

R.F. Schmidt G. Thews (Eds.)

Human Physiology

Second, Completely Revised Edition

Translated by Marguerite A. Biederman-Thorson

With 643 Figures, Most in Color

Springer-Verlag Berlin Heidelberg New York
London Paris Tokyo HongKong

Table of Contents

Part I. General Physiology of the Cell and of Intercellular Communication

1	Fundamentals of Cell Physiology (J. Dudel)	2
1.1	The Cell as a Compartment for Physiological Exchange Processes	2
1.2	Exchange of Substances between Cell and Surroundings	4
1.3	Exchange of Substances within the Cell	10
1.4	Control of Cell Functions	15
1.5	References	17
2	Information Transfer by Electrical Excitation (J. Dudel)	19
2.1	Resting Potential	19
2.2	The Action Potential	22
2.3	Currents through Potential-Dependent Membrane Channels	28
2.4	Electrotonus and Stimulus	33
2.5	Propagation of the Action Potential	36
2.6	The Triggering of Impulse Volleys by Long-Lasting Depolarization	40
2.7	References	41
3	Transmission of Excitation from Cell to Cell (J. Dudel)	43
3.1	Chemical Synaptic Transmission	43
3.2	Interactions of Synapses	49
3.3	Microphysiology of Chemical Synaptic Transmission	53
3.4	Electrical Synaptic Transmission	58
3.5	References	59

Part II. Motor and Integrative Functions of the Nervous System; Muscle Physiology

4	Muscle (J.C. Rüegg)	62
4.1	The Molecular Mechanism of Contraction	62
4.2	The Regulation of Muscle Contraction	66
4.3	Muscle Mechanics	72
4.4	Muscle Energetics	76
4.5	Smooth Muscle	78
4.6	References	80

5	Motor Systems (R.F. Schmidt and M. Wiesendanger)	82
5.1	Neural Control of Posture and Movement: A Survey	82
5.2	Sensors for Motor Functions: Muscle Spindles and Tendon Organs	85
5.3	Spinal Motor Reflexes	87
5.4	Motor Centers in the Brainstem	96
5.5	Cerebellum	102
5.6	Basal Ganglia	107
5.7	Motor Fields of the Cerebral Cortex	112
5.8	Functional Restitution after Lesions in the Motor System	120
5.9	References	122
6	Integrative Functions of the Central Nervous System (R.F. Schmidt)	124
6.1	Definition and Localization of Integrative Functions	124
6.2	General Physiology of the Cerebral Cortex	127
6.3	Waking and Sleeping	138
6.4	Neurophysiological Correlates of Consciousness and Speech	147
6.5	Plasticity, Learning, Memory	153
6.6	Functions of the Frontal Lobes	162
6.7	References	164
7	The Nervous System in the Context of Information Theory (M. Zimmermann)	166
7.1	Introduction to Information Theory	166
7.2	Information Theory in Sensory Physiology	168
7.3	Measurement of Information in Psychology	171
7.4	References	172
Part III. General and Special Sensory Physiology		
8	General Sensory Physiology (H.O. Handwerker)	176
8.1	Subject Matter of General Sensory Physiology	176
8.2	General Objective Sensory Physiology	178
8.3	General Subjective Sensory Physiology	185
8.4	Integrative Sensory Physiology	193
8.5	References	195
9	The Somatovisceral Sensory System (M. Zimmermann)	196
9.1	Psychophysics of Cutaneous Mechanoreception	196
9.2	Cutaneous Mechanosensors	198
9.3	Psychophysics of Thermoreception	202
9.4	Thermosensors	203
9.5	Visceral Sensibility	204
9.6	Proprioception	206

9.7	Functional and Anatomical Survey of the Central Somatosensory System	207
9.8	The Transfer of Somatovisceral Information in the Spinal Cord . . .	210
9.9	Somatosensory Functions of the Brainstem	213
9.10	Thalamus	214
9.11	Somatosensory Projection Areas in the Cortex	216
9.12	Control of Afferent Input in the Somatosensory System	219
9.13	References	221
10	Nociception and Pain (R.F. Schmidt)	223
10.1	The Characterization of Pain	223
10.2	Neurophysiology of Pain	227
10.3	Pathophysiology of Nociception and Pain	231
10.4	Endogenous and Exogenous Inhibition of Pain	233
10.5	References	235
11	The Sense of Sight (O.-J. Grüsser and U. Grüsser-Cornehls)	237
11.1	Seeing, Looking, Gazing	237
11.2	Light and the Eye	240
11.3	Signal Reception and Processing in the Retina	248
11.4	Neurophysiology and Psychophysics of the Perception of Light and Dark	254
11.5	Signal Processing in the Central Visual System	258
11.6	Practical and Clinical Applications of Visual Physiology	263
11.7	Color Vision	269
11.8	References	275
12	Physiology of the Sense of Equilibrium, Hearing and Speech (R. Klinke)	277
12.1	Physiology of the Sense of Equilibrium	277
12.2	Physiology of Hearing	283
12.3	Physiology of the Speech Apparatus	299
12.4	References	304
13	Taste and Smell (H. Altner and J. Boeckh)	306
13.1	Characterization of the Chemical Senses	306
13.2	The Sense of Taste	307
13.3	The Sense of Smell	309
13.4	References	313
14	Thirst and Hunger: General Sensations (R.F. Schmidt)	314
14.1	Thirst	314
14.2	Hunger	318
14.3	References	322

Part IV. Neuronal and Hormonal Regulatory Processes

15	General Principles of Regulation (M. Zimmermann)	324
15.1	Basic Elements of Biological and Technical Control Circuits	324
15.2	Dynamic and Static Behavior of Control Circuits	327
15.3	Special Features of Control Systems	330
15.4	References	332
16	Autonomic Nervous System (W. Jänig)	333
16.1	Peripheral Autonomic Nervous System	333
16.2	Central Organization of the Autonomic Nervous System in Spinal Cord and Brainstem	345
16.3	Micturition and Defecation	350
16.4	Genital Reflexes	352
16.5	Functions of the Hypothalamus	356
16.6	Limbic System and Behavior	362
16.7	References	369
17	Endocrinology (W. Wuttke)	371
17.1	General Aspects of Endocrinology	371
17.2	The Posterior Pituitary System	376
17.3	The Anterior Pituitary System	379
17.4	The Thyroid System	383
17.5	The Adrenal Cortex Systems	386
17.6	The Pancreatic Hormones	391
17.7	Homeostasis of Calcium and Phosphate Balance	395
17.8	Hormones of the Adrenal Medulla	396
17.9	Additional Hormonal Systems	397
17.10	References	398

Part V. Blood and the Circulatory System

18	Functions of the Blood (Ch. Weiss and W. Jelkmann)	402
18.1	Basic Concepts	402
18.2	Blood Plasma	403
18.3	Erythrocytes	409
18.4	Leukocytes	414
18.5	Thrombocytes	417
18.6	Hemostasis and Coagulation	418
18.7	The Role of the Blood in Defense	425
18.8	Human Blood Groups	434
18.9	References	438
19	Function of the Heart (H. Antoni)	439
19.1	General Structural and Functional Aspects	439
19.2	Basic Processes of Excitation and Excitation-Contraction Coupling	440

19.3	Electrocardiogram	451
19.4	The Mechanical Action of the Heart	462
19.5	Dynamics of Adjustment to Changing Work Loads	468
19.6	Energetics of the Heartbeat	474
19.7	References	479
20	Functions of the Vascular System (E. Witzleb)	480
20.1	Fundamentals of Hemodynamics	481
20.2	Properties of the Vessel Walls and Variability of Vessel Diameter	485
20.3	Functional Organization of the Vascular System	488
20.4	The Arterial Part of the Systemic Circulation	491
20.5	Venous Part of the Systemic Circulation	497
20.6	Microcirculation	501
20.7	The Lymphatic System	505
20.8	Regulation of Regional (Local) Blood Flow	506
20.9	Regulation of the Overall Circulation	511
20.10	The Pulmonary Circulation	523
20.11	Circulatory Adjustments to Physiological and Pathological Circumstances	525
20.12	Circulation through Special Organs and Its Control	533
20.13	Measurement of Pressure, Flow and Volume in the Vascular System	537
20.14	References	541

Part VI. Respiration

21	Pulmonary Respiration (G. Thews)	544
21.1	Breathing Movements	544
21.2	Ventilation	548
21.3	Mechanical Factors in Breathing	553
21.4	Exchange of Gases	560
21.5	Pulmonary Perfusion and Oxygenation of the Blood	565
21.6	Central Rhythmogenesis and the Control of Breathing	568
21.7	References	576
22	Blood Gas Transport and Acid-Base Balance (G. Thews)	578
22.1	The Structure and Properties of Hemoglobin	578
22.2	The O ₂ -Transport Function of the Blood	582
22.3	The CO ₂ -Transport Function of the Blood	587
22.4	The Acid-Base Status of the Blood	589
22.5	References	596
23	Tissue Respiration (J. Grote)	598
23.1	Metabolism and Oxygen Requirements of the Tissues	598
23.2	Tissue Oxygen Supply	601
23.3	Regulation of O ₂ Supply and Effects of O ₂ Deficiency	607
23.4	References	611

Part VII. Energy Balance, Work, and Environment

24	Energy Balance (H.-V. Ulmer)	614
24.1	Energy Expenditure	614
24.2	Parameters of Metabolism	614
24.3	Metabolic Rates under Special Conditions	617
24.4	Measurement Techniques	618
24.5	Measurement of the Oxygen Uptake of the Whole Body	620
24.6	Diagnostic Significance of Energy Expenditure	622
24.7	References	623
25	Thermal Balance and the Regulation of Body Temperature (K. Brück) .	624
25.1	Heat Production, Body Temperature and Body Size	624
25.2	The Temperature of the Human Body	627
25.3	Heat Loss	629
25.4	The Regulation of Body Temperature	632
25.5	Ontogenetic and Adaptive Changes in Thermoregulation	639
25.6	Pathophysiology of Thermoregulation	641
25.7	References	643
26	Work Physiology (H.-V. Ulmer)	645
26.1	Fundamentals of Work Physiology	645
26.2	Adjustments to Physical Work	647
26.3	Responses of the Organism to Non-Physical Loads	654
26.4	Limits of Performance Capacity	654
26.5	Fatigue and Exhaustion	656
26.6	Variability in Performance Capacity	659
26.7	Training	660
26.8	Performance and Aptitude Tests	662
26.9	References	664
27	Environmental Physiology (H.-V. Ulmer)	666
27.1	Altitude; Low Pressures	666
27.2	Diving; High Pressures	670
27.3	Climate and Room Ventilation	672
27.4	Noise, Vibration and Acceleration	675
27.5	References	676

Part VIII. Nutrition, Digestion and Excretion

28	Nutrition (H.-V. Ulmer)	678
28.1	Foods: Their Composition and Functions	678
28.2	Nutritional Requirements; Symptoms of Deficiency and Overdosage .	682

28.3	Utilization of Foodstuffs; Dietetics	687
28.4	Evaluation of Body Weight and the Surface Area of the Body	690
28.5	References	691
29	Functions of the Alimentary Canal (K. Ewe and U. Karbach)	693
29.1	General Bases of Gastrointestinal Function	693
29.2	Oral Cavity, Pharynx and Esophagus	705
29.3	Stomach	709
29.4	Pancreas	715
29.5	Liver and Biliary System	717
29.6	Small Intestine	721
29.7	Colon	730
29.8	References	733
30	The Function of the Kidneys (P. Deetjen)	735
30.1	Fundamentals of Renal Function	735
30.2	Renal Blood Flow	736
30.3	Glomerular Filtration	738
30.4	Tubular Transport	742
30.5	Special Tubular Transport Mechanisms	749
30.6	The Adjustment of Urine Concentration	757
30.7	References	760
31	Water and Electrolyte Balance (P. Deetjen)	763
31.1	Water Balance	763
31.2	Electrolyte Balance	768
31.3	Generalized Disturbances of Water and Electrolyte Balance	771
31.4	References	772
 Part IX. Reproduction, Pregnancy and Aging		
32	Sexual Functions (W. Wuttke)	774
32.1	Sexual Differentiation	774
32.2	Hormonal Regulation of Gonadal Functions	775
32.3	Hormonal Regulation of Male Sexual Functions	776
32.4	Hormonal Regulation of the Female Sexual Functions	778
32.5	Puberty and Menopause	782
32.6	References	784
33	Reproduction and Pregnancy (W. Wuttke)	785
33.1	Coitus	785
33.2	Pregnancy, Birth and Lactation	786
33.3	References	788

34	Aging and Old Age (R.K. Zahn)	789
34.1	Basic Features of the Biological Aging Process	789
34.2	Age-Related Functional Changes	791
34.3	References	793

Part X. Appendix

Physiological Units (G. Thews)	796
---	------------

Subject Index	799
--------------------------------	------------