Contents

Preface xi
Introduction I Embryology: Clinical Relevance and Historical Perspective xxi

Part 1 • General Embryology 1

Chapter 1 • Introduction to Molecular Regulation and Signaling 3

Introduction 3
Gene Transcription 3
Other Regulators of Gene Expression 5
Induction and Organ Formation 6
Cell Signaling 6
Key Signaling Pathways for Development 9
Summary 12

Chapter 2 • Gametogenesis: Conversion of Germ Cells into Male and Female Gametes 14

Primordial Germ Cells 14
The Chromosome Theory of Inheritance 15
Morphologic Changes During Maturation of the Gametes 26
Summary 33

Chapter 3 • First Week of Development: Ovulation to Implantation 35

Ovarian Cycle 35
Fertilization 38
Cleavage 43
Blastocyst Formation 44
Epiblast, Hypoblast, and Axis Formation 45
Uterus at the Time of Implantation 47
Summary 49

Chapter 4 • Second Week of Development: Bilaminar Germ Disc 5
Introduction 51
Day 8 51
Day 9 52
Days 11 and 12 53
Day 13 54
Summary 58

Chapter 5 • Third Week of Development: Trilaminar Germ Disc 60
Gastrulation: Formation of Embryonic Mesoderm and Endoderm 60
Formation of the Notochord 60
Establishment of the Body Axes 61
Fate Map Established During Gastrulation 66
Growth of the Embryonic Disc 68
Further Development of the Trophoblast 69
Summary 71

Chapter 6 • Third to Eighth Weeks: The Embryonic Period 73
Introduction 73
Derivatives of the Ectodermal Germ Layer 74
Derivatives of the Mesodermal Germ Layer 81
Derivatives of the Endodermal Germ Layer 89
Patterning of the Anteroposterior Axis: Regulation by Homeobox Genes 91
External Appearance During the Second Month 92
Summary 95

Chapter 7 • The Gut Tube and the Body Cavities 98
A Tube on Top of a Tube 98
Formation of the Body Cavity 99
Serous Membranes 99
Diaphragm and Thoracic Cavity 103
Formation of the Diaphragm 104
Summary 107

Chapter 8 • Third Month to Birth: The Fetus and Placenta 108
Development of the Fetus 108
Fetal Membranes and Placenta 112
Chorion Frondosum and Decidua Basalis 114
Structure of the Placenta 116
Amnion and Umbilical Cord 120
Placental Changes at the End of Pregnancy 120
Amniotic Fluid 121
Fetal Membranes in Twins 122
Parturition (Birth) 123
Summary 128

Chapter 9 • Birth Defects and Prenatal Diagnosis 130
Birth Defects 130
Prenatal Diagnosis 141
Fetal Therapy 145
Summary 145

Part 2 • Systems-Based Embryology 147

Chapter 10 • The Axial Skeleton 149

Introduction 149
Skull 149
Vertebrae and the Vertebral Column 158
Ribs and Sternum 160
Summary 161

Chapter 11 • Muscular System 162

Introduction 162
Striated Skeletal Musculature 162
Innervation of Axial Skeletal Muscles 163
Skeletal Muscle and Tendons 165
Molecular Regulation of Muscle Development 165
Patterning of Muscles 165
Head Musculature 165
Limb Musculature 166
Cardiac Muscle 166
Smooth Muscle 166
Summary 167

Chapter 12 • Limbs 169

Limb Growth and Development 169
Limb Musculature 171
Summary 179

Chapter 13 • Cardiovascular System 181

Establishment and Patterning of the Primary Heart Field 181
Formation and Position of the Heart Tube 183
Formation of the Cardiac Loop 185
Molecular Regulation of Cardiac Development 188
Blood Flow and Cardiac Development 189
Development of the Sinus Venosus 189
Formation of the Cardiac Septa 191
Formation of the Conducting System of the Heart 208
Vascular Development 208
Circulation Before and After Birth 219
Summary 221

Chapter 14 • Respiratory System 225

Formation of the Lung Buds 225
Larynx 227
Trachea, Bronchi, and Lungs 227
Maturation of the Lungs 228
Summary 231

Chapter 15 • Digestive System 232

Divisions of the Gut Tube 232
Molecular Regulation of Gut Tube Development 233

Mesentery 234
Foregut 235
Molecular Regulation of Liver Induction 244
Pancreas 246
Midgut 247
Hindgut 254
Summary 256

Chapter 16 • Urogenital System 259

Introduction 259
Urinary System 259
Genital System 270
Summary 287

Chapter 17 • Head and Neck 289

Introduction 289
Pharyngeal Arches 291
Pharyngeal Pouches 295
Pharyngeal Clefts 296
Molecular Regulation of Facial Development 297
Tongue 302
Thyroid Gland 303
Face 305
Intermaxillary Segment 306
Secondary Palate 306
Nasal Cavities 313
Teeth 313
Molecular Regulation of Tooth Development 315
Summary 316

Chapter 18 • Central Nervous System 318

Introduction 318
Spinal Cord 320
Brain 329
Molecular Regulation of Brain Development 341
Cranial Nerves 346
Autonomic Nervous System 346
Summary 352

Chapter 19 • Ear 356

Introduction 356
Internal Ear 356
Middle Ear 359
External Ear 361
Hearing 361
Summary 364

Chapter 20 • Eye 365

Optic Cup and Lens Vesicle 365
Retina, Iris, and Ciliary Body 367
Lens 367
Choroid, Sclera, and Cornea 369

Vitreous Body 369
Optic Nerve 370
Molecular Regulation of Eye Development 370
Summary 374

Chapter 21 • Integumentary System 375

Skin 375
Hair 377
Fingernails and Toenails 378
Sweat Glands 378
Mammary Glands 378
Summary 380

Part 3 • Appendix 381

Answers to Problems 383

Figure Credits 395
Glossary of Key Terms 401
Index 415