

Table of Contents

Preface xi

SECTION I. INTRODUCTION

1. The General & Cellular Basis of Medical Physiology 1

- Introduction 1
- Body Fluid Compartments 1
- Units for Measuring Concentration of Solutes 3
- Composition of Body Fluids 4
- Forces Producing Movement of Substances Between Compartments 5
- The Capillary Wall 8
- Sodium & Potassium Distribution & Total Body Osmolality 8
- Functional Morphology of the Cell 10
- Transport Across Cell Membranes & Membrane Potentials 22
- Intercellular Communication 26
- Homeostasis 32
- Aging 32

Section I References: 33

SECTION II. PHYSIOLOGY OF NERVE & MUSCLE CELLS

2. Excitable Tissue: Nerve 35

- Introduction 35
- Nerve Cells 35
- Electrical Phenomena in Nerve Cells 37
- Ionic Basis of Excitation & Conduction 42
- Properties of Mixed Nerves 44
- Nerve Fiber Types & Function 44
- Nerve Growth Factor 46
- Glia 47

3. Excitable Tissue: Muscle 48

- Introduction 48
- Skeletal Muscle 48
 - Morphology 48
 - Electrical Phenomena & Ionic Fluxes 49
 - Contractile Responses 50
 - Energy Sources & Metabolism 54
 - Properties of Muscles in the Intact Organism 56
- Cardiac Muscle 58
 - Morphology 58
 - Electrical Properties 58
 - Mechanical Properties 60
 - Metabolism 61
 - Pacemaker Tissue 61
- Smooth Muscle 61

Morphology 61
Visceral Smooth Muscle 62
Multi-Unit Smooth Muscle 64

4. Synaptic & Junctional Transmission 65

Introduction 65
Synaptic Transmission 65
 Functional Anatomy 65
 Electrical Events at Synapses 67
 Inhibition & Facilitation at Synapses 70
 Chemical Transmission of Synaptic Activity 73
Neuromuscular Transmission 86
 The Myoneural Junction 86
 Nerve Endings in Smooth & Cardiac Muscle 87
 Denervation Hypersensitivity 88

5. Initiation of Impulses in Sense Organs 90

Introduction 90
Sense Organs & Receptors 90
The Senses 90
Electrical & Ionic Events in Receptors 92
"Coding" of Sensory Information 94

Section II References: 95

SECTION III. FUNCTIONS OF THE NERVOUS SYSTEM

6. Reflexes 97

Introduction 97
Monosynaptic Reflexes: The Stretch Reflex 98
Polysynaptic Reflexes: The Withdrawal Reflex 103
General Properties of Reflexes 104

7. Cutaneous, Deep, & Visceral Sensation 106

Introduction 106
Pathways 106
Touch 109
Proprioception 109
Temperature 110
Pain 110
Differences Between Somatic & Visceral Sensory Mechanisms 112
Visceral Pain 112
Referral & Inhibition of Pain 114
Other Sensations 115

8. Vision 117

Introduction 117
Anatomic Considerations 117
The Image-Forming Mechanism 121
The Photoreceptor Mechanism: Genesis of Action Potentials 124
Responses in the Visual Pathways & Cortex 127
Other Aspects of Visual Function 130
Color Vision 133
Eye Movements 135

9. Hearing & Equilibrium 137

Introduction 137
Anatomic Considerations 137
Hair Cells 141

Hearing	142	
Vestibular Function	147	
10. Smell & Taste		150
Introduction	150	
Smell	150	
Receptors & Pathways	150	
Physiology of Olfaction	151	
Taste	153	
Receptor Organs & Pathways	153	
Physiology of Taste	154	
11. Arousal Mechanisms, Sleep, & the Electrical Activity of the Brain		156
Introduction	156	
The Reticular Formation & the Reticular Activating System	156	
The Thalamus & the Cerebral Cortex	156	
Evoked Cortical Potentials	157	
The Electroencephalogram	158	
Physiologic Basis of the EEG, Consciousness, & Sleep	160	
12. Control of Posture & Movement		166
Introduction	166	
General Principles	166	
Pyramidal System	167	
Anatomy	167	
Function	169	
Extrapyramidal Mechanisms	170	
Spinal Integration	171	
Medullary Components	172	
Midbrain Components	174	
Cortical Components	174	
Basal Ganglia	175	
Cerebellum	177	
Anatomic & Functional Organization	177	
Physiology	180	
13. The Autonomic Nervous System		183
Introduction	183	
Anatomic Organization of Autonomic Outflow	183	
Chemical Transmission at Autonomic Junctions	185	
Responses of Effector Organs to Autonomic Nerve Impulses	185	
14. Central Regulation of Visceral Function		189
Introduction	189	
Medulla Oblongata	189	
Hypothalamus	190	
Anatomic Considerations	190	
Hypothalamic Function	192	
Relation of Hypothalamus to Autonomic Function	192	
Relation to Sleep	193	
Relation to Cyclic Phenomena	194	
Hunger	194	
Thirst	196	
Control of Posterior Pituitary Secretion	197	
Control of Anterior Pituitary Secretion	201	
Temperature Regulation	204	
15. Neural Basis of Instinctual Behavior & Emotions		209
Introduction	209	
Anatomic Considerations	209	
Limbic Functions	209	

Sexual Behavior 211
 Fear & Rage 213
 Motivation 214
 Brain Chemistry, Behavior, & Synaptic Transmission in the Central Nervous System 215

**16. "Higher Functions of the Nervous System":
 Conditioned Reflexes, Learning, & Related Phenomena 219**

Introduction 219
 Methods 220
 Learning & Memory 220
 Functions of the Neocortex 223

Section III References: 227

SECTION IV. ENDOCRINOLOGY & METABOLISM

17. Energy Balance, Metabolism, & Nutrition 229

Introduction 229
 Energy Metabolism 229
 Intermediary Metabolism 233
 Carbohydrate Metabolism 235
 Protein Metabolism 241
 Fat Metabolism 247
 Nutrition 257

18. The Thyroid Gland 262

Introduction 262
 Anatomic Considerations 262
 Formation & Secretion of Thyroid Hormones 263
 Transport & Metabolism of Thyroid Hormones 265
 Effects of Thyroid Hormones 268
 Mechanism of Action of Thyroid Hormones 270
 Regulation of Thyroid Secretion 270
 Clinical Correlates 271

19. Endocrine Functions of the Pancreas & the Regulation of Carbohydrate Metabolism. 276

Introduction 276
 Islet Cell Structure 276
 Structure, Biosynthesis, & Secretion of Insulin 277
 Fate of Secreted Insulin 278
 Consequences of Insulin Deficiency & Actions of Insulin 279
 Insulin Excess 286
 Mechanism of Action of Insulin 286
 Regulation of Insulin Secretion 287
 Glucagon 290
 Other Islet Cell Hormones 292
 Endocrine Regulation of Carbohydrate Metabolism 292
 Hypoglycemia & Diabetes Mellitus in Humans 294

20. The Adrenal Medulla & Adrenal Cortex 297

Introduction 297
 Adrenal Morphology 297
 Adrenal Medulla 298
 Structure & Function of Medullary Hormones 298
 Regulation of Adrenal Medullary Secretion 301
 Adrenal Cortex 301
 Structure & Biosynthesis of Adrenocortical Hormones 301
 Transport, Metabolism, & Excretion of Adrenocortical Hormones 305
 Effects of Adrenal Androgens & Estrogens 307
 Physiologic Effects of Glucocorticoids 308
 Pharmacologic & Pathologic Effects of Glucocorticoids 310

- Regulation of Glucocorticoid Secretion 311
- Effects of Mineralocorticoids 314
- Regulation of Aldosterone Secretion 317
- Role of Mineralocorticoids in the Regulation of Salt Balance 319
- Summary of the Effects of Adrenocortical Hyper- & Hypofunction in Humans 319

21. Hormonal Control of Calcium Metabolism & the Physiology of Bone 321

- Introduction 321
- Calcium & Phosphorus Metabolism 321
- Bone Physiology 322
- Vitamin D & the Hydroxycholecalciferols 325
- The Parathyroid Glands 327
- Calcitonin 329
- Effects of Other Hormones & Humoral Agents on Calcium Metabolism 331

22. The Pituitary Gland 333

- Introduction 333
- Morphology 333
- Intermediate Lobe Hormones 335
- Growth Hormone 337
- Physiology of Growth 340
- Pituitary Insufficiency 342
- Pituitary Hyperfunction in Humans 344

23. The Gonads: Development & Function of the Reproductive System 346

- Introduction 346
- Sex Differentiation & Development 346
 - Chromosomal Sex 346
 - Embryology of the Human Reproductive System 349
 - Aberrant Sexual Differentiation 352
 - Puberty 353
 - Precocious & Delayed Puberty 354
 - Menopause 355
- Pituitary Gonadotropins & Prolactin 355
- The Male Reproductive System 357
 - Structure 357
 - Gametogenesis & Ejaculation 358
 - Endocrine Function of the Testes 360
 - Control of Testicular Function 363
 - Abnormalities of Testicular Function 364
- The Female Reproductive System 364
 - The Menstrual Cycle 364
 - Ovarian Hormones 369
 - Control of Ovarian Function 373
 - Abnormalities of Ovarian Function 375
- Pregnancy 376
- Lactation 378

24. Other Endocrine Organs 381

- Introduction 381
- The Endocrine Functions of the Kidneys: Renin & Erythropoietin 381
- The Endocrine Function of the Heart: Atrial Natriuretic Peptide 385
- Pineal 386

Section IV References: 387

SECTION V. GASTROINTESTINAL FUNCTION

25. Digestion & Absorption 391

- Introduction 391
- Carbohydrates 391

Proteins & Nucleic Acids 394
Lipids 395
Absorption of Water & Electrolytes 397
Absorption of Vitamins & Minerals 399

26. Regulation of Gastrointestinal Function 401

Introduction 401
Anatomic Considerations 401
Gastrointestinal Hormones 402
Mouth & Esophagus 406
Stomach 408
Regulation of Gastric Secretion & Motility 411
Other Functions of the Stomach 413
Exocrine Portion of the Pancreas 414
Liver & Biliary System 416
Small Intestine 421
Colon 423

Section V References: 427

SECTION VI. CIRCULATION

27. Circulating Body Fluids 429

Introduction 429
Blood 429
 Bone Marrow 429
 White Blood Cells 431
 Immune Mechanisms 433
 Red Blood Cells 438
 Blood Types 441
 Plasma 444
 Platelets 445
 Hemostasis 446
Lymph 449

28. Origin of the Heartbeat & the Electrical Activity of the Heart 450

Introduction 450
Origin & Spread of Cardiac Excitation 450
The Electrocardiogram 452
Cardiac Arrhythmias 457
Electrocardiographic Findings in Other Cardiac & Systemic Diseases 462

29. The Heart as a Pump 466

Introduction 466
Mechanical Events of the Cardiac Cycle 466
Cardiac Output 470

30. Dynamics of Blood & Lymph Flow 477

Introduction 477
Anatomic Considerations 477
Biophysical Considerations 480
Arterial & Arteriolar Circulation 485
Capillary Circulation 488
Lymphatic Circulation & Interstitial Fluid Volume 489
Venous Circulation 491

31. Cardiovascular Regulatory Mechanisms 493

Introduction 493
Local Regulatory Mechanisms 493
Systemic Regulatory Mechanisms 494

32. Circulation Through Special Regions	504
Introduction 504	
Cerebral Circulation 504	
Anatomic Considerations 504	
Cerebrospinal Fluid 505	
The Blood-Brain Barrier 507	
Cerebral Blood Flow 509	
Regulation of Cerebral Circulation 510	
Brain Metabolism & Oxygen Requirements 513	
Coronary Circulation 514	
Splanchnic Circulation 517	
Circulation of the Skin 518	
Placental & Fetal Circulation 519	

33. Cardiovascular Homeostasis in Health & Disease	523
Introduction 523	
Compensations for Gravitational Effects 523	
Exercise 525	
Hemorrhage & Hemorrhagic Shock 527	
Other Forms of Shock 530	
Fainting 531	
Hypertension 532	
Heart Failure 534	

Section VI References: 535

SECTION VII. RESPIRATION

34. Pulmonary Function	537
Introduction 537	
Properties of Gases 537	
Mechanics of Respiration 538	
Gas Exchange in the Lung 547	
Pulmonary Circulation 547	
Other Functions of the Respiratory System 549	

35. Gas Transport Between the Lungs & the Tissues	551
Introduction 551	
Oxygen Transport 551	
Buffers in Blood 554	
Carbon Dioxide Transport 556	

36. Regulation of Respiration	558
Introduction 558	
Neural Control of Breathing 558	
Regulation of Respiratory Center Activity 560	
Chemical Control of Breathing 560	
Nonchemical Influences on Respiration 564	

37. Respiratory Adjustments in Health & Disease	567
Introduction 567	
Effects of Exercise 567	
Hypoxia 569	
Hypoxic Hypoxia 570	
Other Forms of Hypoxia 574	
Oxygen Treatment 575	
Hypercapnia & Hypocapnia 576	
Effects of Increased Barometric Pressure 577	
Artificial Respiration 578	

Section VII References: 580

SECTION VIII. FORMATION & EXCRETION OF URINE

38. Renal Function & Micturition 581

- Introduction 581
- Functional Anatomy 581
- Renal Circulation 584
- Glomerular Filtration 586
- Tubular Function 588
- Water Excretion 593
- Acidification of the Urine & Bicarbonate Excretion 598
- Regulation of Na^+ & Cl^- Excretion 600
- Regulation of K^+ Excretion 602
- Diuretics 602
- Effects of Disordered Renal Function 603
- Filling of the Bladder 605
- Emptying of the Bladder 605
- Abnormalities of Micturition 606

39. Regulation of Extracellular Fluid Composition & Volume 607

- Introduction 607
- Defense of Tonicity 607
- Defense of Volume 607
- Defense of Specific Ionic Composition 608
- Defense of H^+ Concentration 608

Section VIII References: 613

Appendix 615

- General References 615
- Normal Values & the Statistical Evaluation of Data 615
- Appendix References 617
- Abbreviations & Symbols Commonly Used in Physiology 618
- Standard Respiratory Symbols 622
- Equivalents of Metric, United States, & English Measures 622
- Greek Alphabet 623

Index 625

Tables

- Atomic Weights Inside Front Cover
- Ranges of Normal Values in Human Whole Blood, Plasma, or Serum Inside Back Cover