting experiments, 7
Gene therapy for bone bioengineering, 354
muscular dystrophies and, 395–396
nonviral, 516
for periodontal engineering, 516–517
potential of, 388, 389
stem cells and, 388–389
Genetically ablated satellite cells, 400
Genetically altered cells, potential of, 389
Genetically modified mouse models, phenotypic analyses of, 79
Genetic alterations, iPSC-related, 217
Genetic bone defects, correcting via gene and cell therapy, 389
Genetic-fate mapping experiments, 320
Genetic lineage tracing, 274–275, 330
Genetic muscle diseases, 403
Genetic mutations, osteoblast development and, 57
Genetic regulatory interactions, 179
Genome microarrays, 331
Genome-wide gene expression changes, across E–M compartments, 184, 185
Genome-wide spatiotemporal expression profiling, 185
Genomic migration, of transgenes, 387
Germ layer development, specification of, 214
Germ layer tissues, 3
coordinated integration of, 21
Gimble, Jeffrey, x, 241
Gingival tissue, stem and progenitor cells from, 285–302
Gingival tissue–derived MSCs (GMSCs), 298. See also Mesenchymal stem cells (MSCs) as a cell source for medical applications, 299
immunoregulatory properties of, 305
for periodontal bioengineering, 510
Gittens, Rolando, x, 341
Gland duct ligation, 278
Glandular mesenchyme, 276
Glandular regeneration, 273
Glenn fossa Ihh activation and, 79–80a of the temporomandibular joint, 73, 74, 76
Glenn fossa blastema, 72, 73
Glenn fossa development, tissue interactions and, 78–79
Glenn fossa primordium, mesenchymal condensation of, 72–73
Gli1 expression, 320
Gli3 Hedgehog repressor, 64–65
Glia, 12
Gli1al cell line–derived neurotrophic factor (GDNF), 466
Global gene expression analysis, 191
Glossal structure, 16
Glycolic/lactic acid copolymer (PGLA), 345
Goat(s), as bone regeneration model, 422
Goat(s), as bone regeneration model, 422
Good manufacturing practice facilities, 477, 517
Graft-versus-host disease (GVHD), 488
INDEX

Graft-versus-host disease models, 244
Granular convoluted tubules (GCTs), 272
Granulocyte colony-stimulating factor (G-CSF), 466
Granulocyte–macrophage colony-stimulating factor (GM-CSF), 466
Greffe, Sander, x, 259, 395
Gremlin antagonist, 170
GRN reconstruction, from regulatory data, 186–190. See also Gene regulatory networks (GRNs)
Gronthos, Stan, x, 223, 303
Grova, Monica, x, 379
Growth and cavitation stage, of TMJ development, 72, 73, 74
Growth cones, 20
Growth factor–based therapies, 397–399
Growth factor carriers, biomaterials as, 410
Growth factor cues, for pluripotent stem cell differentiation, 213–214
Growth factor delivery, 508–510, 516 for bone bioengineering, 354
Growth factor–mediated signaling pathways, 64 roles in TMJ development, 80–81
Growth factors (GFs), 60, 264–266, 341–342, 346–349, 502–503, 504. See also Basic fibroblast growth factors (bFGFs); FGF entries; Fibroblast growth factor entries; Hepatocyte growth factor (HGF); Insulin-like growth factor 1 (IGF1); Nerve growth factor (NGF); Platelet-derived growth factors (PDGF); Transforming growth factor β (TGFβ); Vascular endothelial growth factor (VEGF) entries actions of, 372
affecting progenitor cell proliferation, 277
bone bioengineering applications of, 354–358
effect on seeded myoblasts, 401
inhibitory, 266
involved in bone regeneration, 347
muscle disorders/regeneration and, 396
muscle trauma and, 403
osteogenic, 348
osteoductive, 347–348
in primary cartilage development, 80
recombinant, 507–508, 509
satellite cells and, 264–266
stimulatory, 264–266, 267
for tissue regeneration, 510
Growth factor secretion, 351
Gsc expression, 37, 38
Gu, Shuping, x, 71
Guided bone regeneration (GBR), 423, 424, 502
Guided tissue regeneration (GTR), 490, 501
Gustatory papillae development, influence of CNCC-derived tongue mesenchyme on, 44–45
H2B-GFP expression, 320
HA biomaterial composites, 232. See also Hydroxyapatite (HA)
Hair follicle properties, of reptile dental laminae, 146
Hair regeneration, stem cells and, 145–146
Hand2 expression, 41–42
Hard palate, 32
submucous cleft of, 36
HA/SCAP-gelfoam/PDLSC structure, 486–487. See also Hydroxyapatite (HA); Periodontal ligament stem cells (PDLSCs); Stem cells from apical papilla (SCAPs)
HA/TCP carriers, 486, 487, 489. See also Tricalcium phosphate (TCP); β-Tricalcium phosphate (β-TCP)
HA/TCP group, 494–495
Head. See also Cranio- entries
building blocks of, 6
complexity of, 3
congenital defects of, 3
skeletal muscle formation in, 16
skeletal muscles in, 15
vertebrate, 11–12, 14
Head development, endoderm contribution to, 21
Head induction, 9
Head mesoderm, 16
Head mesoderm patterning, phases of, 16
Head muscle development, connecting with heart muscle development, 96–98
Head muscle evolution, 99
Head muscles, 261
Head tissues, registration among, 21
Heart muscle development, connecting with head muscle development, 96–98. See also Cardiac entries
Hedgehog (Hh) gene family, 80
Hedgehog (Hh) pathway, 138
Hedgehog (Hh) pathway inhibitor, 322
Hedgehog (Hh) signaling, 119
in NCCs, 42–43
Hedgehog (Hh) signaling activation, 42
Helix loop helix transcription factors, 94
Helsinki BITE-IT tooth gene expression database, 185, 190
Hemangioblast concept, 18
Hematopoiesis, 225, 227, 307
regulation of, 223
Hematopoietic cells, distinguishing, 226
Hematopoietic precursor cell marker, 290
Hematopoietic progenitor cells, 227
Hematopoietic stem cells (HSCs), 206, 227, 286, 401
Homing of, 368, 469
tissue homeostasis and, 303
Hensen’s node, 7
Heparan sulfate proteoglycans (HS-PGs), 81
Hepatocyte growth factor (HGF), 244, 264, 265, 397, 401
Hepatocyte growth factor (HGF), 244, 264, 265, 397, 401
immunoregulatory properties of, 305
Hereditary orbitozygomatic defects, repair of, 248
Hermann, Christopher D., x, 341
HERS function impairment, 173. See also Hertwig’s epithelial root sheath (HERS)

HERS growth, in cellular cementum formation, 163
HERS–odontoblast communication, 169
Hertwig’s epithelial root sheath (HERS), 111, 158, 160
cementogenesis and, 170
disruption of, 162
in tooth root development, 168
hESC-derived cell lines, 215–216. See also Human embryonic stem cells (hESCs)
hESC-derived cells, 215
Heterodont teeth, 109, 316
Heterotopic reassociations, 441, 442
Hewitt, Kyle J., x, 205
Hh receptors, 80. See also Hedgehog (Hh) entries
Higher vertebrates, tissue regeneration in, 64
High-throughput data, 196
High-throughput technologies, 82
Hindbrain, 8
Ho, Joshua W. K., x, 179
Hoffman, Matthew P., x, 271
Homeodomain transcription factors, 88, 90, 91–92, 96
Homeostasis, of adult tissues, 315
Homing factors, 469, 470. See also Cell homing entries
“Homing” signals, 513
Homodonts, 316
Homogeneous cell population, achieving, 382
Horizontal tooth replacement, 124
Hoxa2 expression, 16
forced, 52
Hox code, craniofacial bone patterning and, 52
Huang, George T.-J., ix, xi, 205, 285, 461
Human adipose-derived stromal cells (hASCs), as building blocks for cell-based therapy, 383
Human allogeneic MSCs, immunogenicity of, 474. See also Mesenchymal stem cells (MSCs)
Human bone marrow CFU-F phenotype, 229–230. See also Colony-forming units–fibroblastic (CFU-F)
Human bone narrow MSCs, perivascular properties of, 228–230. See also Mesenchymal stem cells (MSCs)
Human cementoblastoma–derived protein, 509
Human craniofacial disorders, 101
Human dental epithelial stem cells, 286
Human dental pulp–dentin, de novo regeneration of, 465
Human dental tissues, regenerating lost, 409
Human dentition, development of, 112
Human-derived ASCs, 245. See also Human adipose-derived stromal cells (hASCs)
Human embryonic stem cells (hESCs), 208–209. See also hESC-derived entries
derivation of, 210
Human fibroblasts, 211
Human gene mutations, resulting in calvarial bone phenotypes, 58–59
Human impacted molar DFCs (HIM-DFCs), 511
Human maxillofacial repair, 248
Human mesenchymal stem cells (MSCs), 127
Human PDL, cryopreserved, 491. See also Periodontal ligament (PDL)
Human PDLSCs, 491. See also Periodontal ligament stem cells (PDLSCs)
Human pulp stem cells, recovering and expanding, 472
Humans, successional lamina in, 140
Human SCAPs, 487. See also Stem cells from apical papilla (SCAPs)
Human temporomandibular joint (TMJ). See also Temporomandibular joint (TMJ)
organisms of, 73
development of, 73
Human tooth replacement, 123
Hyaluronic acid (HA), 476. See also Hydroxypatite (HA)
Hydrogel matrices, for periodontal bioengineering, 505
Hydrogels
bone bioengineering and, 355
for periodontal bioengineering, 503
self-shaped, 515
Hydrogel sponges, 515
Hydrophilic surfaces, 507
Hydrophobic materials, 507
Hydroxypatite (HA). See also HA entries
in dental tissue engineering, 411
for periodontal bioengineering, 504, 505–506
Hydroxypatite scaffold, 371, 476
Hypertrophic chondrocytes, 76
Hypodontia, 125
Hypoglossal cord, 90
Hypodontic ectodermal dysplasia (HED) syndrome, 116, 144
Hypoplastic branchiomeric skeletal muscles, 94
Hypoplastic muscles, 94
Hypophysal, 271, 272, 278
Hypoplastic mandible, 36
Hypoplastic mandible, 36
Hypoplastic mandible, 36
Hypodontid teeth, 316, 317
Hypodontic teeth, 316
Hun, Jeong S., x, 379
ID progenitors, 274. See also Intercalated ducts (IDs)
Ihh activation, 79–80
Ihh controlled-diffusion range, 81
Ihh signaling, 80
Immature dental pulp stem cells (IDPSCs), 290
Immature root papilla stem cells (iRPSCs), 304
Immature tooth revitalization, 462–464
INDEX

clinical protocol for, 463
Immune component regulation, 305
Immune helper antigens, 230
Immunogenicity, 243–244
Immunological properties, of periodontal ligament stem cells, 493
Immunomodulatory regulation, 243–244
Immunoregulatory properties, 305
Immunosuppression, 244
Immunosuppressive activity, 244
Immunosuppressive factors, 305
Implants. See also Dental implants
innervation of, 432, 433
regulatory guidelines for, 358
Incisal tip niche, 335–336
Incisor pulp chamber, 330
Incisor renewal, overproduction of progeny during, 324
Incisor repair, 335–336
Incisors. See also Mouse incisor(s)
continuous growth of, 329–330
epithelial stem cell localization in, 317
self-sharpening, 330
Incisor stem cell biology, 323–324
Incisor stem cell location, 317–320
Incisor stem cell regulation
by microRNAs, 322–323
Incisor stem cells, identifying, 320
Indefinite tooth replacement, 145
lack of, 140–141
Indolent-2,3-dioxygenase (IDO), 230
Induced pluripotent stem cells (iPSCs), 206, 211, 289, 292, 385–388, 436. See also iPSC entries
autologous, 386
disease-specific, 217
embryonic stem cells vs., 212
ESCs vs., 386
intrinsic vs. acquired immunogenicity of, 386
MSCs derived from, 217
reprogrammed from senescent fibroblasts, 216
similarity to ESCs, 211–214
telomere/telomerase activity of, 211
tetraploid complementation and, 211–212
for therapeutic use, 212–213
transgene-free human, 387
Induced vascularization, 469–470
Inducible NO synthase (iNOS), 230
Inductive epithelial signal(s), 441
Inductive influences, in tooth root development, 165–168
inductive interactions, 180
Inductive tissue interactions, 180
organ formation and, 197
Inferior border of the mandible model, 424
Inflamed PDL–tissue PDLSCs (thPDLSCs), 291, 493. See also Periodontal ligament stem cells (PDLSCs)
Inflamed pulp DPSCs (DPSCs-IP), 290. See also Dental pulp stem cells (DPSCs)
Ingrown periapical tissues, 464
“Inhibitory cascade,” 124
Inhibitory growth factors, 266
Initiation stage
in mouse odontogenesis, 181
of TMJ development, 72
Injectable scaffolds, 507, 514–515
Injured tissue, homing to, 368
Inner enamel epithelium (IEE), root formation and, 158
Innervation. See also Reinnervation
of implants, 432, 433
of teeth, 111
Insertional mutagenesis, 387
Insulin-like growth factor 1 (IGF1), 264, 265, 397
in tooth root development, 168
Insulin-producing pancreatic β-like cells, 216
Integrative genomics, new techniques in, 196
Integrin clustering, 346
Integrins, 262
Intercalated ducts (IDs), 272. See also ID progenitors
Intercalated progenitors, acinar cell repopulation by, 274
Interferon-γ (IFN-γ), 266, 305–306
Intercellular, 278
Interinterstitial self-sustaining feedback circuits, 195
Intact interstitial cells, 278
Intrapulmonary Wnt-Bmp signaling circuit, 193
Intramembranous bone development/regeneration, 51–70
Intramembranous bone growth, modeling, remodeling, suture formation, and function, 61–64
Intramembranous bone regeneration, 65–66
Intramembranous bone development processes, 59
Intramembranous bone phenotypes, human gene mutations resulting in, 57–59
Intramembranous bones, origin from osteogenic condensations, 53
Intramembranous ossification, 51, 54
of the temporomandibular joint, 73
Intramuscular blood vessel development, 19
Intramuscular plexus formation, 18
Intrinsic immunogenicity, of iPSCs, 386
Intrinsic neural crest cell specification, 11
In vitro models, in dental tissue engineering, 415–417
In vivo bone formation, using ASCs, 384
In vivo models
in dental tissue engineering, 417–425
for periodontal regeneration, 419
In vivo orthotopic bone tissue regeneration, using GMSCs, 298
In vivo tooth organ replacement, 452–455
iPSC-derived cell lines, 215–217. See also Induced pluripotent stem cells (iPSCs)
INDEX

iPSC-derived tissues, potential therapeutic applications of, 216
iPSC differentiation, 213
iPSC generation, cell types for, 212
iPSC transplants, 387
Irradiated glands
loss of acinar cells in, 272–273
regenerating, 271
Irradiation-activated material surface, 507
Irradiation-induced cell death, 278
Irradiation treatment, salivary gland damage from, 271
Isl1-expressing cells, 97
Isl1-expressing progenitor cells, 96
Isl1 expression, 93
ISL1 function, 97
ISL1-positive cells, 99
Isl-expressing cells, analysis of, 98–99
Isolation methods, for adipose tissue harvesting, 242
Jansen, John A., xi, 409
Jaw muscle differentiation anomalies, 16
Jaw muscle morphology, evolutionary diversity in, 17
Jheon, Andrew H., xi, 315
Jiang, Nan, xi, 367
Jin, Yan, xi, 501
Joint regulation, of Wnt and Bmp expression, 189
Juuri, Emma, xi, 109
Keller, L., xi, 431
Kelly, Robert G., xi, 87
Kit+ end-bud cells, 276
Kit+ progenitors, 278, 279, 280
multipotent/self-renewing, 275–276
Klein, Ophir D., xi, 315
Kong, Kimi, xi, 367
Krt14 expression, 322
Kuchler-Bopp, S., xi, 431
Labeled stem cells, 286
Labeling experiments, 317
Label-retaining assay, 274
Label-retaining cells (LRCs), 126–127, 320
Labial CL, 317–320, 321. See also Cervical loops (CLs)
LacZ+. See β-Galactosidase (LacZ+)
Lamina stage, 448
Large-animal bone defect models, 231
Large-animal models, for bone regeneration, 422
Large-scale screening, of drug compounds, 217
Large skeletal defect reconstruction, 379–381
Laryngeal structure, 15
Laryngoglossal craniofacial skeletal muscles, 15, 16
Larynx muscles, 93
Late-passage ASCs, 243
Lateral cranial mesoderm, 91
Lateral lingual swellings, 40
Lee, Chang Hun, xi, 367
Lee, Christopher S. D., xi, 341
Left1 expression, 141–142, 143
Left1 transcription factor, 114
Lens placode, 12
Lesot, Hervé, xi, 431
Leukocyte trafficking, 368
Lhx6 expression, 37, 38
Lhx7 expression, 37, 38
Lhx expression, 37
Ligand/receptor cascade, 368
Limb muscles, 94
craniofacial muscles vs., 266–267
Lineage formation, by salivary gland progenitors, 274–275
Lingual CL, 317–320. See also Cervical loops (CLs)
Lingual papillae, 44–45
Liposcraptes, 383
Lipomatosis, facial, 249
Liposuction techniques, 242
Lipotransfer, cell-assisted, 249
Liu, Yi, xii, 485
Lo, David D., xii, 379
Lombaert, Isabelle M. A., xii, 271
Longaker, Michael T., xii, 379
Long bone development, 80
Longitudinal skeletal muscles, Tbx1-positive, 99
Long noncoding RNAs (lncRNAs), 196
Lower jaw, proximal–distal patterning of, 41. See also Mandibular entries
LRP6 coreceptor, suppression of, 9
L-selectin, 369
Maas, Richard L., xii, 179
Macrophage colony–stimulating factor (M-CSF), 59, 60
Macrophages
in mammary glands, 278
muscle regeneration and, 264
Malformation syndromes, 22
Mammalian condylar development, 73–74
Mammalian hair regeneration, stem cells and, 145–146
Mammalian neural crest cell induction, 10
Mammalian organogenesis, 179
Mammalian PRC1, 331–332, 333. See also Polycomb repressor complex 1 (PRC1) proteins
Mammalian teeth, 109
Mammalian TMJ condyles, secondary cartilage in, 76–78. See also Temporomandibular joint (TMJ)
Mammalian tooth development schematic, 111
Mammal-line amniota, tooth replacement in, 136
Mammals
temporomandibular joint structure among, 71–72
tooth initiation in, 110
tooth reduction in, 136
tooth renewal in, 121
Mammary glands, macrophages in, 278
Mandible bioengineering, 357
Mandibular arch, 100
Mandibular arch patterning, 101–102
Mandibular CNCCs, 32. See also Cranial neural crest cells (CNCCs)
Mandibular ectoderm, 37
Mandibular process, 41
Mandibular prominence, 31–32
Mandibular ramus model, 423–424
Mandibular structures, 38
Mandolfo, Hilde, 180
Mantle dentin, 160
Mao, Jeremy J., xii, 367
Marker identification, 320
Markers
of aging, 472
dentinogenic, 486
expressed by CFU-F, 227
of mesenchymal stem cells, 330
Mastication muscles, 87, 92–93
Materials, used in dental tissue engineering, 410
See also Extracellular matrix entries;
Nanofibrous matrices; Stiff matrices
Matrix–membrane–microfilament interactions, 440–441
Matrix metalloproteinase 3 (MMP3), 466, 467
Matrix metalloproteinase (MMP)–degradable peptides, 354
Matrix mineralization, 351
Matrix proteins, 158
Matrix scaffold-treated dentin matrix (TDM), 487.
See also Treated dentin matrix (TDM) scaffolds
Matrix secretion, 351
Maturation stage, of TMJ development, 72
Mature root papilla stem cells (mRPSCs), 304
Mature teeth with complete apical closure, pulp regeneration in, 465–474
Maxillary CNCCs, 32. See also Cranial neural crest cells (CNCCs)
Maxillary molar domain, establishment of, 38
Maxillary prominence, 31–32
Maxillary sinus augmentation, 231, 357
Maxillary sinus augmentation model, 424–425
Maxillary structures, 38
Maxillofacial bone bioengineering, 357
Maxillofacial repair, human model for, 248
M-cadherin, 399. See also E-cadherin; N-cadherin expression
mdx mouse model, 399
Mechanical loading, in dental tissue engineering, 416
Mechanically induced periodontal ligament cell regulation, 416
Mechanical stress, response of bioengineered teeth to, 454
Mechanotransduction, 440–441
Mecckel’s cartilage, 73, 78
Medial cranial mesoderm, 91
Medial–lateral axis, 35
Median lingual swelling, 40
Medical research, stem cell and regenerative, 245
Mendelson, Avital, xii, 367
MES cells, apoptosis of, 34. See also Midline epithelial seam (MES)
Mesencephalon, 8
Mesenchymal Bmp4 expression, 190–191
Mesenchymal cell condensation, 53
Mesenchymal cell heterogeneity, 433
Mesenchymal cell requirements, for tooth engineering, 438–442
Mesenchymal cells. See also Mesenchymal stem cells (MSCs)
differentiation potentials of, 443
dissociated dental, 439
embryonic dental, 439
odontogenic potential of, 434
in rodent teeth, 370
Mesenchymal cell sources, 436–438
Mesenchymal condensation(s), 38
lack of, 53
proximity to epithelia, 53
of the temporomandibular joint, 72–73
Mesenchymal condensation formation, 52–53
Mesenchymal differentiation, trilineage, 226
Mesenchymal FGFI0, in tooth root development,
168. See also FGFI0 entries; Fibroblast growth factor entries
Mesenchymal preodontoblasts, 118
Mesenchymal stem cell markers, 291
Mesenchymal stem cell niches
cell populations within, 331
in rodent tooth pulp, 329–338
Mesenchymal stem cells (MSCs), 40, 65, 127, 206,
286, 329, 437, 466. See also Mesenchymal stromal cells (MSCs); MSC entries
allogeneic, 474
alternative sources of, 472–473
cell homing by, 332–334
dental/peridental, 436–438
derived from iPSCs, 217
future prospects for, 336–337
identifying in vivo, 330
immunosuppressive effects of, 488, 517
inhibitory effects of, 230
markers of, 330
non-dental-derived, 245
in osteoblast origination/differentiation, 56
potential of, 223
regenerative capability of, 512
stemness of, 305
tissue homeostasis and, 303
Mesenchymal stem cells (MSCs) (Continued)
tissue origin of, 349–350
transplantation of, 472
Mesenchymal stromal cells (MSCs), 381–383. See also Mesenchymal stem cells (MSCs); MSC entries
in bone regeneration, 382
isolation and characterization of, 382
multipotent capacity of, 382
Mesenchymal tissue development, 79
Mesenchymal transcription factors, 115, 190
disruption of, 182
Mesenchyme glandular, 276
odontogenetic potential induction in, 112–115
Pax9 and Msx1 function in dental, 191, 192
stem cell origin in, 437–438
Mesenchyme-derived factors, in lingual papillae development, 44
Mesoangioblasts, 400, 403
Mesoderm, 3, 4–6
endothelial cells and, 17–20
formation and patterning of, 15–16
muscle and, 15–17
regionalization of, 15
Mesodermal cells, in craniofacial bone development, 52
Mesodermal cores, 21
Mesodermal layer, 260
Mesoderm-derived myoblasts, distribution and alignment of, 22
Mesoderm/ectoderm/neural crest cells relationships, 21–22
Mesoderm/neural crest cell interactions, 100
Mesoderm–neural crest interactions, 16–17
Metallic biomaterials, in dental tissue engineering, 412
Methylation analysis, 212–213
Microarrays, 330. See also Genome microarrays
Methylation analysis, 212–213
Microarrays, 330. See also Genome microarrays
Microglossia, 43
MicroRNAs (miRNAs), 171, 196
incisor stem cell regulation by, 322–323
role in MSC differentiation, 309
Microvascular ectopic bone flap, 384
Methylation analysis, 212–213
MicroRNA analysis, 492
Mice, 144. See also Mouse entries
bioengineered teeth in, 127
successional tooth formation in, 125
supernumerary tooth development in, 125–126
Michon, Frederic, xii, 315
Molecular blueprint, for craniofacial morphogenesis/development, 3–29
Molar CLs, 323. See also Cervical loops (CLs)
Molar mesenchymal stem cell niche, 336, 337
Molar morphologies, 117
Molar odontogenesis, E–M interactions in, 180
Molars brachydont, 316–317
posterior addition of, 124
Mineralization gene-related, 247
of osteoid, 55
of teeth, 110–111
tooth eruption and, 120
Mineralized tissues, in tooth roots, 153–154
Mineral metabolism, hormonal regulators of, 171
Mineral trioxide aggregate (MTA), 464, 465
Mitochondrial permeability transition pore (mPTP), 403
Mixed cell aggregates, 450
Mixed-lymphocyte reaction, 244
MMP2/9, 369
Models. See also Animal bone defect models; Animal models; Bone defect models; Calvaria-defect models; Cell homing models; Craniofacial preclinical animal models; Dental tissue engineering models; Ectopic model; Genetically modified mouse models; Graft-versus-host disease models; In vitro models; Large-animal bone defect models; Mouse (mice) models; Mutant mouse models; Orthotopic model; Periodontal cell culture models; Preclinical animal models; Rat models; Severe combined immunodeficiency (SCID) mouse model; Three-dimensional (3D) culture models
acute–chronic, 420–421
acute defect, 418
alveolar extraction sockets, 423
bicortical defect in the mandible, 424
bone regeneration, 421–425
chronic defect, 418
dental root fragment, 418
dental tissue engineering scaffold, 425
dog periodontal regeneration, 495
fenestration defect, 419–420
furcation defect, 421
inferior border of the mandible, 424
intrabony defect, 420–421
mandibular ramus, 423–424
maxillary sinus augmentation, 424–425
periodontal defect, 418
periodontal regeneration, 418–421
prenatal, 409
pulp–dentin complex regeneration, 417–418
supraalveolar defect, 421
swine periodontitis, 493–495
tooth regenerative therapy as, 456
Molar CLs, 323. See also Cervical loops (CLs)
Molar mesenchymal stem cell niche, 336, 337
Molar morphologies, 117
Molar odontogenesis, E–M interactions in, 180
Molars
Molecular controls, of successional lamina reformation, 141–142
Molecular regulation of dental mesenchymal stem cell differentiation, 306–308
of tooth development, 109
of tooth replacement, 123, 124–126
Monkeys, furcation defect studies in, 227
Mononuclear cells, from adult bone marrow, 227
Montoro, Daniel, xii, 379
Morphogenesis, branching, 272
Morphogenetic cell movement, 4–6
Morphogenetic signaling pathways, roles of, 321
Morphogenetic signaling molecules, 474–475
Morphometric analysis, 352, 353
Morsczeck, Christian, xii, 285, 303
Mouse embryonic fibroblasts (MEFs), 208
Mouse embryonic head coronal sections, 75–76
Mouse embryonic stem (ES) cells (mESCs), 208, 209, 332
Mouse incisor(s)
continuous growth of, 322
epithelial stem cell niche in, 317–323
fibroblast growth factors and, 147
renewal of, 317
stem cell niche in, 319
as tooth renewal model, 315–327
Mouse incisor model, 336–337
Mouse induced pluripotent stem cells (miPSCs), 211. See also Induced pluripotent stem cells (iPSCs); Murine iPSCs
Mouse (mice) models, 399. See also Severe combined immunodeficiency (SCID) mouse model
bone bioengineering and, 355
for dental development, 136–137
successional tooth formation in, 125
for tooth root development, 169
Mouse mutant analysis, 323
Mouse odontogenesis, stages in, 181–182
Mouse salivary gland epithelia, model of, 273
Mouse skeletal muscle development, 89
Mouse temporo mandibular joint, early development of, 77
Mouse TMJ coronal section, 74. See also Temporomandibular joint (TMJ)
Mouse TMJ organogenesis, 73
Mouse transplants, chicken teeth from, 115
MRF4 function, 90, 91. See also Myogenic regulatory factors (MRFs)
MRF expression, 92
onset of, 92
MRF gene activation, 88–90, 91, 95
MRF genes, 94
MSC-based therapies, 383. See also Mesenchymal stem cells (MSCs); Mesenchymal stromal cells (MSCs)
MSC differentiation potential, 303–304
MSC hypothesis, 224–225
MSC-mediated therapeutic alternatives, 233
Msx1 expression, 32–34, 36
Msx1 function in dental mesenchyme, 191
in odontogenesis, 191
Msx1 loss of function, 182, 183
Msx1-null mice, restoring dental tissue differentiation in, 193
Msx1 mutants, systems analysis of, 192–193
Msx2 induction, 117
Multicomponent injectable materials, in periodontal endogenous regeneration, 513
Multiple-bioengineered-teeth unit, 452
Multiple condensations, 53
Multipotent ASCs, 243. See also Adipose-derived stromal cells (ASCs); Adipose tissue-derived stromal and stem cells (ASCs)
Multipotent cells, source of, 383
Multipotential bone marrow MSC, 223
Multipotential cells, source of, 230
Multipotent mesenchymal cells, 54
Multipotent mesenchymal stem cells (MSCs) defining, 226
identification and locality of, 228
Muscle. See also Myo- entries; Skeletal muscle(s) formation and patterning of, 15–16
mesoderm and, 15–17
Muscle defects, future perspectives for, 403
Muscle-derived stem cells (MDSCs), 400
Muscle development, genetic module required for, 396
Muscle disorders, 395–396
treatment strategies for, 396
Muscle fibroblasts, 264
Muscle formation, in head and trunk, 16
Muscle function improvement, approaches to, 397
Muscle matrix transplantation, 401
Muscle morphology, species-specific, 17
Muscle myopathies, 267
Muscle progenitor cells, 87, 260
regulatory factors in, 265
Muscle regeneration, 396–397
macrophages and, 264
regulatory factors in, 265
Muscle regeneration stages, 396
Muscle repair, 399
Muscle side population (SP) cells, 400
Muscle strain injuries, 395
Muscle tissue engineering approaches, 395–408
Muscle tissue loss, 395
Muscle tissue malformations, 396
Muscle tissue regeneration, enhancing, 397
Muscle trauma, growth factors and, 403
Muscle–vasculature interactions/integration, 18–19
Muscular activity, alterations in, 62
Muscular dystrophies, 395–396, 402–403
Muscular pharynx, 99
Musculature, formation of, 5
Mutant mouse models, 82
Mutations, reprogramming-associated, 213
MYF5 function, 90, 91
Myoblasts, 262, 263
distribution and alignment of, 22
extraocular, 91
fusing into myotubes, 402
growth factor effects on seeded, 401
in cell-based therapies, 399–400
MyoD activation, 90, 91
Myofibers, 262, 263, 264
grafting of, 399
Myogenesis
branchiomeric, 88, 90, 92–93
drivers of, 87
embryonic, 260–262
onset of, 87
regulatory hierarchies driving, 90
triggers of, 88
trunk, 88–90
upstream events driving, 102
vascular pattern and, 19
Myogenic cell population, 399, 400
Myogenic cells, 404
Myogenic determination genes, activating, 102
Myogenic differentiation repression, 97
Myogenic fates, 102
Myogenic model, 370
Myogenic progenitor cells
genetic signatures of, 93
in the hypoglossal cord, 90
somite-derived, 90
Myogenic progenitors, 42–43
Myogenic program maintenance, DLX5 and DLX6
required for, 102
Myogenic proliferation regulation, 41
Myogenic regulatory factor family, 88
Myogenic regulatory factors (MRFs), 260. See also
MRF entries
Myogenic regulatory family (MRF), 88
Myogenic regulatory hierarchies, 88–90
Myogenic specification, transcriptional regulators
for, 94
MYOR function, 94, 97
Muscle repair, 399
Muscle side population (SP) cells, 400
Muscle strain injuries, 395
Muscle tissue engineering approaches, 395–408
Muscle tissue loss, 395
Muscle tissue malformations, 396
Muscle tissue regeneration, enhancing, 397
Muscle trauma, growth factors and, 403
Muscle–vasculature interactions/integration, 18–19
Muscular activity, alterations in, 62
Muscular dystrophies, 395–396, 402–403
Muscular pharynx, 99
Musculature, formation of, 5
Mutant mouse models, 82
Mutations, reprogramming-associated, 213
MYF5 function, 90, 91
Myoblasts, 262, 263
distribution and alignment of, 22
extraocular, 91
fusing into myotubes, 402
growth factor effects on seeded, 401
in cell-based therapies, 399–400
MyoD activation, 90, 91
Myofibers, 262, 263, 264
grafting of, 399
Myogenesis
branchiomeric, 88, 90, 92–93
drivers of, 87
embryonic, 260–262
onset of, 87
regulatory hierarchies driving, 90
triggers of, 88
trunk, 88–90
upstream events driving, 102
vascular pattern and, 19
Myogenic cell population, 399, 400
Myogenic cells, 404
Myogenic determination genes, activating, 102
Myogenic differentiation repression, 97
Myogenic fates, 102
Myogenic model, 370
Myogenic progenitor cells
genetic signatures of, 93
in the hypoglossal cord, 90
somite-derived, 90
Myogenic progenitors, 42–43
Myogenic program maintenance, DLX5 and DLX6
required for, 102
Myogenic proliferation regulation, 41
Myogenic regulatory factor family, 88
Myogenic regulatory factors (MRFs), 260. See also
MRF entries
Myogenic regulatory family (MRF), 88
Myogenic regulatory hierarchies, 88–90
Myogenic specification, transcriptional regulators
for, 94
MYOR function, 94, 97
Myosin genes, 99
Myostatin, 266
Myotome development, 260
Myotubes, 402
extraocular, 91
Nakashima, Misako, xii, 461
Nanofibrous matrices, for bone bioengineering, 353
Natural biomaterials, in dental tissue engineering, 410
Natural polymers, for periodontal bioengineering, 503–504
N-cadherin expression, 14. See also E-cadherin; M-cadherin
NCC-derived structures, 42. See also Neural crest cells (NCCs)
Neck muscles, 93
Nerve fiber innervation, of bioengineered teeth, 455.
See also Nerv- entries
Nerve growth factor (NGF), 397, 466, 469
Nervous system, 20. See also Central nervous system (CNS); Peripheral nervous system (PNS)
formation of, 5
Nervous system recovery, following organ transplantation, 454
Neural crest, 4
tooth root formation and, 158
vertebrate, 31
Neural crest cell axial groups, 11
Neural crest cell defects, 22
Neural crest cell development, regulation of, 22
Neural crest cell/endothelial cell interdependency, 20
Neural crest cell formation, induction of, 9–10
Neural crest cell induction
mammalian, 10
novel factors involved in, 20
Neural crest cells (NCCs), 31
in craniofacial bone development, 52
delamination of, 10–11
ectoderm and, 9–11
Hh signaling in, 42–43
migration and differentiation of, 11
in regulation of cranial muscle development, 16–17
Neural crest cells/mesoderm/ectoderm relationships, 21–22
Neural crest cell specification, 11
Neural crest exchange, 102
Neural crest induction, signaling pathways and, 10.
See also Neural crest cell induction
Neural crest mesenchyme, 17
Neural crest–mesoderm interactions, 16–17
Neural crest migration, 14
Neural crest–placode interactions, 14
Neural development, endothelial signaling in, 19
Neural fate, 7
Neural induction, 6
avian, 6
INDEX

“default model” for, 6
ectoderm and, 6–7
vertebrate, 7
Neural markers, 7
Neural plate, 6
regionalized cells in, 8
Neural plate border, 9
Neural stem cells, 289
Neural tube, 8
regionalization of, 6
Neural–vasculature interactions/integration, 19–20
Neuroectoderm, dorsoventral pattern of, 9
Neuroepithelium, posteriorizing, 8
Neurogenesis, endothelial cells and, 19
Neurogenesins, 14
Neuromuscular diseases, treatment of, 402–403
Neuronal–epithelial communication, 277–278
Neuronal markers, 293
Neuronal perceptive potential of bioengineered teeth, 454–455
recovery of, 454–455
Neuronal progenitor cells (NPCs), 466
Neuropilin 2, 20
Neuropheres, 290
Neurovascular disease, 19–20
Neurturin, 279
Neurulation, 6
ectoderm and, 8
Neurulation process, 7
New head, in vertebrates, 42
NG2-expressing pericytes, 334–335
Ngn proneural genes, 14
Niche, 208. See also Artificial niches; Epithelial progenitor–niche communication; Epithelial stem cell niche; Mesenchymal stem cell niches; Molar mesenchymal stem cell niche; Prognitor niche; SMG progenitor cell niche; Stem cell niche
apical, 330–333
environmental, 385
incisal tip, 335–336
perivascular, 230, 334–335
satellite cell, 262–264
stem cell segregation within, 320
Nie, Hemin, xii, 367
Nitric oxide (NO), as a mediator of T-cell suppression, 230
NKX2-5 cardiac transcription factor, 97, 99
Nociti, Francisco H., Jr., xii, 153
Nodes, 186–189
Noggin BMP antagonist, 64–65, 170, 385, 388
Noggin overexpression, 125
Non-dental-derived mesenchymal stem cells, 245
Nondental epithelial cells, in dental tissue formation, 436
Nondental stem cells, for periodontal bioengineering, 510
Nonsprouting process, 18
Nonsyndromic oligodontia, 190
Nonviral DNA, 387
Nonviral gene therapy, 516
Nonviral vectors, 388
Nose formation, 32
Notch pathway activity, 321–322
Notch signaling, 323
Notexin, 399
Nuclear factor IC (Nfκc), 168, 169
loss of, 173
Nuclear reprogramming technology, 386
Occipital somites, 87
O’Connell, Daniel J., xii, 179
Ocular anomalies, 92
Oculo-facio-cardio-dental (OFCD) syndrome, 308
ODE simulation, 193. See also Ordinary differential equation (ODE) model
Odontoblast(i) differentiation, 119, 120, 308, 440.
See also Dent-entries; Teeth; Tooth entries
Odontoblast formation, 330
Odontoblast-like cells, 288
Odontoblast markers, 293, 294
Odontoblasts, 110, 117, 118–120, 438, 439, 448
dysmorphic, 168
pericyte-derived, 335
removal of, 335
in root dentin formation, 160
Odontoblast terminal differentiation, 39
Odontogenesis, 197
cellular heterogeneity during, 432
signaling pathways used in, 181
tooth root formation and, 158
Odontogenetic competence, 113
Odontogenetic competence shift, 114–115
Odontogenetic potential, 113
Odontogenetic potential induction, in epithelium and mesenchyme, 112–115. See also Tooth inductive potential
Odontogenetic tissues, 116
specification of, 112
Odontogenic band, 137
Odontogenic capability, of stem cell populations, 304
Odontogenic cell differentiation potential, 293
Odontogenic E–M GRNs, 196. See also
Epithelial–mesenchymal (E–M) entries; Gene regulatory networks (GRNs)
asumptions underlying, 195
Odontogenic E–M interactions, 180. See also
Epithelial–mesenchymal (E–M) interactions reconstructing GRNs for, 186–190
Odontogenic gene expression, 246
Odontogenic junction, 434
Odontogenic mesenchymal cell population, 127
Odontogenic potential, 434
cell sources, 438
maintenance of, 436, 439–441
Olfactory placode, 12
Oligodontia, 125
nonsyndromic, 190
Olivares–Navarrete, Rene, xiii, 341
Oocytes, in parthenogenesis, 209
Opercular muscles, 96
Optic placode, 12
Optimal scaffolds, development of, 476
Oval cavity
endoderm and, 21
tooth eruption into, 111–112
Oral mucosal tissue, 298
Oral–nasal (ON) axis, CNCC-derived palatal mesenchyme patterning along, 35–36
Ordinary differential equation (ODE) model, of Wnt-Bmp feedback circuit, 189. See also ODE simulation
Org1 functions, 95
Organ development, gene regulatory networks for, 195–196
Organ differentiation, role of endothelial dells in, 19
Organ engineering, 432
Organ formation, inductive tissue interactions and, 78–79, 197
Organ generation strategies, 196–198
Organizer concept, 180
Organogenesis
E–M tissue transcriptional coupling during, 184–185
mammalian, 179
mechanisms and factors controlling, 153
recreating, 449
tooth, 456
vertebrate, 180
Organogenesis-based approaches, 418
Organ regeneration, fundamental principles for, 195
Organ regeneration strategy, 197
Organ-replacement regenerative therapy, whole-tooth regeneration as, 448–452
Organs
bioartificial, 449
cranial neural crest cells in, 31–49
generating ectodermal, 449
reconstructing complex, 448–449
Organ-specific adult stem cells, identifying, 320–321
Organ transplantation, nervous system recovery following, 454
Orofacial bone/bone marrow–derived MSCs (OMSCs), immunoregulatory properties of, 305
Orofacial mesenchymal cells, 370
Orofacial regeneration
cell transplantation in, 370–371
endogenous, 375
ORP150, 20
Orthodontic tooth movement, 164, 165
Orthotopic model, of pulp–dentin engineering/regeneration, 465–476
Orthotopic pulp regeneration, 477
Orthotopic tooth regeneration, 373
Osr1 expression, 35
Osr2–Cre system, 36
Osr2 expression, 35
Osr2 function, 191
Osr2 transcription factor, 191
OSS-related antigen 1 (Fra1), 57
Ossification. See also Bone entries
endochondral, 51
intramembranous, 51
suture and intramembranous, 54
Ossification centers, expansion of, 61
Osteoblast development, genetic mutations and, 57
Osteoblast(inc) differentiation, 55–57, 65–66
bone morphogenetic protein role in, 509 stages of, 55–57
Osteoblast differentiation inhibition, 81
Osteoblast fate, 59
Osteoblast function, 57
Osteoblastogenesis, 349
Osteoblast/osteocyte/osteoclast communication network, 60
Osteoblasts, alterations in, 62
Osteocalcin (OCN), 157, 308
Osteoclast differentiation, 60
inhibition and stimulation of, 60–61
Osteoclast differentiation/function, 59
Osteoclast precursors, 59
Osteoclasts, derivation of, 60
Osteoconductive factors, 348–349
Osteoconductive scaffold matrix, 380
Osteocytes, 60
as bone remodeling orchestrators, 62
Osteodentinogenic potential, of SCAPs, 309
Osteogenesis, 64, 350–351
enhancing, 354
Osteogenesis imperfecta (OI), 389
Osteogenesis optimization strategies, 390
Osteogenesis rate, 62
Osteogenic condensations, 53
Osteogenic differentiation, 380–381
of ASCs, 243
enhancement/improvement of, 385, 388, 389
Osteogenic differentiation potential, of dental follicle cells, 296
Osteogenic fronts, 54
Osteogenic genes, downregulation of, 79
Osteogenic growth factors, 348
Osteogenic stimulation, 294
Osteoid, mineralization of, 57
Osteoinduction, 65
Osteo-inductive effect, 290
Osteoinductive effect, 290
Osteoinductive growth, 380
Osteoinductive growth factors, 347–348
Osteon, 506
INDEX

Osteopontin (OPN), 157
Osteoprogenitor cell proliferation, 348
Osteoprogenitor cells, 381
Osteoprogenitors, 54–57
Osteoprotegerin (OPG), 60
Osterix (Osx), 308, 350
Osx expression, 55–57
Otic placode, 12
Outer enamel epithelium (OEE), root formation and, 158
Ovine PDLSCs, 491. See also Periodontal ligament stem cells (PDLSCs); Sheep Oxytalan elastic fibers, 158
p21 induction, 117
p63 gene mutations, 116
Palatal CNCC-derived mesenchyme, AP patterning of, 34. See also Cranial neural crest cells (CNCCs)
Palatal epithelial cells, 436
Palatal epithelium AP patterning of, 34
CNCC-derived mesenchyme interactions with, 34–35
Palatal fusion, 34
Palatal shelf elevation, 32
Palatal shelves, 32
malformed, 34
Palate development, 32–37
CNCC contribution to, 33
Palatogenesis, 34
TGFβ signaling during, 36–37
Pancreatic β-like cells, 216
Paracrine actions, 244–245
Paracrine interactions, 385
Paracrine signaling, 351
Paracrine signaling pathways, 277
Parada, Carolina, xiii, 31
Parasympathetic nerves, protection of, 279
Parathyroid hormone–related protein (PTHrP), in tooth eruption, 163
Paraxial mesoderm, 15
Parkinson’s disease, 216
Parthenogenesis, 209
Partial pulp regeneration, with pulp stem and progenitor cells, 467–468
Patient-specific autogenous tissue derivation, 386
Pax3-expressing progenitor cells, 96
Pax3 expression, 260, 261
Pax3 expression, 399
PAX3 transcription factor, 88, 90
Pax7 expression, 260, 261
PAX7 transcription factor, 88
Pax8-null mutants, systems analysis of, 190–193, 194
Pax9 expression, 125
Pax9 function in dental mesenchyme, 191
in odontogenesis, 191
Pax9 loss, 34
Pax9-mutant mice, restoring dental tissue differentiation in, 193
Pax9 mutants, systems analysis of, 192–193
Pax9 transcription factor, 38–39
Pax9 upregulation, 115
Pax genes, expression of, 13–14
Pax signaling, neural crest cell formation and, 10
PDGF-BB homodimer, 509. See also Platelet-derived growth factors (PDGF)
PDL cell sheets, 514. See also Periodontal ligament (PDL)
PDLC-derived spheres, 492
PDLC development processes, 170–171
PDLC extracellular matrix, 158
PDLC fiber groups, orientation of, 164
PDLC fibers, in acellular cementum formation, 162
PDLC homeostasis, 171
PDLC progenitors (PDLPs), 291, 292
PDLC-mediated periodontal regeneration, 491–496. See also Periodontal ligament stem cells (PDLSCs)
PDLC sheets, 488, 489
PDL tissue, periodontal ligament stem cells from inflamed, 493
PDL tissue engineering, 292
PEG hydrogel, 476
PEGylated (PEG-modified) fibrin, 475
Perceptive potential, restoration of, 454–455
Periapical dental follicle stem cells (PAFSCs), 297
Periapical follicle, 297
Periapical tissues, ingrown, 464
Pericyte-derived odontoblasts, 335
Pericytes, 334–335, 337, 400–401
systemic delivery of, 403
Peridental mesenchyme, 437
Perifollicular tissues, tooth root formation and, 158
Periodontal attachment complex, 161
Periodontal bioengineering, 502–503. See also Periodontal engineering biomaterials for, 503–508
challenges and future directions of, 517–518
stem cells for, 510–511
Periodontal bioengineering strategies, 501–524
Periodontal cell culture models, 416, 417
Periodontal defect models, 418
Periodontal defects experimental, 418
treatment modalities for, 154
Periodontal development, 297
Periodontal diseases, 486
animal models for, 517
Periodontal endogenous regeneration, facilitating, 511–513
Periodontal engineering, gene therapy for, 516–517.
See also Periodontal bioengineering
Periodontal intrabony defects, 506
Periodontal lesions, 418
See also PDL entries
development of, 163–164
functions/roles of, 157, 454
Periodontal ligament cells, 410
Periodontal ligament (PDL) fiber attachment, 501
Periodontal ligament (PDL) space, 488
Periodontal ligament stem cells (PDLSCs), 245, 291–292, 309, 486, 518
clinical studies of, 495
immunological properties of, 493
immunoregulatory properties of, 305
from inflamed PDL tissue, 493
isolation and identification of, 291, 491–493
for periodontal bioengineering, 510
for periodontal tissue regeneration, 502
Periodontal precursor cells, dental follicle cells as, 297
Periodontal regeneration. See also Periodontal tissue regeneration
in animal models, 418–419
cell sheets for, 495–496
PDLSC-mediated, 491–496
stem cell–based, 513–516
Periodontal regeneration models, 418–421
Periodontal therapies
current, 489–490
objectives of, 501–502
Periodontal tissue regeneration, focus of, 489–490
Periodontal tissues, 510
bioengineering of, 485–486, 488–496
in vivo formation of, 387
pulp space filled with, 463–464
reconstituting, 454
Periodontitis, 488–489, 501
Periodontium-like tissue, 291
Peripheral blood mononuclear cells (PBMCs, PBMNCs), 243–244, 474, 493
immunoregulatory properties of, 305
Peripheral nervous system (PNS), 14, 20
formation of, 5
Peripheral sensory nervous system, 11–12
Perivascular niche, 230, 334–335
Perivascular properties, of human bone narrow MSC, 228–230
Permanent teeth, 112
Permanent tooth germ, 110
Permanent tooth initiation, in ferrets, 123
PERP/P53 apoptosis effector, 120
Pharyngeal arches, 21, 92
Pharyngeal endoderm, 21
Pharyngeal mesoderm, 96–98
myogenic derivatives of, 97
Pharyngeal (pharynx) muscles, 93, 99
Pharyngeal region, regulatory programs in, 95
Phenotypic analyses, of genetically modified mouse models, 79
Phosphate metabolism disorders, 171
Pig(s), as bone regeneration model, 422. See also Swine entries
piggyBac expression vectors, 387
Pitx2-Cre, Dicer1 deletion by, 322
Pitx2 expression, 16, 36, 97, 113, 114, 137
PITX2 function, 94, 97
PITX2 transcription factor, 91–92
Plachokova, Adelina, xiii, 409
Placodal cell adhesion, 14
Placode formation, induction of, 11–13
Placode–neural crest interactions, 14
Placodes, 4. See also Dental placodes; Tooth placode formation
ectoderm and, 11–14
Placode stage, 448
Placodogenesis, 12
Plastic adherence–selected MSCs, 226
Platelet-derived growth factors (PDGF), 264, 347, 469, 516. See also PDGF-BB homodimer
Platelet-rich plasma (PRP), 249, 348, 357, 503, 508, 513, 515
PLGA scaffolds, bone bioengineering and, 355. See also Poly(lactic-co-glycolic acid) (PLGA)
Pluripotency, 206
Pluripotent cell plating, 213
Pluripotent cells
limitations of, 217
in tissue engineering, 389
Pluripotent state, cell types converted to, 386
Pluripotent stem cell differentiation, growth factor cues for, 213–214
Pluripotent stem cells (PSCs), 206–207, 208–213
applying cells derived from, 214–217
in bone bioengineering, 349
for craniofacial tissue engineering, 385
differentiation approaches for, 213–214
Poly(α-hydroxyester)s, for periodontal bioengineering, 505
Polycaprolactone (PCL), as scaffold biomaterial, 345, 371
Polycomb repressor complex 1 (PRC1) proteins, 331–332, 333
Polycomb repressor complex 2 (PRC2) proteins, 331, 332
Poly(ethylene glycol) (PEG), 475. See also PEG entries
Poly(glycolic acid) (PGA), 345
Poly(lactic acid) (PLA), 345
Poly(lactic-co-glycolic acid) (PLGA) for periodontal bioengineering, 505. See also PLGA scaffolds
Poly (L-lactic acid) (PLLA) scaffolds, 310
Polymer meshes, 353
INDEX

Polymers
  in biomechanical scaffolds, 342–345
degradable, 345
  in dental tissue engineering, 411
  for periodontal bioengineering, 503–505
Polyphyodonts, 316
Polyphyodonty, in reptiles, 135
Population doublings (PDs), 224
Postmigratory cranial neural crest cells, 39
TGFβ signaling in, 36–37
Postnatal bone marrow tissue, 223
Postnatal dental pulp stem cells (DPSCs), 286, 287–290
  immunoregulatory properties of, 305
  in nondental tissue regeneration, 289
SCAP/dNC-PCs and, 294, 295
Postnatal stem cells, 206
Postnatal tooth germ cells, 371
Preclinical animal models, findings from craniofacial, 245–249
Preclinical models, 409
Preclinical studies, of bone bioengineering, 355–357
Predentin–dentin, secretion of, 432
Preformed scaffolds, 507
Premature tooth loss, 154
Preosteoblastic state, 57
Preplacodal ectoderm, 13
Preplacodal ectoderm induction, 12–13
Primary capillary plexus, 17
Primary cartilage development, growth factors in, 80
Primary cartilages, gene expression in, 78
Primary dental lamina, 181
Primary dentin, 165
Primary embryonic fibers, 262
Primary embryonic vascular deficiency, 17
Primary enamel knot, 110, 117
ability to induce formation of, 441–442
Primary growth disorders, of the temporomandibular joint, 72
Primary palate, 32
Primary teeth, successional formation of, 124–126
Progenitor cell interdependency, 20
Progenitor cell location, 277
Progenitor cell populations, gene expression patterns in, 97
Progenitor cell proliferation, growth factors affecting, 277
Progenitor cells, 11, 77, 329, 341–342. See also Pulp progenitor cells
  clinical need for, 272–274
  from dental and gingival tissue, 285–302
dental neural crest–derived, 293–294
  in dentin regeneration, 476
  for forebrain, midbrain, and hindbrain, 8
  hematopoietic, 227
  in pulp regeneration, 465–466
  somite-derived, 88, 90
  Progenitor cell sources, 87
  Progenitor cell therapy, 280
  Progenitor differentiation, 276
  Progenitor expansion, 279
  Progenitor germ layer tissues, 6
  Progenitor markers, 278, 295
  Progenitor niche enhancing, 281
  maintenance of, 279
  Progenitor pools, 317
  Progenitor proliferation, 279
  Progenitors. See also Kit+ progenitors; PDL progenitors (PDLPs); Salivary gland progenitors; Salivary progenitors; Specific progenitors
  irradiation-surviving, 273
  potency of, 272
  role in salivary gland development/regeneration, 274–276
Progeny overproduction, during incisor renewal, 324
Programmed cell death, 141. See also Apoptosis
Proinflammatory cytokine inhibition, 305
Proinflammatory cytokines, regulatory effects of, 306
Proliferation marker, 335
Proliferation, 279
Proliferator-activated receptor γ (PPARγ), 308, 309
Prospephalon, 8
Proteins, paracrine action of, 244
Proteoglycans, 157–158
Proximal signals, cemento-inductive roles of, 170
P-selectin, 369
PSG function, 279
Ptch1 expression, 141
PthrP expression, 80
PU.1 transcription factor, 60
Pulp chamber
  in root dentin formation, 160
  vascularized incisor, 330
Pulp–dentin complex, 288
Pulp–dentin complex regeneration models, 417–418
Pulp–dentin engineering/regeneration ectopic model of, 464–465
orthotopic model of, 465–476
Pulp–dentin tissues, regenerating, 461–462
Pulpectomy, 461, 469
Pulp healing/repair, 462–464
Pulp-like tissue, engineering, 467
Pulp migration factors, complete pulp regeneration with, 468–470
Pulp MSCs, transplantation of, 472. See also Mesenchymal stem cells (MSCs); Mesenchymal stromal cells (MSCs); Pulp stem cells
Pulp progenitor cells
  complete pulp regeneration with, 468–470
  in dentin regeneration, 476
  local transplantation of, 466
Pulp progenitor cells (Continued)
partial pulp regeneration with, 467–468
Pulp regeneration, 461–484
advances in, 462
for the aged, 470–472
cytokine delivery and chemotactic effects on, 374
future perspectives on, 477
in mature teeth with complete apical closure, 465–474
pulp stem/progenitor cells in, 465–466
tissue stem cell sources for, 472–473
Pulp space
filled with periodontal tissues, 463–464
severely disorganized calcification of, 464
Pulp stem cell migration, 467
Pulp stem cells
complete pulp regeneration with, 468–470
in dentin regeneration, 476
fractionated, 470
local transplantation of, 466
partial pulp regeneration with, 467–468
Pulp stem/progenitor cells, in pulp regeneration, 465–466
Pulp tissue markers, 470
Pulse-chase experiment, 145
Quiescent cells, 274
Rabbit(s)
bicortical defect in the mandible studies in, 424
cell–scaffold construct studies in, 423
Rabbit calvarial defect model, 388–389
Radiation-induced apoptosis, 279
Rad, Maryam Rezai, xiii, 241
RANK ligand (RANKL), 60
RANK–RANKL system, 60, 61
RANK upregulation, 60
Rapid cell proliferation, 73
Rapidly (R) dividing cells, 331
incisal tip niche and, 335–336
Rat models, bone bioengineering and, 355
Rat PDLSCs, 491–492.
See also Periodontal ligament stem cells (PDLSCs)
Rats, fenestration defect studies in, 419
Reparative (regenerative) cementum, 165
Replacement teeth, formation of, 143
Replacement tooth development, histology of, 123
Reprogramming, epigenetics and, 212–213
Reptile dental laminae, hair follicle properties of, 146
Reptile evolution, 135–136
Reptile-line amniota, tooth replacement in, 136–137
Reptiles, tooth development/replacement in, 137–140
Reptilian tooth regeneration, 135–151
Reptilian tooth replacement, 121, 125
Reticular cells, 228–229
Retinoic acid signaling, 90
Revascularization approach, 462–463
Dental pulp–like tissue regeneration; Muscle regeneration entries; Orthotopic tooth regeneration; Periodontal endogenous regeneration; Pulp regeneration; Skeletal muscle regeneration; Tooth regeneration; Tooth root regeneration by cell homing, 370–375
endogenous orofacial, 477
facilitated endogenous, 512–513
of functional tissues, 477
glandular, 273
of irradiated salivary glands, 271
stem cell–based periodontal, 513–516
stem cell differentiation for, 213–214
study of, 324
Regeneration approach, 462, 463
Regeneration potential, of adipose tissue–derived stem cells, 241–258
Regenerative bone formation, 231
Regenerative cell therapy, 275
Regenerative cementum, 165
Regenerative medical research, 245
Regenerative medicine, 215, 380
Regenerative medicine approaches, translation of biological processes into, 278–279
Regenerative potential, in adults, 65
Regenerative strategies, tissue engineering approaches and, 425
Regenerative therapy (therapies), 215–217
advances in, 447–448
stem cell use in, 174
whole-tooth regeneration as, 448–452
Regulatory data, GRN reconstruction from, 186–190
Regulatory factors, in muscle regeneration, 265
Regulatory hierarchies, myogenic, 88–90
Regulatory mechanisms, understanding, 45
Reinnervation, as a prerequisite for pulp regeneration, 465–466
Reparative (regenerative) cementum, 165
Reparative ( reactionary) dentin, 119, 165
Reparative dentinogenesis, 438
Replacement odontoblasts, 294
Replacement teeth, formation of, 143
Replacement tooth development, histology of, 123
Reproducible craniofacial bone formation, 384
Reprogramming, epigenetics and, 212–213
Reptile dental laminae, hair follicle properties of, 146
Reptile evolution, 135–136
Reptile–line amniota, tooth replacement in, 136–137
Reptiles, tooth development/replacement in, 137–140
Reptilian tooth regeneration, 135–151
Reptilian tooth replacement, 121, 125
Reticular cells, 228–229
Retinoic acid signaling, 90
Revascularization approach, 462–463
INDEX
Revitalization approach, 462–463
Revitalization approach outcome of, 463–464
successes using, 463
RGD peptides. See Arginine–glycine–aspartic acid (RGD) peptides
Rhombencephalon, 8
Rice, David P., xiii, 51
Rice, Ritva, xiii, 51
Richman, Joy M., xiii, 135
Ring1a protein, 331, 332, 333
Ring1b protein, 331, 332, 333
Robo2 expression, 14
Rodent incisor growth, 370
Rodent incisor mesenchymal stem cell niche(s), 329–335
Rodents, tooth renewal capacity of, 317
Rodent teeth, 316
mesenchymal cells in, 370
Rodent tooth pulp, mesenchymal stem cell niches in, 329–338
Rolling processes, chemokines in regulating, 368–369
Romberg’s syndrome, 249
Root apical papilla, stem cells from, 486–487. See also Tooth root entries
Root canal therapy, 372
Root dentin, 160
Root dentin development, Nfic-mediated control of, 168
Root dentin formation, 160
Root development
mineral metabolism and, 171
mouse models for, 169
signaling and inductive influences in, 165–168
signaling pathways and, 168–171
Root developmental regulation, 173
Root formation
developmental processes in, 158–165
events leading up to, 158
Root hypoplasia, 173
Root morphogenesis, disturbance of, 170
Root morphology conditions, 173
Root pathologies, 172, 173
Root regeneration, future directions for stem cell-mediated, 496
Root resorption, 165
Root tissue regeneration, 173–174
stem cell–based strategies for, 165
Rudimentary lamina, apoptosis in, 141
Runx2 function, 126
Runx2 protein, 37
Runx2 (Runx2) transcription factor, 55, 79, 308, 350
Runx genes, in tooth root development, 168
Saliva production, loss of, 273
Salivary gland damage, 271
Salivary gland development/regeneration
role of multiple progenitors in, 274–276
stem cells in, 271–274
Salivary gland field, future directions in, 280–281
Salivary gland organs, 272
Salivary gland progenitors
dynamics of, 274
specific lineage formation by, 274–275
Salivary gland regeneration, improving, 279
Salivary glands, in vivo transplantation of, 275
Salivary progenitors, 272–274
isolating, 275
SATB2 transcription factor, 387
Satellite cell activation, 370
Satellite cell migration, 396
Satellite cell niche, 262–264
Satellite cells (SCs), 87–88, 95–96, 259–260, 261–262, 401
asymmetric self-renewal of, 262
in cell-based therapies, 399–400
craniofacial, 266–267
cultured, 400
genetically ablated, 400
growth factors and, 264–266
role of, 267
self-renewal of, 396
Satellite cell seeding, 401
Scaffold-based approaches, 418
Scaffold-based cell delivery, 514–516
Scaffold-based therapies, 401–402
Scaffold composites, 231, 232
Scaffold degradation, 345
Scaffold delivery vehicle, 389
Scaffold design, 515–516
Scaffold-free cell delivery, 513–514
Scaffold materials, characteristics of, 343–344
Scaffold method, 450
Scaffold optimization, 506
Scaffolds. See Alginic scaffolds; “Bioactive” scaffolds; Biodegradable scaffolds; Bioengineered bone scaffolds; Biomaterial scaffolds; Biomechanical scaffolds; Biomimetic scaffold; Bioscaffolds; Calcium phosphate (CaP) cement scaffold; Cell–scaffold constructs; Ceramic scaffolds; Chitosan-based gel-like scaffolds; Chitosan–collagen composite scaffold; Collagen composite scaffolds; Collagen scaffolds; Composite hybrid polymeric scaffolds; Decellularized tissue scaffold; Dental tissue engineering scaffold models; Extracellular matrix scaffolds; Fibrin scaffolds; Hydroxypatite scaffold; Injectable scaffolds; Optimal scaffolds; Osteoconductive scaffolding matrix; PLGA scaffolds; Poly(L-lactic acid) (PLLA) scaffolds; Preformed scaffolds; Soft scaffolds; Solid scaffolds; TCP scaffolds; β-TCP scaffolds; Three-dimensional (3D) scaffolds; Tooth scaffolds; Tooth-shaped scaffolds. See also Alginate scaffolds; “Bioactive” scaffolds; Biodegradable scaffolds; Bioengineered bone scaffolds; Biomaterial scaffolds; Biomechanical scaffolds; Biomimetic scaffold; Bioscaffolds; Calcium phosphate (CaP) cement scaffold; Cell–scaffold constructs; Ceramic scaffolds; Chitosan-based gel-like scaffolds; Chitosan–collagen composite scaffold; Collagen composite scaffolds; Collagen scaffolds; Composite hybrid polymeric scaffolds; Decellularized tissue scaffold; Dental tissue engineering scaffold models; Extracellular matrix scaffolds; Fibrin scaffolds; Hydroxypatite scaffold; Injectable scaffolds; Optimal scaffolds; Osteoconductive scaffolding matrix; PLGA scaffolds; Poly(L-lactic acid) (PLLA) scaffolds; Preformed scaffolds; Soft scaffolds; Solid scaffolds; TCP scaffolds; β-TCP scaffolds; Three-dimensional (3D) scaffolds; Tooth scaffolds; Tooth-shaped...
Scaffolds (Continued)

Scaffolds; Treated dentin matrix (TDM) scaffolds

SCAP differentiation, 486–487. See also Stem cells from apical papilla (SCAPs)

SCAP/odNC-PCs, DPSCs and, 294, 295

Scar tissue formation, 259

SC behavior, regulation of, 264. See also Satellite cells (SCs)

SC functioning, future studies on, 267

Schwartz, Zvi, xiii, 341

Scleraxis, 291, 491

Scleraxis expression, 100

Sclerostin (SOST), 61

Screening, of drug compounds, 217

Scx expression, 17

SDF1 signaling, 369

Secondary cartilage

in mammalian TMJ condyles, 76–78

TGFβ signaling and, 80–81

Secondary dentin, 119, 165

Secondary enamel knots, 117, 140

Secondary fetal fibers, 262

Secondary palate, 32

Second heart field, 96–97

Secreted molecules, 6

Secreted proteins, paracrine action of, 244

Seeded myoblasts, growth factor effects on, 401

Segmentation algorithms, 352

Seidel, Kerstin, xiii, 315

Selectins, 369

Selective laser melting, 352

‘‘Self-renewal,’’ 272

do satellite cells, 396

Self-shaped hydrogels, 515

Self-sharpening incisors, 330

Self-sustaining E–M interactions, 197. See also

Epithelial–mesenchymal (E–M) interactions

Self-sustaining feedback circuits, 195

Sensate fibroblasts, induced pluripotent stem cells reprogrammed from, 216

Sequential communication mode, between epithelium and mesenchyme, 183

Sequential inductive E–M interactions, 180–182

Sequential signaling, in E–M interactions, 182–183

Severe combined immunodeficiency (SCID) mouse model, 384

Severe pulp infection, 464

Shamis, Yulia, xiii, 205

Shape memory materials, 515

Shared extracellular matrix proteins, 157–158

Sharpe, Paul T., xiii, 329

Sharpey’s fibers, 164, 291

Sheep. See also Ovine PDLSCs

as bone regeneration model, 422

maxillary sinus augmentation studies in, 424–425

Shh (sonic hedgehog), as a negative regulator of

Wnt signaling, 143

Shh expression, 34, 113, 114, 124, 141, 168, 322

Shh localization, 137

Shh mediator, 115

Shh pathway, 125, 141

Shh signaling, 35

for tooth morphogenesis, 169

Shi, Songtao, xiii, 223, 285, 303

Shiba goat(s), furcation defect studies in, 421

Shox2 expression, 32–33

Shox2 homeobox gene, 79

Side population (SP) cells, 400. See also CD31+

side population (SP) cells; CD31– side population (SP) cells

Signal exchange, between core mesoderm and crest cells, 101

Signaling-based gene regulatory network (GRN), 187–188. See also Gene regulatory networks (GRNs)

Signaling centers, dental placodes as, 116

Signaling molecule expression, 186

reciprocal shift in, 190

regulation of, 189

Signaling molecule genes, cross-regulatory control of, 189

Signaling molecules, 81, 308

stem cell regulation by, 320–322

Signaling networks, regulating tooth development, 109–110

Signaling pathway interactions, during successional lamina formation, 143

Signaling pathway responses, 198

Signaling pathways. See also BMP signaling;

Developmental signaling families; Diffusible signaling molecules; Ectodysplasin, 116–117

in epithelial–mesenchymal interactions, 179–180

investigating, 141–142
involved in crown formation, 171
neural crest induction and, 10
paracrine, 277
during replacement tooth development, 124–125
TGFβ/BMP, 36
in tooth morphogenesis, 112, 115–117
in tooth root development, 165–171
used in odontogenesis, 181
Signaling pathway target factors, 90
Signaling pathway targets, genes as, 141–142
Signaling regulation, of dental stem cell differentiation, 307
Signal transduction components, genes that encode, 184
Simultaneous communication mode, between epithelium and mesenchyme, 183
Six1/4 gene expression, 13
Six1 function, 97
SIX1 function, 96
Six1 gene mutations, 13
Skeletal defect reconstruction, 379–381
Skeletal muscle(s), 259
capillary network associated with, 18
functions controlled by, 87
in head, 15
somite-derived, 88
Skeletal muscle determination/differentiation, 88
Skeletal muscle development, 43
of mouse, 89
Skeletal muscle engineering, contributions of, 395
Skeletal muscle formation, in head and trunk, 16
Skeletal muscle regeneration, 396–397
Skeletal muscle stem cells, 87–88, 259–270
Skeletal muscle tissue, 263
Skeletal myogenesis, control of, 88
Skeletal precursor cells, 55
Skeletal precursor populations, relationships among, 224
Skeletogenic cell differentiation, early, 55
Skeletogenic condensation, 52–54
Skeleton, formation of, 5
Skin, engineered, 215
Skin allograft survival, 488
Slit-Robo signaling, 14
Slow (S) cycling cells, 330, 331
Smad4, 36, 37
Smad4 ablation, 39, 43–44
Smad4 factor, 168, 169
Smad4 inactivation, 36
Smad4 loss, 118
Smad-interacting protein 1 (SIP1), 10
Smad proteins, 142
Smads, BMP-associated, 35
SMAD signaling inhibition, 214
Small integrin-binding ligand n-linked glycoprotein (SIBLING) family, 157
Smart biomaterials, 425
SMG growth, 277–278. See also Submandibular glands (SMGs)
SMG Kit+ progenitors, 276
SMG progenitor cell niche, 276
SMG progenitors, 280
SMG regeneration, improving, 279
Snail transcription factor gene family, 10
Snake tooth replacement, 124
Soft palate, 32
Soft scaffolds, 515
Soft tissue reconstruction, 247–248
Solid freeform fabrication (SFF), 352
Solid scaffolds, 515
Somatic cell nuclear transfer (SCNT), 209
Somatic cell reprogramming, 206
Somatic cells, reprogramming, 385–386
Somatic stem cells, 285
Somerman, Martha J., xiii, 153
Somite-derived myogenic progenitor cells, 90
Somite-derived progenitor cells, 88
Somite-derived skeletal muscle, 88
Somite development, 260
Somites
anteriorm, 87
epithelial, 88
Somitic muscles, 93
Somitic myogenesis, 88–90
Sonic hedgehog. See Shh entries
Sox2 expression, 127, 320
Sox2 function, 126
Sox2 gene, 126
Sox2 transcription factor, 275
Sox9 deletion, 53
Sox9 expression, 320
Sox9 inactivation, 79
Sox9 protein, 54, 57
Sox9 transcription factor, 79, 309
Sox family genes, 13
Sox-positive cells, 320
Spatiotemporal expression profiling, 185
Spatiotemporal gene expression data set, 184
Species-specific muscle morphology, 17
Specific cell fates, directing, 214
Specific lineage formation, by salivary gland progenitors, 274–275
Specific progenitors, in salivary glands, 275
Spemann, Hans, 180
Spemann’s organizer, 6
Spinal fusion procedures, rhBMP-2 in, 388
Splanchnic mesoderm, 97
Sprouting process, 17–18
Sprouty (Spry) genes, 44–45, 321
Squamates, 136
dental lamina in, 138
tooth development/replacement in, 137–140
Squamate teeth, developmental stages of, 138–140
Squamous tooth replacement, stem cells in, 144–146
Stem cell–based bioengineering, of craniofacial bone, 379–394
Stem cell–based periodontal regeneration, 513–516
Stem cell–based regenerative medicine, long-term goals of, 388
Stem cell–based tissue engineering, 381
Stem cell–based tooth renewal, 121
Stem cell biology, 205–206
advancement in, 502
Stem cell differentiation, 206
for regeneration and therapy, 213–214
T-cell regulation of, 305–306
Stem cell division, 147
Stem cell factor (SCF) signaling, 369
Stem cell homing, 368
Stem cell labeling, 147
Stem cell loss, crown-to-root transition and, 323
Stem cell marker genes, 127
Stem cell–mediated root regeneration, future directions for, 496
Stem cell medical research, 245
Stem cell niche, 208, 230, 262, 285. See also
Mesenchymal stem cell niches
destruction of, 324
in mouse incisor, 319
Stem cell population(s)
in adult teeth, 40
in irradiated salivary glands, 271
odontogenic capability of, 304
vessel-associated, 400
Stem cell potency stages, 207
Stem cell regulation, by signaling molecules, 320–322
Stem cells, 205–206, 341–342. See also
Adipose-derived stem cells (ADSCs); Adipose tissue–derived stromal and stem cells (ASCs);
Allogeneic stem cell transplantation; Bone marrow–derived mesenchymal stem cells
(BMSCs, BMMSCs); Dental epithelial stem cells; Dental stem cells; Dental mesenchymal stem cells; Dental pulp stem cells (DPSCs);
Embryonic stem (ES) cells (ESCs); Endogenous stem cells; Epithelial stem cells;
Follicle-derived embryonic neural crest (FENC) stem cells; Hematopoietic stem cells (HSCs);
Immature dental pulp stem cells (IDPSCs);
Incisor stem cells; Mesenchymal stem cells (MSCs); Multipotent stem cells; Organ-specific adult stem cells; Periapical dental follicle stem cells (PFAFSCs); Periodontal ligament stem cells (PDLSCs); Postnatal dental pulp stem cells (DPSCs); Pulp stem cells; Skeletal muscle stem cells; Somatic stem cells; Umbilical cord–derived stem cells
autologous, 517
in bone bioengineering, 349–351, 354–358
categories of, 206–207
as the cell source for craniofacial bone, 380–381
definitions and concepts of, 206–208
from dental and gingival tissue, 245, 285–302
in dental and peridental mesenchymes, 437
in dental epithelium, 144–145
directed movement of, 367
in early embryonic dental lamina, 123
evolutionarily conserved, 137
expanding, 515
gene therapy and, 388–389
human dental epithelial, 286
labeled, 286
mammalian hair regeneration and, 145–146
mesenchymal origin of, 437–438
modulating the fate of, 441
neural, 289
for periodontal bioengineering, 510–511
in pulp regeneration, 465–466
regenerative capacities of, 351
for regenerative therapies, 455
regulated migration of, 370
from root apical papilla, 486–487
in salivary gland development/regeneration,
271–284
self-renewal ability of, 65–66
in squamous tooth replacement, 144–146
tissue origin of, 349–350
in tooth renewal, 315–327
use in regenerative therapies, 174
Stem cell segregation, within a niche, 320
Stem cells from apical papilla (SCAPs), 212, 245.
See also Stem cells from human apical papilla (SCAPs); Stem cells from root apical papilla (SCAPs)
osteodentinogenic potential of, 309
Stem cells from exfoliated deciduous teeth (SHEDs), 212, 245, 290, 304
immunoregulatory properties of, 305
for periodontal bioengineering, 510
Stem cells from human apical papilla (SCAPs), 293
dNC-PCs and, 294, 295
Stem cells from root apical papilla (SCAPs), 486–487
for periodontal bioengineering, 510
Stem cell subpopulations, 510
Stem cell surface markers, 440
Stem cell technologies, 215
Stem cell therapies, 517
Stem cell use, optimizing, 389
Stemness, theories of, 207–208
Stiff matrices, for craniofacial bone bioengineering,
342–345
Stimulatory growth factors, 264–266, 267
Stomodeum, 32
Stratum intermedium, 139, 436
INDEX

Striated ducts (SDs), 272
Striated muscle, development of, 99
STRO1+ bone marrow cells, 228
STRO1™/CD106+ expression, 228, 229
STRO1™/CD146+ expression, 228, 229
STRO1+ cells, 227
STRO1 expression, 291
STRO1 murine monoclonal antibody, 227
STRO1 selected cells, 227
Stromal cells. See also Adipose tissue–derived stromal and stem cells (ASCs); Bone marrow–derived mesenchymal stromal cells (BMSCs); Bone marrow stromal entries; Clonogenic stromal cell types; Mesenchymal stromal cells (MSCs) adipose-derived, 383–385 distinguishing, 226
Stromal derived factor 1 (SDF1), 244, 372, 373, 469, 470
Stromal derived factor 1α (SDF1α), 264, 266
Stromal vascular fraction (SVF) cells, 242
characterization of, 242–245
future directions of, 249
Stromovascular fraction (SVF), 383
Stylopharyngeal muscle, 93
Submandibular glands (SMGs), 272, 274, 275, 276, 279. See also SMG entries
Subtractive fabrication methods, 352
Successional dental lamina, 123, 124
Successional formation, of primary teeth, 124–126
Successional lamina, 140, 145
apoptosis in, 124
dental lamina gene expression patterns and, 142–143
relationship to tooth regeneration, 140–141 vestigial, 141, 143–144
Wnt pathway activity in, 141–142
Successional lamina formation, signaling pathway interactions during, 143
Successional lamina reformation, molecular controls of, 141–142
Successional lamina reformation/survival, ectodysplasin and fibroblast growth factors in, 143–144
Successional tooth formation, 125–126 in mice, 125
during tooth replacement, 121
Superficial facial muscles, 15
Supernumerary teeth, formation of, 144
Supernumerory tooth development, in mice, 125–126
Supraalveolar defect model, 421
critical-sized, 421
Sutural bone growth, 63–64
Suture biogenesis tension, effects of, 63
Suture line, bones sliding across, 63
Suture ossification, 55
Suture patency, 64–65
Sutures, as sites of osteogenesis, 63
Swine, bioroot in, 490. See also Pig(s)
Swine PDLSCs, 492–493. See also Periodontal ligament stem cells (PDLSCs)
Swine periodontitis model, 493–495
Synovial joints, 71
Synthetic biomaterials, in dental tissue engineering, 410
Synthetic hydrogels, matrices, for periodontal bioengineering, 505
Synthetic materials, in dental tissue engineering, 411–412
Synthetic matrices, for periodontal bioengineering, 504–505. See also Synthetic hydrogel matrices
Synthetic peptides, 475
Synthetic polymers
in dental tissue engineering, 411
for periodontal bioengineering, 504–505
Systemic immunity, 305
Systems analysis of Pax9- and Msx1-null mutants, 190–193, 194
of Pax9 and Msx1 mutants, 192–193
Systems-based approaches, 195
Systems biology, 196
defined, 180
of early tooth development, 179–202
of E–M signaling dynamics, 184–194
Tabby mouse, 144
Tamoxifen, 332
Taste bud patterning abnormalities, 44
Taste buds, 44–45
Taste papilla development, FGF10 and, 44
Taurodontism, 172, 173
T-box factor TBX2, 99. See also Tbx entries
T-box genes, 95
Tbx1 expression, 16, 97
Tbx1 expression/functions, 94, 95
TBX1 function, 94–95, 97
Tbx1-null mutant embryos, 100
Tbx1-null embryos, 100
sporadic myogenesis in, 94
Tbx1-positive longitudinal skeletal muscles, 99
Tbx22-null mice, 34
T-cells, stem cell differentiation regulation by, 305–306
T-cell suppression, nitric oxide as mediator of, 230
Tcf4 expression, 17
Tcf7 transcription factor, 142
TCP scaffolds, 357
β-TCP scaffolds, 506. See also β-Tricalcium phosphate (β-TCP)
Teeth, 447. See also Dent- entries; Odonto- entries;
Pulp entries; Root entries; Tooth entries;
Whole-tooth entries
bioengineered, 127
bioengineering of functional, 447–459
epithelial progenitor cells in, 123
Teeth (Continued)

eruption into the oral cavity, 111–112
functions of, 461
innervation and mineralization of, 110–111
mineralized tissues of, 165
morphological features of, 456
regenerating, 142–143

Telomerase, 308
Telomerase activity
of induced pluripotent stem cells, 211
vitamin C induction of, 495

Telomerase enzyme complex, 224
Telemere/telomerase activity, of induced pluripotent stem cells, 211

Temporomandibular joint (TMJ). See also TMJ entries
congenital malformations of, 72
developmental abnormalities of, 79
evolution of, 71–72
roles of, 71
vulnerability of, 72
Temoromandibular joint development, 71–85
extrinsic factor contribution to, 81
genetic control of, 78
questions related to, 81–82
regulation by extracellular matrix, 81
roles of growth factor–mediated signaling pathways in, 80–81
TGFβ signaling in, 80–81
tissue interaction roles in, 78–79
Teratoma formation, risk of, 387–388

Teratomas, 209
Tertiary (reparative) dentin, 119, 165
Tetraploid complementation, induced pluripotent stem cells and, 211–212
TGFβ/BMP signaling pathways, 36, 37. See also Transforming growth factor β (TGFβ)
TGFβ signaling
in postmigratory cranial neural crest cells, 36–37
in TMJ development, 80–81
in tooth root development, 168
TGFβ signaling pathway, significance of, 43–44
TGFβ superfamily, 39
in cellular processes, 385
regulatory effects of, 306–307

TGFβ type 1 receptor, 40
Tgfbr2 gene ablation, 36
Therapeutic transgenes, delivering, 516
Therapeutic use, iPSCs for, 212–213
Therapeutic vehicles, 230–231
Therapy (therapies). See also Bone marrow
MSC–based therapies; Bone regeneration therapies; Cell-based therapies; Cell therapy; Gene therapy; Growth factor–based therapies; MSC-based therapies; Periodontal therapies; Progenitor cell therapy; Regenerative cell therapy; Regenerative therapy (therapies); Root canal therapy; Scaffold-based therapies; Tooth regenerative therapy pluripotent-based, 217
stem cell, 517
stem cell differentiation for, 213–214
Thesleff, Irma, ix, xiii, 109
3D architecture, 214–215
Three-dimensional (3D) cell manipulation methods, 450, 451
Three-dimensional (3D) culture models, 416
Three-dimensional (3D) imaging modalities, 342
Three-dimensional (3D) matrices, 402
Three-dimensional (3D) pellet cultivation system, 514
Three-dimensional (3D) printing, for bone bioengineering, 352
Three-dimensional (3D) scaffolds, 214–215, 401–402, 403–404. See also Biomaterial scaffolds
Three-dimensional (3D) tissue engineering methods, 450
Tip cells, 20
Tissue construction, using ectodermal cells, 215
Tissue damage, directed cell migration toward, 333–334
Tissue damage repair, MSCs and, 332, 333–334
Tissue engineering, 214–215, 380. See also Muscle tissue engineering approaches advancement in, 502
pluripotent cells in, 389
tooth regeneration through, 128
Tissue engineering approaches/strategies, 397–403
regenerative strategies and, 425
Tissue engineering methods, 384
Tissue interaction roles, in temporomandibular joint development, 78–79
Tissue-nonspecific alkaline phosphatase (TNAP), in acellular cementum formation, 162
Tissue-nonspecific alkaline phosphatase (TNAP) deficiency, 171
Tissue regeneration
advances in, 467
cell homing in, 371
growth factors for, 510
in higher vertebrates, 65
Tissue-specific stem cell niches, 208
Tissue stem cell sources, for pulp regeneration, 472–473
Tissue–tissue interactions, 42, 43
Titanium, in dental tissue engineering, 412
TMJ condyles. See also Temporomandibular joint (TMJ)
growth potential of, 72
mesenchymal cell condensation of, 72
mesenchymal condensation of mouse, 73
rapid growth of, 76
TMJ defects, 80, 81
TMJ developmental stages, 72
INDEX

TMJ development regulation, by transcription factors, 79–80
TMJ disk formation, 80
TMJ disorders, 72
TMJ primordia, 73
Tongue, early development of, 41
Tongue connective tissue, 40–41
Tongue defects, 43
Tongue development, 40–45
disruption of, 42
Dlx genes in, 42
Tongue epithelium, derivation of, 44
Tongue mesenchyme, hybrid origin of, 40–43
Tongue muscle formation/myogenesis, 40–43, 43–44
Tongue muscles, 93
Tongue structure, 16
Tooth agenesis, 125
Tooth bioengineering, 127
Tooth bioengineering strategies, 197
Tooth bud cells, 370
Tooth bud formation, 38
Tooth cell lineages, 317
Tooth classes, 116
ToothCODE, 190
Tooth crown development, tooth root formation and, 158
Tooth development, 37–40
arrested, 38–39
biology of, 127
gene regulatory networks in, 112
molecular regulation of, 109–110
stages of, 448
Tooth development/replacement, in squamates, 137–140
Tooth development stages, 115–116
Tooth engineering, 431
mesenchymal cell requirements for, 438–442
Tooth eruption, 163
mineralization and, 119
Tooth eruption process, 452
Tooth evolution, odontogenic capacity and, 37
Tooth families, decreased size of, 142
Tooth family size, 140, 141
Tooth field patterning, 38
Tooth formation
de novo, 113
developmental anatomy of, 110–112
molecular roles of genes in, 186
during tooth replacement, 121
Tooth formation periodicity, in squamates, 138
Tooth-forming capacity, cells with, 128
Tooth fragment approach, 464, 465
Tooth functions, restoration of, 447
Tooth germ, 110
artificial, 450
Tooth germ bioengineering, via cell aggregation method, 450–452
Tooth germ cells, 371
Tooth germ formation, 448
Tooth germ production, using a biodegradable scaffold, 450
Tooth germs, 112
transplantation of, 452–454
Tooth germ tissues, availability of, 292
Tooth identity, 113
Tooth induction, control of, 115
Tooth inductive potential, 113. See also Odontogenetic potential induction
Tooth initiation
CNCC-derived mesenchyme patterning during, 37–38
key signaling events during, 115
Tooth innervation, 432, 433
Tooth loss, treatment protocols for, 485
Tooth morphogenesis, 110
Bmp and vertebrate, 142
CNCC and, 38–39
epithelial–mesenchymal interactions for, 112–113, 114
regulation of, 112–115
Tooth morphogenesis/renewal, 109–124
Tooth organogenesis, 456
Tooth organ replacement, in vivo, 452–455
Tooth placode formation, 113, 114
in amniotes, 135–136
by cell transplantation, 371
dental stem cells and, 126–127
evolution of, 135
future challenges related to, 147–148
mechanisms controlling, 135
successional lamina relationship to, 140–141
through tissue engineering, 128
Tooth regeneration experiments, 246
Tooth regeneration research/studies, 147–148
using ASCs, 245–247
Tooth regeneration strategies, 196–197
Tooth regenerative therapy, 448
future directions of, 455–456
as a study model, 456
Tooth renewal, 121–126
mouse incisor as a model for, 315–327
stem cells in, 315–327
Tooth renewal/replacement, 126–127
Tooth replacement, 121–124, 316–317
in basal amniotes, 136–137
indefinite, 140–141, 145
in mammals, 316
molecular regulation of, 123, 124–126
in reptiles, 135
stimulating, 147
study of, 128
successional tooth formation during, 121
Tooth replacement capacity, in amniotes, 136
Tooth replacement rates, 140
Tooth replacement restriction, 124
Tooth root(s)
  bioengineering of, 485–490, 496
  mineralized tissues in, 153–154
  remodeling and homeostasis in, 164–165
Tooth root development, 111, 153–177, 297. See also Root entries
  alveolar bone formation and, 157
  arrested, 173
  disruption in, 168–169
Tooth root engineering
  allogeneic mesenchymal stem cells for, 487–488
  dental follicle cell sheets for, 487
Tooth root formation, 448
  signaling pathways and candidate factors associated with, 166–167
Tooth root regeneration, future directions for stem cell-mediated, 496
Tooth root tissues
  key characteristics of, 155–156
  mineral content of, 157
  structure and composition of, 154–158
Tooth scaffolds, preshaped, 431
Tooth-shaped scaffolds, materials for, 450
Tooth size control, 452
Tooth systems biology, Web resource for, 190
Tooth tissue–derived stem cells, differentiating into dental lineage cells, 455
Tooth units, transplantation of, 452–454
TOPGAL reporter mice, 322
Totipotency, somatic cell nuclear transfer and, 209
Totipotent stem cells, 206, 207
Trainor, Paul A., xiii, 3
Transcriptional coupling of E–M tissues, during organogenesis, 184–185
Transcriptional regulation, of dental mesenchymal stem cell differentiation, 308–309
Transcription factors
  role of, 190
  TMJ development regulation by, 79–80
Transendothelial migration, 268
Transforming growth factor β (TGFβ), 36, 347, 397. See also TGFβ entries
  in periodontia development, 170
Transforming growth factor β1 (TGFβ1), 266
Transforming growth factor β1 (TGFβ1) coreceptor, 384
Transforming growth factor β3 (TGFβ3), 371
Transgene-free human iPSCs, 387. See also Induced pluripotent stem cells (iPSCs)
Transgenes, genomic migration of, 387
Transgenic manipulation, 165
Transient epithelial signaling centers, enamel knots as, 117
Transit-amplifying cells (TACs), 145, 330, 331, 332, 333
Transplantation. See also Allogeneic stem cell transplantation
  of allogeneic dental pulp stem cells, 492
  of mesenchymal stem cells, 472
  as a tooth replacement strategy, 452–454
Treacher–Collins syndrome, 22
Treated dentin matrix (TDM) scaffolds, 296, 487
Tricalcium phosphate (TCP), in dental tissue engineering, 411
β-Tricalcium phosphate (β-TCP), 248, 384. See also TCP scaffolds
  for periodontal bioengineering, 505, 506
Trigeminal placode, 12
Trilineage mesenchymal differentiation, 226
Triploid blastocyst generation, 305
Tumor necrosis factor–α (TNFα), 305–306, 308, 309
Two-color FACS, 228
Two-dimensional (2D) cell culture systems, 415, 416
Type I collagen, 157
Ubiquitin ligase activity, 332
Umbilical cord–derived stem cells, 65
Undifferentiated PDL cells, potential of, 291. See also Periodontal ligament (PDL)
United States, bone grafts performed in, 379. See also U.S. Food and Drug Administration (FDA)
Upper lip formation, 32
U.S. Food and Drug Administration (FDA), on dental tissue engineering models, 412
Vagal neural crest cells, 10
Vascular cell adhesion molecule 1 (VCAM1) antigen, 228
Vascular development, VEGF signaling during, 20
Vascular endothelial growth factor (VEGF), 244, 264, 266, 347, 469. See also VEGF entries
Vascular endothelial growth factor A (VEGF-A), 464
Vascular endothelial growth factor (VEGF) signaling, 18, 20
  during muscle development, 19
Vascularization
  of dental papilla, 434
  induced, 469–470
  in pulp, 477
  Vascularization promotion, 244
Vascularized bone marrow microenvironment, regenerating, 229
Vascularized incisor pulp chamber, 330
Vascular pattern, myogenesis and, 19
Vascular plexus formation, 19
Vascular system, 20
craniofacial morphogenesis and, 17
spatiotemporal formation and remodeling of, 17
Vascularity, formation of, 5
Vascularity–muscle interactions/integration, 18–19
Vascularity–neural interactions/integration, 19–20
Vascularogenesis, 17–18
Vector-free iPSCs, 211. See also Induced pluripotent stem cells (iPSCs)
Vectors, viral and nonviral, 388
VEGF-mutant embryos, 20. See also Vascular endothelial growth factor (VEGF) entries
VEGF protein, in head muscles, 19
Vegfr1−/−-mutant embryos, 18
Vegfr2 (Kdr)−/− embryos, 18
Ventricular progenitor cells, 97
Vertebrate evolution, 99
Vertebrate head, 11–12
Vertebrate neural crest, 31
Vertebrate neural induction, 7
Vertebrate organogenesis, 180
Vertebrates
new head in, 42
tissue regeneration in, 65
Vertebrate tooth morphogenesis, Bmp and, 142
Vessel-associated stem cell populations, 400
Vestigial diastema teeth, 144
Vestigial successional lamina, 141, 143–144
Viral vectors, 388
iPSCs and, 211
Viruses, adeno-associated, 403
Visceral endoderm, 21
Visceral muscularization, 99
Visceral origins, of branchiomeric skeletal muscles, 98–99
Vitamin C, telomerase activity induced by, 495
Von den Hoff, Johannes W., xiv, 259, 395
Walboomers, X. Frank, xiv, 409
Wan, Derrick C., xiv, 379
Wang, Lei, xiv, 409
Wang, Songlin, xiv, 485
Wei, Fuian, xiv, 485
Wharton’s duct, 272
Whitlock, John A., xiv, 135
Whole-pulp regeneration, 468–470
Whole-tooth engineering, 431–446
challenges related to, 431–432
usefulness of, 442–443
Whole-tooth organ engineering, using embryonic dental cells, 432–435
Whole-tooth regeneration, 418
as an organ-replacement regenerative therapy, 448–452
Whole-tooth regeneration strategy, 456
Whole-tooth replacement, novel technologies used for, 448
Whole-tooth replacement strategies, 449
Wisdom teeth, 112
Wnt1-Cre, Dicer1 deletion by, 322
Wnt1-Cre system, 36
Wnt3a activator, 349
WNT3 activity, reducing, 9
Wnt5a activator, 349
Wnt5b activator, 349
Wnt10a expression, 118
Wnt activation, in restoring dental tissue differentiation, 193–194
Wnt active dental epithelial cells, 143
Wnt activity regulation, by Bmps, 143
Wnt antagonist Dkk1, 182
Wnt-β-catenin dependent (canonical) pathway, 349
Wnt-β-catenin independent (Wnt-noncanonical) pathways, 349
Wnt/β-catenin signal pathway, 113–114
Wnt-Bmp feedback circuit, 190, 195–196
ordinary differential equation model of, 189
validating, 193
Wnt-Bmp intertissue feedback circuit, 189
Wnt-Bmp signaling circuit, 193
Wnt expression, cross-regulation of, 189
Wnt (WNT) inhibitors, 93, 170
Wnt ligands, 142
Wnt pathway, 189, 141–142
Eda regulation by, 144
Wnt pathway mutations, 126
WNT (Wnt) proteins, 7, 39, 348–349, 389
Wnt (WNT) signaling, 8, 55, 113, 119, 169–170
in ameloblasts, 119
constitutive activation of, 193, 194
in early odontogenesis, 182–183
during incisor renewal, 322
neural crest cell formation and, 9–10
regulation of, 9
Shh and, 143
Wnt signaling inhibitors, 61
Wnt signaling pathway modulators, 124
Wnt signaling pathways, role in tooth development, 306
Wound repair, 215
Xerostomia, 272
X-linked inhibitor of apoptosis protein (XIAP), 306
Yan, Xing, xiv, 205
Yang, Fang, xiv, 409
Yao, Shaoqian, xiv, 421
Yu, Na, xiv, 409
Zebrafish, craniofacial myogenesis in, 96
Zfh1b gene, 10
Zheng, Ying, xiv, 367
Zhou, Jian, xiv, 367
Zou, Xiaoying, xiv, 205