

Contents

1	Anatomy of the Cardiovascular Apparatus	1
1.1	Vasculature Architecture and Function	1
1.2	Systemic and Pulmonary Circulation	2
1.3	Fetal Blood Circulation	2
1.4	Stresses and Strains in the Vasculature	3
1.5	Space and Time Scales	4
1.6	Heart	5
1.6.1	Atria	7
1.6.2	Ventricles	11
1.6.3	Aortic Valve	12
1.6.4	Internal Anatomical Features of the Heart	16
1.6.5	Heart Vascularization	18
1.6.6	Heart Innervation	18
1.6.7	Fractal Geometry	25
1.6.8	Cardiogenesis	29
1.6.9	Early Stages of Cardiogenesis and Chemical Control	29
1.6.10	Cardiac Progenitor Cells and Repair	33
1.7	Vasculature	35
1.7.1	Systemic and Pulmonary Circulation	35
1.7.2	Blood Circuit	36
1.7.3	Blood Compartments	36
1.7.4	Local Geometry and Blood Flow	37
1.7.5	Particular Structures	39
1.7.6	Microcirculation and Macrocirculation	40
1.7.7	Adaptation	42
1.7.8	Fractal Vasculature	42
1.7.9	Circulatory Networks	45
1.8	Innervation of the Cardiovascular Apparatus	58
1.8.1	Parasympathetic and Sympathetic Control	58
1.8.2	Role of Reactive Oxygen Species	63
1.8.3	Inputs from Vascular Sensors	64

2	Anatomy of the Ventilatory Apparatus	73
2.1	Upper Airways	75
2.1.1	Nose	75
2.1.2	Mouth	83
2.1.3	Pharynx	83
2.1.4	Larynx	84
2.2	Thoracic Respiratory System	87
2.2.1	Chest Wall	87
2.2.2	Mediastinal Airways	91
2.2.3	Lungs	94
2.3	Tracheobronchial Tree	101
2.3.1	Bronchi	104
2.3.2	Bronchioles	108
2.3.3	Fractal Modeling	109
2.3.4	Bronchial Walls	113
2.3.5	Bronchiolar Walls	114
2.3.6	Pulmonary Alveolus	115
2.3.7	Between-Airway Communications	116
2.4	Development of Intrathoracic Airways and Airspaces	116
2.4.1	Developmental Phases	118
2.4.2	Development at the Macroscopic Scale	119
2.4.3	Development at the Microscopic Scale	120
2.4.4	Influence Factors	122
2.4.5	Computational Model of Early Intrathoracic Airway Morphogenesis	127
2.5	Pulmonary Vascularization	131
2.5.1	Communications Between Pulmonary and Bronchial Circulation	131
2.5.2	Development of Intrapulmonary Blood Vessels	132
2.5.3	Pulmonary Circulation	133
2.5.4	Pulmonary Arterial Circulation	134
2.6	Innervation of Ventilatory Organs	136
2.6.1	Neurons	140
2.6.2	Autonomic Nervous System	141
2.6.3	Parasympathetic and Sympathetic Control	141
2.6.4	Evolution of Innervation of the Ventilatory Apparatus	149
2.6.5	Nerve Subpopulations	150
2.6.6	Mechanosensors – Baroreceptors and Voloreceptors	151
2.6.7	Baroreflex	153
2.6.8	Chemosensors	153
2.6.9	Arterial Chemoreflex	154
3	Cardiovascular Physiology	157
3.1	Heart	159
3.1.1	Left Ventricle Cycle	161
3.1.2	Stroke Volume	165

3.1.3	Pressure–Volume Curve	167
3.1.4	Interferences Between Cardiac Cells in the Cardiac Function	171
3.1.5	Cardiomyocyte Organelles and Coupled Metabolism, Energetics, Signaling, and Contraction	172
3.1.6	Influence of Post-Translational Modifications of Regulators	185
3.1.7	Energetics	186
3.1.8	Ketone Bodies	219
3.1.9	Matching of ATP Supply to Demand	225
3.1.10	Myocardial Oxygen Consumption	226
3.1.11	Cardiac Electrophysiology	228
3.1.12	Calcium Handling During Exercise	244
3.2	Large Blood Vessels	245
3.2.1	Arterial Circulation	245
3.2.2	Venous Return	247
3.2.3	Metabolic Blood Flow Regulation	249
3.2.4	Coronary Circulation	250
3.2.5	Cerebral Circulation	255
3.2.6	Pulmonary Circulation	258
3.3	Microcirculation	259
3.3.1	Capillary Flow	260
3.3.2	Capillary Recruitment	261
3.3.3	Transcapillary Transfer of Materials	261
3.4	Rhythmicity	286
3.5	Convective Heat Transfer	289
3.6	Regulation of the Circulation	291
3.6.1	Autoregulation in the Arterial Bed	293
3.6.2	Neural Effects on Heart and Blood Vessels	312
3.6.3	Adrenergic and Cholinergic Receptors	329
3.6.4	Circulation Sensors	331
3.6.5	Short-Term Control of the Circulation	332
3.6.6	Response to Stress	333
3.6.7	Delayed Control of the Circulation	340
4	Physiology of Ventilation	353
4.1	Main Features and Input Data of the Body’s Respiration	353
4.1.1	Oxygen Input and Cell Metabolism	353
4.1.2	Gas Mixture	355
4.1.3	Gas Transfer	357
4.1.4	Inhaled Air	360
4.1.5	Breathing Modes	366
4.1.6	Functions of the Body’s Respiration	367
4.1.7	Body’s Oxygen and Carbon Dioxide Content	368
4.1.8	Respiratory Epitheliocytes	369

4.1.9	Respiratory Cilia	370
4.1.10	Deformation of the Lung Parenchyma	371
4.2	Lung Volumes	371
4.2.1	Pressure–Volume–Temperature Relations of an Ideal Gas	372
4.2.2	Measurement of Pulmonary Volumes and Respiratory Flow Rates	375
4.2.3	Lung Volumes Measured by Spirometry	376
4.2.4	Dead Spaces	378
4.3	Mode of Ventilation	379
4.4	Mechanics of Ventilation	380
4.4.1	Monoalveolar Model	381
4.4.2	Quiet Breathing	383
4.4.3	Effort Breathing	386
4.4.4	Elastic Properties of the Lung and Chest Wall	387
4.4.5	Ventilatory Resistances	392
4.4.6	Ventilatory Work	392
4.5	Ventilation–Perfusion Ratio	393
4.6	Gas Transport	397
4.6.1	Inhaled Air Distribution	397
4.6.2	Gas Content in the Serial Compartments	398
4.6.3	Alveolar Ventilation	398
4.6.4	Gas Transport and Mixing	400
4.6.5	Alveolocapillary Transfer	401
4.6.6	Pulmonary Gas Transfer Capacity	403
4.6.7	Pulmonary Circulation	405
4.6.8	Blood O ₂ Affinity Curve	407
4.6.9	CO ₂ Blood Transport	410
4.7	Maintenance of pH Homeostasis—Hydrogen Ion Control	412
4.8	Control of the Respiration	414
4.8.1	Respiration Nervous Centers	417
4.8.2	Respiratory Clock, a Synchronous Bilateral Command ...	419
4.8.3	Respiratory Nerves	424
4.8.4	Ventilation Receptors	427
4.9	Oxygen Sensing	428
4.10	Immune Defense of the Ventilatory Apparatus	429
4.10.1	Organization of the Immune System of the Ventilatory Apparatus	431
4.11	Metabolic Functions of the Lung	436
4.11.1	Detoxification Enzymes	436
4.11.2	Circulating Substance Fate	438
4.11.3	Respiratory Cell Production	439

5 Medical Images and Physiological Signals	441
5.1 Imaging and Geometry Modeling	441
5.1.1 Imaging Techniques	442
5.1.2 3D Reconstruction	456
5.1.3 Meshing	460
5.2 Hemodynamics Signals.....	462
5.2.1 Volume and Pressure.....	462
5.2.2 Flow Rate and Velocity	466
5.3 Measurement of Heart Electric and Magnetic Properties	469
5.3.1 Electrocardiogram	470
5.3.2 Vectroelectrocardiography.....	474
5.3.3 Magnetocardiography.....	474
5.3.4 Impedance Plethysmography	474
5.4 Upper Airway Patency and Resistance	475
5.5 Lung Function Testing.....	476
5.5.1 Breathing Mechanics—Main Measuring Devices and Procedures.....	476
5.5.2 Breathing Function—Blood Gas Measurements	481
5.5.3 Carbon Monoxide Transfer Capacity	481
5.5.4 Clearance by Respiratory Epithelium	482
5.5.5 Respiratory Indices	483
5.5.6 Blood Gas	485
Conclusion	487
References	491
Notation Rules: Aliases and Symbols	525
List of Currently Used Prefixes and Suffixes	533
List of Aliases and Primary Symbols	537
Complementary Lists of Notations	567
Index	575