

Contents

<i>Preface</i>	<i>page xi</i>
Chapter 1. Form and Function	1
Historical Foundation	1
Skeletal Pattern Formation	5
Skeletal Evolution	11
Dermal, Perichondral, and Endochondral Bone	13
Bony Epiphyses and Sesamoid Bones	16
Mechanobiology in the Mammalian Skeleton	18
Human Skeletal Growth and Functional Adaptation	20
Chapter 2. Skeletal Tissue Histomorphology and Mechanics	31
Cartilage	31
Bone	33
Tendons and Ligaments	38
Levels of Consideration in Mechanobiology	40
Stress and Strain	42
Single-Phase Material Representations	43
Two-Phase Porous Hydrated Material Representations	47
Structural Mechanics and Stress Analysis	48
Chapter 3. Cartilage Differentiation and Growth	53
Tendon Development and Fibrocartilage Metaplasia	53
Secondary Cartilage	62
Joint Surface Morphogenesis	62
Chapter 4. Perichondral and Periosteal Ossification	73
Bone Formation	73
Biological and Mechanobiological Factors	75
Mathematical Model for Growth and Adaptation	80
Model Development	80
	vii

Normal Growth and Aging Simulations	86
Comparisons Between Clinical Data and Simulations	90
Mechanobiological Effects in Growth and Adaptation	94
Creating a More Complete Model	96
Stress/Strain Histories	96
Site Specificity, Lining Cells, and Time Lags	98
Chapter 5. Endochondral Growth and Ossification	106
Morphology and Biology	106
Biological Factors	110
Mechanobiological Regulation of Growth and Ossification Patterns	114
Mechanobiology and Endochonral Ossification Patterns	117
Development of the Femur	118
Ossification Patterns in the Sternum	122
Long Bone Ossification	125
Epiphyses and Pseudoepiphyses	132
Chapter 6. Cancellous Bone	138
Biology and Morphology	138
A Continuum Model Approach for Mechanically Regulated Remodeling	140
Normal Development and Adaptation of Cancellous Bone Architecture	150
Functional Adaptation Caused by Changes in Physical Activities	154
Modifications in Bone Structure by Biological Factors	155
Bone Remodeling around Implants	156
Creating a More Complete Model	158
Chapter 7. Skeletal Tissue Regeneration	161
Biology and Mechanobiology	161
The Bone-Implant Interface	168
Fracture Healing	172
Rigid Internal Fixation	172
Nonrigid Fixation	176
Pseudarthrosis	181
Cyclic Compression Osteogenesis vs. Distraction Osteogenesis	184
Neochondrogenesis and Joint Repair	191
Chapter 8. Articular Cartilage Development and Destruction	201
Growth and Ossification Near Joint Surfaces	201
Articular Cartilage Development and Maintenance	210
Joint Adaptation and Aging	220
Osteoarthritis	222
Chapter 9. Mechanobiology in Skeletal Evolution	235
Bone Scaling and Developmental Mechanics	236

CONTENTS	ix
Scaling Influences on Joints	246
Long Bone Cross Sections in Different Taxa	253
Bony Epiphyses and Growth Plates	255
Chapter 10. The Physical Nature of Living Things	265
Appendix A. Material Characteristics	267
Stress	267
Strain	274
Elastic Material Properties	276
Viscoelasticity and Poroelasticity	279
Bone	279
Ligament/Tendon	280
Cartilage	281
Appendix B. Structural Characteristics	283
Strength of Materials Approach	283
Experimental and Computational Stress Analysis	287
Appendix C. Failure Characteristics	292
A Simplification of Material Behavior	292
Monotonic Material Failure Criteria	292
Uniaxial Fatigue and Creep Damage	297
Multiaxial Fatigue	300
Fatigue and Strain Energy Regulation of Biology	302
<i>Index</i>	309