

PHARMACY
EDUCATION
SERIES

ESSENTIALS OF HUMAN PHYSIOLOGY AND PATHOPHYSIOLOGY FOR PHARMACY AND ALLIED HEALTH

LAURIE K. MCCORRY
MARTIN M. ZDANOWICZ
CYNTHIA Y. GONNELLA



Essentials of Human
Physiology and
Pathophysiology
for Pharmacy and
Allied Health



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

Essentials of Human Physiology and Pathophysiology for Pharmacy and Allied Health

Laurie K. McCorry
Martin M. Zdanowicz
Cynthia Y. Gonnella

First published 2019
by Routledge
711 Third Avenue, New York, NY 10017

and by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

© 2019 Taylor & Francis

The right of Laurie K. McCorry, Martin M. Zdanowicz, and Cynthia Y. Gonnella to be identified as authors of this work has been asserted by them in accordance with sections 77 and 78 of the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this book may be reprinted or reproduced or utilised in any form or by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publishers.

Trademark notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

ISBN: 978-0-367-00046-2 (hbk)
ISBN: 978-0-367-00048-6 (pbk)

Typeset in Palatino LT Std
by Lumina Datamatics

Contents

Preface.....	xxv
Authors.....	xxvii
Chapter 1 The cell	1
1.1 Plasma membrane.....	2
1.1.1 Structure and function of the plasma membrane	2
1.1.2 Membrane transport	6
1.2 Membrane potential.....	11
1.2.1 Development of the resting membrane potential.....	12
1.3 Electrical signals	15
1.3.1 Graded potentials.....	15
1.3.2 Action potentials.....	17
1.3.3 Conduction of the action potential	20
1.4 Synaptic transmission.....	26
1.4.1 Chemical synapses	26
1.4.2 Summation	30
1.4.3 Interconnections between neurons	32
1.4.4 Factors affecting synaptic transmission	33
1.4.4.1 Altered release of a neurotransmitter	33
1.4.4.2 Altered interaction of a neurotransmitter with its receptor	34
1.4.4.3 Altered removal of a neurotransmitter from the synaptic cleft.....	35
1.4.4.4 Replacement of a deficient neurotransmitter	35
1.5 Cell injury.....	35
1.5.1 Cellular adaptation.....	36
1.5.2 Mechanisms of cell injury.....	38
1.5.3 Manifestations of cellular injury	40
1.5.4 Cell death.....	41
1.5.5 Tissue repair	43
1.5.6 Steps in tissue (wound) repair.....	44
Medical terminology	47
Bibliography	49

Chapter 2 Homeostasis.....	51
2.1 Homeostasis	51
2.1.1 Negative feedback	54
2.1.2 Positive feedback	55
Medical terminology	56
Bibliography	57
Chapter 3 The immune system.....	59
3.1 Overview of immune function	59
3.1.1 Agents of infectious disease.....	60
3.1.2 Effector cells of the immune system	62
3.1.3 Immune responses.....	62
3.1.4 Innate immune system	63
3.1.5 Adaptive immune system	65
3.1.5.1 Classification of antibodies	66
3.1.5.2 Structure of antibodies.....	67
3.1.5.3 Actions of antibodies.....	68
3.1.5.4 Clonal selection theory	70
3.1.5.5 Primary versus secondary responses.....	71
3.1.5.6 Active versus passive immunity	72
3.1.5.7 Types of T cells	74
3.1.5.8 Actions of T cells.....	75
3.1.5.9 MHC molecules	77
3.2 Alterations in immune function.....	78
3.2.1 Hypersensitivity reactions	78
3.2.1.1 Type I hypersensitivity reaction	78
3.2.1.2 Type II hypersensitivity reaction.....	80
3.2.1.3 Type III hypersensitivity reaction.....	83
3.2.1.4 Type IV hypersensitivity reaction	83
3.2.2 Autoimmune disease	84
Medical terminology	85
Bibliography	87
Chapter 4 Inflammation	89
4.1 Inflammatory mediators	95
4.1.1 Histamine and mast cells	95
Chapter 5 Blood and hemostasis.....	99
5.1 Blood	100
5.1.1 Plasma	100
5.1.2 Erythrocytes	101
5.1.3 Leukocytes.....	105
5.1.4 Platelets	107

5.2	Hemostasis	108
5.3	Alterations in hemostasis.....	114
5.3.1	Conditions associated with decreased coagulation.....	114
5.3.1.1	Hemophilia	114
5.3.1.2	von Willebrand disease.....	114
5.3.1.3	Vitamin K deficiency	115
5.3.1.4	Liver disease	115
5.3.2	Conditions affecting platelets	115
5.3.2.1	Thrombocytopenia	115
5.3.2.2	Immune thrombocytopenia purpura.....	116
5.3.2.3	Antiphospholipid syndrome.....	116
5.3.3	Conditions leading to increased blood coagulation (hypercoagulability).....	116
5.3.4	Disseminated intravascular coagulation (DIC).....	117
5.3.4.1	Manifestations of DIC	117
5.3.4.2	Treatment of DIC	117
5.4	Alterations in hematologic function and oxygen transport.....	118
5.4.1	Hematopoiesis	118
5.4.2	Anemia.....	119
5.4.2.1	General manifestations of anemia.....	119
5.4.3	Types of anemia	120
5.4.3.1	Hemolytic anemia.....	120
5.4.3.2	Blood loss anemia	120
5.4.4	Inherited anemia.....	121
5.4.4.1	Sickle cell disease.....	121
5.4.4.2	Thalassemia	125
5.4.4.3	Glucose-6-phosphate dehydrogenase deficiency....	126
5.4.4.4	Aplastic anemia.....	126
5.4.4.5	Polycythemia.....	127
	Medical terminology	128
	Bibliography	128
	Chapter 6 The circulatory system.....	131
6.1	Blood vessels.....	133
6.2	Blood pressure	137
6.3	Blood flow	139
6.4	Regulation of arterial pressure	141
6.4.1	Vasomotor center	145
6.4.2	Baroreceptors.....	146
6.4.3	Chemoreceptors.....	148
6.4.4	Low-pressure receptors	149
6.4.5	Vasoconstrictors.....	150
6.4.6	Vasodilators	154

6.5	Venous regulation.....	155
6.5.1	Blood volume.....	157
6.5.2	Sympathetic stimulation of the veins.....	158
6.5.3	Skeletal muscle activity.....	158
6.5.4	Respiratory activity.....	158
6.6	Effects of gravity on the circulation.....	159
6.7	Regulation of blood flow through tissues.....	160
6.7.1	Active hyperemia.....	160
6.7.2	Autoregulation.....	161
6.8	Effects of acute exercise on the circulatory system.....	161
6.9	Capillary exchange.....	163
6.10	Disease of blood vessels.....	168
6.10.1	Arterial disease.....	168
6.10.2	Atherosclerosis and dyslipidemia.....	169
6.10.3	Inflammatory disease of arteries.....	173
6.10.4	Aneurysm.....	175
6.10.4.1	Clinical manifestations of aneurysm.....	175
6.10.4.2	Treatment of aneurysms.....	176
6.10.5	Disease of the veins.....	176
6.10.5.1	Venous thrombosis.....	176
6.10.5.2	Embolism.....	179
6.10.5.3	Anticoagulant and thrombolytic drug therapy.....	179
6.10.5.4	Varicose veins.....	180
6.10.5.5	Chronic venous insufficiency.....	180
6.11	Disorders of blood pressure.....	180
6.11.1	Primary (Essential) hypertension.....	181
6.11.2	Secondary hypertension.....	182
6.11.3	Malignant hypertension.....	183
6.11.4	Hypertension in pregnancy.....	183
6.11.5	Effects of chronic hypertension.....	184
6.11.6	Diagnosis and treatment of essential hypertension.....	185
6.11.7	Treatment of hypertension.....	186
6.11.8	Hypotension.....	187
6.11.8.1	Manifestations of hypotension.....	187
6.11.8.2	Treatment of hypotension.....	188
6.12	Shock.....	188
6.12.1	Hypovolemic shock.....	188
6.12.1.1	Physiologic responses to hypovolemic shock.....	189
6.12.1.2	Stages of symptoms of hypovolemic shock.....	190
6.12.1.3	Treatment of hypovolemic shock.....	190
6.12.2	Distributive shock.....	191
6.12.2.1	Symptoms of distributive shock.....	191
6.12.2.2	Treatment of distributive shock.....	191

6.12.3	Cardiogenic shock.....	193
6.12.3.1	Symptoms of cardiogenic shock.....	194
6.12.3.2	Treatment of cardiogenic shock.....	194
6.12.4	Complications of shock	194
	Medical terminology	195
	Bibliography	196
Chapter 7	The heart	199
7.1	Functional anatomy of the heart	202
7.1.1	Myocardial wall.....	205
7.2	Electrical activity of the heart	209
7.3	Electrocardiogram	215
7.4	Cardiac cycle.....	218
7.4.1	Ventricular filling.....	219
7.4.2	Isovolumetric contraction	219
7.4.3	Ejection.....	221
7.4.4	Isovolumetric relaxation.....	221
7.5	Cardiac output	222
7.6	Control of heart rate	224
7.7	Control of stroke volume.....	227
7.8	Effect of exercise on cardiac output	232
7.9	Diseases of the heart.....	233
7.9.1	Disorders of the pericardium, myocardium, and endocardium	233
7.9.1.1	Disorders of the pericardium.....	233
7.9.2	Diseases of the myocardium.....	235
7.9.2.1	Myocarditis.....	235
7.9.2.2	Cardiomyopathies	236
7.9.3	Disorders of the endocardium and heart valves	239
7.9.3.1	Infectious endocarditis.....	239
7.9.3.2	Rheumatic heart disease.....	240
7.9.4	Disorders of the heart valves.....	241
7.9.4.1	Mitral valve prolapse	243
7.9.4.2	Congenital heart defects.....	245
7.10	Myocardial ischemia	246
7.10.1	Manifestations of myocardial ischemia	247
7.10.2	Acute coronary syndromes.....	248
7.10.2.1	Rationale for treatment of myocardial ischemia.....	248
7.10.2.2	Treatment of myocardial ischemia	249
7.11	Myocardial infarction.....	250
7.11.1	Coronary blood flow and myocardial infarction.....	250
7.11.2	Clinical manifestations of myocardial infarction.....	252
7.11.3	Compensatory mechanisms for myocardial infarction	252
7.11.4	Complications of myocardial infarction	254

7.11.5	Rationale for therapy	254
7.11.5.1	Treatment for myocardial infarction.....	255
7.12	Heart failure.....	256
7.12.1	Classification of heart failure.....	256
7.12.2	Left heart failure	257
7.12.2.1	Manifestations of left-heart failure.....	257
7.12.3	Right heart failure	258
7.12.3.1	Manifestations of right-heart failure.....	259
7.12.4	Physiologic compensation for heart failure.....	259
7.12.5	Diagnosis of heart failure	264
7.12.6	Rationale for treatment of heart failure.....	265
7.13	Cardiac arrhythmia	266
7.13.1	Factors that may contribute to the development of a cardiac arrhythmia	267
7.13.2	Inherited arrhythmias.....	267
7.13.3	Mechanisms of cardiac arrhythmia	267
7.13.4	Types of arrhythmia	269
7.13.4.1	Sinus node arrhythmia	270
7.13.4.2	Atrial arrhythmia.....	270
7.13.4.3	Ventricular arrhythmia	271
7.13.5	Heart block.....	272
7.13.5.1	First-degree heart block	272
7.13.5.2	Second-degree heart block	272
7.13.5.3	Third-degree heart block	273
7.13.5.4	Stokes-Adams syndrome.....	273
7.13.5.5	Bundle branch block	273
7.13.6	Diagnosis of arrhythmia.....	273
7.13.7	Rationale for the treatment of cardiac arrhythmia	273
7.13.8	Treatment of cardiac arrhythmia.....	274
7.13.8.1	Pharmacologic.....	274
7.13.8.2	Non-pharmacologic treatment of arrhythmia.....	275
	Medical terminology	275
	Bibliography	277
Chapter 8	The respiratory system	279
8.1	Blood-gas interface	281
8.2	Airways.....	282
8.2.1	Cartilage.....	282
8.2.2	Epithelium.....	283
8.3	The pleura	284
8.4	Mechanics of breathing.....	284
8.4.1	Thoracic volume	284
8.4.2	Inspiration	284
8.4.3	Expiration	285

8.4.4	Lung volume	285
8.4.5	Pulmonary pressures	286
8.5	Interdependence.....	293
8.6	Airway resistance.....	293
8.6.1	Lung volume.....	294
8.6.2	Airway obstruction	294
8.6.3	Bronchial smooth muscle tone.....	295
8.7	Ventilation	297
8.7.1	Standard lung volumes.....	297
8.7.2	Total ventilation	300
8.7.3	Alveolar ventilation	300
8.7.4	Dead space.....	301
8.8	Diffusion.....	302
8.9	Partial pressures.....	304
8.10	Gas transport	309
8.10.1	Transport of oxygen.....	309
8.10.2	Factors affecting the transport of oxygen	312
8.10.3	Transport of carbon dioxide	314
8.11	Regulation of ventilation	315
8.11.1	Chemoreceptor response to decreased arterial PO_2	319
8.11.2	Chemoreceptor response to increased arterial PCO_2	320
8.11.2.1	Chemoreceptor response to increased arterial hydrogen ion concentration	321
8.12	Ventilatory response to exercise.....	321
8.13	Disorders of the respiratory system	322
8.13.1	Respiratory infections.....	323
8.13.1.1	Infections of the upper respiratory tract	323
8.13.1.2	Infections of the lower respiratory tract.....	326
8.13.2	Cancers of the respiratory tract.....	331
8.13.2.1	Laryngeal cancer.....	331
8.13.2.2	Lung cancer	331
8.13.3	Obstructive and restrictive pulmonary disorders.....	332
8.13.4	Obstructive pulmonary disorders	333
8.13.4.1	Asthma.....	333
8.13.5	Chronic obstructive pulmonary disease (COPD).....	337
8.13.5.1	Bronchitis.....	337
8.13.5.2	Emphysema.....	338
8.13.6	Cystic fibrosis.....	342
8.13.6.1	Manifestations of cystic fibrosis	342
8.13.6.2	Diagnosis of cystic fibrosis	343
8.13.6.3	Treatment of cystic fibrosis.....	343
8.13.7	Restrictive pulmonary disorders	344
8.13.7.1	Pleuritis, pleural effusion	344
8.13.7.2	Pneumothorax.....	344

8.13.7.3	Atelectasis.....	346
8.13.7.4	Bronchiectasis.....	347
8.13.8	Acute respiratory distress syndrome	348
8.13.8.1	Manifestations of ARDS	349
8.13.8.2	Treatment of ARDS.....	349
8.13.9	Respiratory distress syndrome of the newborn.....	349
8.13.9.1	Manifestations of respiratory distress syndrome in the newborn	350
8.13.9.2	Treatment of respiratory distress syndrome in the newborn	350
8.13.10	Interstitial lung diseases.....	350
8.13.10.1	Manifestations of interstitial lung disease	350
8.13.10.2	Treatment of interstitial lung diseases.....	351
8.13.11	Respiratory failure.....	351
8.13.11.1	Manifestations of respiratory failure	351
8.13.11.2	Treatment of respiratory failure	352
	Medical terminology	352
	Bibliography	354
Chapter 9	The digestive system.....	355
9.1	Digestive tract wall.....	357
9.1.1	Mucosa.....	357
9.1.2	Submucosa	358
9.1.3	Muscularis externa	358
9.1.4	Serosa	359
9.2	Regulation of gastrointestinal function	360
9.2.1	Intrinsic nerve plexuses.....	360
9.2.2	Extrinsic autonomic nerves.....	361
9.2.3	Gastrointestinal hormones.....	361
9.3	Mouth.....	363
9.4	Pharynx	365
9.5	Esophagus.....	366
9.6	Stomach.....	366
9.6.1	Gastric motility	367
9.6.2	Gastric secretion	369
9.7	Liver.....	373
9.8	Gallbladder	375
9.9	Pancreas.....	376
9.10	Transport of bile and pancreatic juice.....	376
9.11	Small intestine	377
9.11.1	Motility of the small intestine.....	378
9.11.2	Digestion and absorption in the small intestine	378
9.11.3	Carbohydrates	378
9.11.4	Proteins	380

9.11.5	Lipids	381
9.11.6	Water and electrolytes	382
9.12	Large intestine	382
9.12.1	Motility of the large intestine	383
9.12.2	Secretion of the large intestine.....	384
9.13	Gastrointestinal disorders	384
9.13.1	Abnormalities of the esophagus	384
9.13.1.1	Swallowing disorders—dysphagia.....	384
9.13.1.2	Manifestations of GERD	385
9.13.1.3	Treatment of GERD	387
9.13.2	Disorders of the stomach.....	387
9.13.2.1	Gastritis	387
9.13.2.2	Peptic ulcers	388
9.13.3	Disorders of the intestines.....	390
9.13.3.1	Irritable bowel syndrome (IBS)	390
9.13.3.2	Inflammatory bowel disease.....	390
9.13.4	Disorders of intestinal motility and absorption.....	396
9.13.4.1	Diarrhea	396
9.13.4.2	Constipation.....	396
9.13.4.3	Intestinal malabsorption.....	397
9.13.5	Gastrointestinal cancers.....	398
9.13.5.1	Esophageal cancer	398
9.13.5.2	Stomach cancer	398
9.13.5.3	Colorectal cancer.....	398
9.14	Hepatobiliary disorders.....	398
9.14.1	Tests of liver function.....	399
9.14.2	Infectious disease of the liver	399
9.14.2.1	Viral hepatitis	399
9.14.3	Alcoholic liver disease	402
9.14.4	Cirrhosis.....	403
9.14.4.1	Manifestations of cirrhosis and liver failure.....	403
9.14.4.2	Treatment of cirrhosis	405
9.14.5	Liver cancer	405
9.14.6	Disorders of the gallbladder	406
9.14.6.1	Gallstone formation (Cholelithiasis)	406
9.14.6.2	Cholecystitis	407
9.14.7	Disorders of the pancreas.....	407
9.14.7.1	Pancreatitis	407
9.14.7.2	Pancreatic cancer	408
9.14.7.3	Clinical manifestations of pancreatic cancer	409
	Medical terminology	409
	Bibliography	410

Chapter 10	The renal system	413
10.1	Functional anatomy of the kidneys	415
10.1.1	Vascular component	417
10.1.2	Tubular component	418
10.2	Basic renal processes	419
10.3	Glomerular filtration	420
10.3.1	Filtration barrier	420
10.3.2	Determinants of filtration	421
10.4	Tubular reabsorption	423
10.4.1	Sodium reabsorption	425
10.4.2	Chloride reabsorption	427
10.4.3	Water reabsorption	427
10.4.4	Production of urine of varying concentrations	428
10.4.5	Potassium ion secretion	434
10.4.6	Hydrogen ion secretion	434
10.5	Plasma clearance	434
10.6	Renal blood flow	436
10.6.1	Autoregulation	437
10.6.2	Myogenic mechanism	437
10.6.3	Tubuloglomerular feedback	438
10.6.4	Resistance of the afferent arteriole	439
10.6.5	Sympathetic nerves	439
10.6.6	Angiotensin II	441
10.6.7	Prostaglandins	442
10.7	Control of sodium excretion	443
10.8	Control of water excretion	445
10.9	Disorders of the kidney and urinary tract	448
10.9.1	Evaluation of renal function	448
10.9.2	Disorders of the glomerulus	449
10.9.2.1	Acute glomerulonephritis	449
10.9.2.2	Rapidly progressing glomerulonephritis	449
10.9.2.3	IgA nephropathy (Berger's disease)	449
10.9.3	Nephrotic syndrome	450
10.9.4	Pyelonephritis	451
10.9.5	Urinary tract infections	451
10.9.5.1	Manifestations of urinary tract infection	451
10.9.5.2	Treatment of urinary tract infection	452
10.9.6	Renal calculi (kidney stones)	452
10.9.6.1	Manifestations of renal calculi	452
10.9.6.2	Diagnosis of renal calculi	453
10.9.6.3	Treatment of renal calculi	453
10.9.7	Renal tumors	453
10.9.7.1	Manifestations of renal tumors	453
10.9.7.2	Treatment of renal tumors	453

10.9.8	Polycystic kidney disease.....	454
10.9.8.1	Manifestations of polycystic kidney disease	454
10.9.8.2	Treatment of polycystic kidney disease	454
10.9.9	Renal failure	454
10.9.9.1	Acute renal failure.....	455
10.9.9.2	Manifestations of acute renal failure	455
10.9.9.3	Treatment of acute renal failure.....	455
10.9.10	Chronic renal failure	455
10.9.10.1	Manifestations of chronic renal failure.....	456
10.9.10.2	Treatment of renal failure	456
10.10	Disorders of the bladder and urethra.....	459
10.10.1	Urine reflux	459
10.10.2	Neurogenic bladder	460
10.10.3	Urinary incontinence	461
10.10.3.1	Treatment of overactive bladder	461
10.10.4	Bladder cancer	461
	Medical terminology	461
	Bibliography	462
Chapter 11 The endocrine system.....		465
11.1	Biochemical classification of hormones	467
11.2	Transport of hormones	469
11.3	Functional classification of hormones.....	470
11.4	Hormone interactions.....	471
11.5	Mechanisms of hormone action	471
11.6	The pituitary gland	476
11.7	Relationship between the hypothalamus and the pituitary gland.....	477
11.8	Negative feedback control	479
11.9	Neurohypophysis.....	479
11.9.1	Antidiuretic hormone	479
11.9.2	Oxytocin.....	482
11.10	Adenohypophysis	483
11.10.1	Gonadotropins	483
11.10.2	Thyroid-stimulating hormone (TSH)	484
11.10.3	Adrenocorticotrophic hormone (ACTH)	484
11.10.4	Prolactin.....	484
11.10.5	Growth hormone (GH).....	485
11.11	Thyroid gland	486
11.11.1	Thyroid hormones.....	486
11.11.2	Calcitonin	489
11.12	Parathyroid glands.....	489

11.13	Adrenal glands	491
11.13.1	Adrenal medulla.....	491
11.13.2	Adrenal cortex	491
11.13.3	Mineralocorticoids	491
11.13.4	Glucocorticoids.....	493
11.13.5	Adrenal androgens.....	495
11.14	Pancreas.....	495
11.14.1	Insulin	496
11.14.2	Glucagon.....	497
11.15	Endocrine disorders.....	498
11.15.1	Abnormalities of the hypothalamus/pituitary glands.....	498
11.15.1.1	Hypopituitarism	499
11.15.2	Disorders of the anterior pituitary gland.....	499
11.15.2.1	Alterations of growth hormone secretion	499
11.15.3	Disorders of the posterior pituitary.....	502
11.15.3.1	Syndrome of inappropriate ADH (SIADH).....	502
11.15.3.2	Diabetes insipidus	502
11.15.4	Alteration of thyroid function	503
11.15.4.1	Tests of thyroid function.....	503
11.15.4.2	Hypothyroidism	504
11.15.4.3	Hyperthyroidism.....	506
11.15.5	Disorders of the adrenal glands	507
11.15.5.1	Hyosecretion of adrenal hormones	507
11.15.6	Disorders of the adrenal medulla	512
11.15.6.1	Pheochromocytoma	512
11.15.6.2	Diagnosis of pheochromocytoma.....	512
11.15.6.3	Manifestations of pheochromocytoma.....	512
11.15.6.4	Treatment of pheochromocytoma	512
11.16	Diabetes	512
11.16.1	The endocrine pancreas.....	513
11.16.2	Diabetes mellitus	514
11.16.2.1	Types of diabetes	514
11.16.2.2	Type 1 diabetes.....	516
11.16.3	Long-term complications of diabetes	518
11.16.3.1	Diabetic neuropathy.....	519
11.16.3.2	Diabetic nephropathy	520
11.16.3.3	Vascular disease.....	521
11.16.3.4	Diabetic retinopathy.....	521
11.16.3.5	Impaired healing and increased infections risk	521
11.16.3.6	Increased risk of infection	522

11.16.4	Diabetes in pregnancy	522
11.16.4.1	Gestational diabetes	522
	Medical terminology	522
	Bibliography	524
Chapter 12	The reproductive system.....	527
12.1	Gametogenesis	528
12.1.1	Spermatogenesis.....	528
12.1.2	Oogenesis	528
12.2	Male reproductive system	529
12.2.1	Testes	529
12.2.2	Epididymides.....	529
12.2.3	Vas deferens	530
12.2.4	Ejaculatory ducts.....	530
12.2.5	Penis	530
12.2.6	Prostate	530
12.2.7	Seminal vesicles.....	530
12.2.8	Bulbourethral glands	531
12.3	Female reproductive system	532
12.3.1	Ovaries.....	532
12.3.2	Fallopian tubes.....	533
12.3.3	Uterus.....	533
12.3.4	Vagina.....	533
12.3.5	Follicular phase.....	534
12.3.6	Luteal phase	535
12.3.7	Hormonal regulation of the ovarian cycle.....	535
12.4	Disorders of the male reproductive system	539
12.4.1	Disorders of the penis.....	539
12.4.1.1	Peyronie’s disease.....	539
12.4.1.2	Priapism.....	539
12.4.1.3	Impotence	540
12.4.2	Disorders of the testis and scrotum	540
12.4.2.1	Spermatocele	540
12.4.2.2	Varicocele.....	540
12.4.2.3	Testicular cancer	540
12.4.3	Disorders of the prostate	541
12.4.3.1	Prostatitis	541
12.4.3.2	Benign prostatic hyperplasia (BPH)	541
12.4.3.3	Prostate cancer	543
12.5	Disorders of the female reproductive system.....	544
12.5.1	Disorders of the vagina, cervix, and uterus.....	544
12.5.1.1	Vaginitis	544
12.5.1.2	Cervical lesions and cervical cancer	544
12.5.1.3	Endometriosis	545

12.5.1.4	Endometrial (Uterine) cancer.....	546
12.5.1.5	Uterine fibroids.....	547
12.5.1.6	Uterine prolapse.....	547
12.5.2	Disorders of the ovaries.....	547
12.5.2.1	Polycystic ovary syndrome.....	547
12.5.2.2	Ovarian cancer.....	548
12.5.3	Menstrual disorders.....	549
12.5.3.1	Amenorrhea.....	549
12.5.3.2	Dysmenorrhea.....	549
12.5.3.3	Menopause.....	550
12.5.3.4	Symptoms.....	550
12.5.3.5	Treatment.....	550
12.5.4	Disorders of the breast.....	550
12.5.4.1	Mastitis.....	550
12.5.4.2	Fibrocystic changes.....	551
12.5.4.3	Proliferative changes.....	551
12.5.5	Breast cancer.....	551
12.5.5.1	Risk factors for breast cancer.....	551
12.5.5.2	Diagnosis.....	552
12.5.5.3	Treatment.....	552
12.5.5.4	Prognosis.....	552
12.6	Sexually transmitted diseases.....	552
12.6.1	Diagnosis.....	553
12.6.2	Risk factors.....	553
12.6.2.1	Bacterial STDs.....	553
12.6.2.2	Viral STDs.....	554
12.6.2.3	Other STDs.....	554
12.6.2.4	Long-term consequences of STDs.....	555
	Medical terminology.....	555
	Bibliography.....	556
Chapter 13	The nervous system.....	559
13.1	Neurons.....	561
13.2	Level of CNS function.....	562
13.3	The brain.....	563
13.4	Blood-brain barrier.....	578
13.5	Cerebrospinal fluid.....	580
13.6	The spinal cord.....	581
13.6.1	Functions of the spinal cord.....	583
13.6.1.1	Composition of the spinal cord.....	583
13.6.1.2	Ascending tracts.....	586
13.6.1.3	Descending tracts.....	587

13.6.2	Spinal reflexes	590
	13.6.2.1 Withdrawal reflex	591
	13.6.2.2 Crossed-extensor reflex.....	593
13.7	Disorders of the nervous system	593
13.7.1	Disorders of the brain	593
	13.7.1.1 Brain injury	593
	13.7.1.2 Traumatic brain injury	594
	13.7.1.3 Intracranial hematoma.....	594
	13.7.1.4 Increased intracranial pressure.....	596
	13.7.1.5 Symptoms of increased ICP	596
	13.7.1.6 Treatment of increased ICP	596
	13.7.1.7 Brain ischemia and hypoxia.....	597
	13.7.1.8 Causes of brain ischemia or hypoxia.....	597
	13.7.1.9 Manifestations of cerebral ischemia or hypoxia.....	597
13.7.2	Stroke.....	598
	13.7.2.1 Symptoms of stroke.....	599
	13.7.2.2 Complications of stroke.....	600
	13.7.2.3 Diagnosis of stroke	600
	13.7.2.4 Treatment of stroke.....	600
13.7.3	CNS infections	600
	13.7.3.1 Manifestations of CNS infections.....	602
	13.7.3.2 Diagnosis of CNS infections	602
	13.7.3.3 Treatment of CNS infections	602
13.7.4	CNS tumors.....	602
	13.7.4.1 Type of CNS tumors.....	603
	13.7.4.2 Manifestations of CNS tumors	603
	13.7.4.3 Diagnosis of CNS tumors.....	604
	13.7.4.4 Treatment of CNS tumors.....	604
13.7.5	Seizure disorders	604
	13.7.5.1 Epilepsy.....	604
	13.7.5.2 Type of seizures	604
	13.7.5.3 Focal seizures	604
	13.7.5.4 Generalized seizures	605
	13.7.5.5 Diagnosis of seizure disorders.....	606
	13.7.5.6 Treatment of seizure disorders	607
13.7.6	Headache.....	607
	13.7.6.1 Primary headaches	607
	13.7.6.2 Secondary headaches	608
13.7.7	Degenerative disorders of the brain and CNS	608
	13.7.7.1 Parkinson’s disease	608
	13.7.7.2 Alzheimer’s disease	611
	13.7.7.3 Huntington’s disease	615

13.7.7.4	Amyotrophic lateral sclerosis	616
13.7.7.5	Multiple sclerosis	617
13.7.8	Spinal injury	618
13.7.8.1	Manifestations of spinal cord injury	619
13.7.8.2	Treatment of spinal cord injury	619
	Medical terminology	619
	Bibliography	621
Chapter 14	The autonomic nervous system	623
14.1	Regulation	624
14.2	Pathways	625
14.3	Divisions	626
14.4	Neurotransmission	630
14.5	Receptors	633
14.6	Functions	636
	Medical terminology	641
	Bibliography	642
Chapter 15	Pain	645
15.1	Nociceptors	646
15.2	Hyperalgesia	648
15.3	Neurotransmission	649
15.4	Pain pathways	649
15.5	Types of pain	654
15.5.1	Tissue ischemia	654
15.5.2	Muscle spasm	654
15.5.3	Visceral pain	655
15.5.4	Referred pain	655
15.6	Treatment of pain	657
15.6.1	Nonnarcotic analgesics	657
15.6.2	Opioid analgesics	658
15.6.3	Adjuvant analgesics	659
	Medical terminology	659
	Bibliography	659
Chapter 16	Muscle	661
16.1	Smooth muscle	662
16.1.1	Structure of smooth muscle	662
16.1.2	Calcium and the mechanism of contraction	664
16.1.3	Smooth muscle contraction is slow and prolonged	665
16.1.4	Types of smooth muscle	666
16.1.5	Factors influencing the contractile activity of smooth muscle	668

16.1.6	Length–tension relationship	669
16.1.7	Hyperplasia	670
16.2	Skeletal muscle	670
16.2.1	Muscle tension and movement	671
16.2.1.1	Isometric versus isotonic contraction	672
16.2.2	Structure of skeletal muscle	672
16.2.2.1	Sarcomeres	673
16.2.2.2	Thick filaments	673
16.2.2.3	Thin filaments	675
16.2.3	Neuromuscular junction	675
16.2.4	Mechanism of contraction	676
16.2.4.1	Sources of ATP for muscle contraction	680
16.2.5	Muscle fatigue	681
16.2.6	Oxygen debt	682
16.2.7	Types of muscle fibers	682
16.2.8	Muscle mechanics	684
16.2.8.1	Number of muscle fibers contracting	685
16.2.8.2	Amount of tension developed by each contracting muscle fiber	686
16.3	Disorders of skeletal muscle	688
16.3.1	Metabolic disorders of skeletal muscle	688
16.3.1.1	McArdle’s disease	689
16.3.1.2	Pompei disease	689
16.3.2	Cerebral palsy	690
16.3.2.1	Symptoms	690
16.3.2.2	Treatment	690
16.3.3	Muscular dystrophy (MD)	690
16.3.3.1	Duchenne muscular dystrophy	691
16.3.3.2	Becker muscular dystrophy	692
16.3.3.3	Facioscapulohumeral muscular dystrophy	692
16.3.3.4	Limb girdle muscular dystrophy	692
16.3.4	Myasthenia gravis	693
16.3.4.1	Symptoms	693
16.3.4.2	Diagnosis	693
16.3.4.3	Treatment	694
	Medical terminology	694
	Bibliography	695
	Chapter 17 The skeletal system	697
17.1	Bone as a tissue and an organ	698
17.2	Hemopoiesis	698
17.2.1	Erythropoiesis	698
17.2.2	Thrombopoiesis	698
17.2.3	Leukopoiesis	699

17.3	Mineral deposition	699
17.4	Mineral resorption	699
17.5	Calcium homeostasis.....	700
17.6	Disorders of the skeletal system	700
17.6.1	Osteoporosis.....	701
17.6.1.1	Manifestations of osteoporosis	702
17.6.1.2	Diagnosis of osteoporosis.....	702
17.6.1.3	Treatment of osteoporosis	702
17.6.2	Paget's disease	702
17.6.2.1	Clinical manifestations of Paget's disease	702
17.6.3	Osteomalacia.....	703
17.6.3.1	Clinical manifestations of osteomalacia.....	703
17.6.4	Rheumatoid arthritis (RA)	704
17.6.4.1	Manifestations of rheumatoid arthritis	704
17.6.4.2	Diagnosis of rheumatoid arthritis.....	705
17.6.4.3	Treatment of rheumatoid arthritis.....	706
17.6.5	Systemic Lupus Erythematosus.....	706
17.6.5.1	Manifestations of SLE	706
17.6.5.2	Diagnosis and treatment of SLE.....	706
17.6.6	Ankylosing spondylitis	707
17.6.7	Osteoarthritis	707
17.6.7.1	Manifestations of OA.....	707
17.6.7.2	Treatment of OA	709
17.6.8	Gout.....	709
17.6.8.1	Manifestations of gout.....	709
17.6.8.2	Treatment of gout	710
Chapter 18 Cancer		711
18.1	Introduction.....	711
18.2	Cancer terminology.....	711
18.2.1	Specific nomenclature examples	713
18.3	Theories of oncogenesis.....	714
18.3.1	Mutation of DNA	714
18.3.2	Hereditary	715
18.4	Local effects of cancer	715
18.5	Systemic effects of cancer	716
18.6	Tumor staging	717
18.7	Cancer detection	717
18.7.1	Tumor cell markers	717
18.7.2	Tumor grading	718
18.7.3	Visualization	719
18.7.4	Biopsy.....	719

18.8	Rationale for cancer therapy	719
18.8.1	Treatment of cancer	719
18.8.2	Hormonal therapy	719
18.8.3	Radiation therapy	720
18.8.4	Immune-based therapies (“biologic response modifiers”)	720
Chapter 19	HIV	721
19.1	Introduction	721
19.2	HIV structure and lifecycle	722
19.3	Stages in an HIV infection	725
19.3.1	Acute illness stage	725
19.3.2	Asymptomatic stage	725
19.3.3	Symptomatic or AIDS stage	725
19.4	Epidemiology of HIV infection	726
19.5	Laboratory of diagnosis of HIV	726
19.6	Rationale for treatment of HIV	727
19.6.1	Treatment of HIV	727
Index	731



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

Preface

The presentation of material within the chapters was designed to maximize clarity and facilitate conveyance of key points to the students. Numerous subheadings, bulleted lists, tables, and definitions of key terms are included in each chapter along with study objectives that are designed to focus students on important concepts within each chapter. The word “pathophysiology” is derived from the Greek word “pathos” which means “suffering, disease” and “physiology” which is the science of the normal function of living things.” Pathophysiology content in this text is specifically designed to build upon the information provided in the sections related to the normal physiology. We also believe that pathophysiology is a bridge between physiology and pharmacology. As a result of the authors’ experience in teaching both pathophysiology and pharmacology it has become clear that the time to introduce health science students to therapeutics is in pathophysiology where the mechanism and effects of disease are explored in detail and the application of the drugs makes the most sense. A rationale for drug therapy section is therefore included in each chapter to allow students to correlate information they have learned on selected diseases to the clinical application of drugs.



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

Authors

Laurie K. McCorry, PhD, was a professor for 18 years teaching courses that included human physiology, pathophysiology, cardiovascular physiology, and exercise physiology at the Massachusetts College of Pharmacy and Health Sciences, Boston, Massachusetts, as well as anatomy and physiology at Bay State College, Boston, Massachusetts. She is currently the dean of science, engineering and mathematics at Bunker Hill Community College in Boston, Massachusetts.

Martin M. Zdanowicz received a BS in biology from NYU-Polytechnic, Brooklyn, New York, an MA in biology/physiology from S.U.N.Y. Binghamton, Vestal, New York, and a PhD in pharmaceutical sciences (Pharmacology) from St. John's University, New York. After completing his doctorate, he went on to work as a research scientist at North Shore University Hospital-Cornell Medical College, New York, in the area of endocrinology and metabolism. He assumed a full-time faculty appointment with the Massachusetts College of Pharmacy and Health Sciences, Boston, Massachusetts, and served as chair of pharmaceutical sciences and director of graduate studies. Dr. Zdanowicz moved to the South University School of Pharmacy in Savannah, Georgia where he served as chair of pharmaceutical sciences. He was promoted to full professor in January 2008. Teaching areas include pharmacology, pathophysiology, and pharmacogenomics. Dr. Zdanowicz has received the Trustee's Award for teaching excellence and was voted teacher of the year seven times by students at three institutions. His current research interests include pharmacogenomics, drug addiction, cardiovascular pharmacology, and curriculum development. Dr. Zdanowicz holds membership in a number of professional societies and has published numerous peer-reviewed articles and several textbooks. He is currently completing an MPH online from the University of South Florida, Tampa, Florida. Dr. Zdanowicz currently serves as the associate dean for health studies at the University of Miami School of Nursing and Health Studies, Coral Gables, Florida, where he oversees programs in public health, health science, and health informatics.

Cynthia Y. Gonnella has been teaching anatomy and physiology, general biology, and nutrition at Bunker Hill Community College in Boston, Massachusetts, for the past 25 years. She also teaches at Middlesex Community College in Lowell, Massachusetts. She earned her degree from the University of Massachusetts and has designed numerous web-based courses for life sciences. When she is not teaching, she enjoys a successful writing career, and also paints and explores the land along the Concord River in Massachusetts.

chapter one

The cell

Study objectives

- Describe the function of each of the components of the plasma membrane
- Understand the physiological importance of the permeability barrier created by the plasma membrane
- Describe the factors that affect diffusion
- Explain how osmosis takes place
- Understand the clinical significance of the osmotic pressures of solutions
- Describe the factors that affect mediated transport
- Compare and contrast facilitated diffusion and active transport
- Define membrane potential
- Compare the distribution and permeability differences of ions across the cell membrane
- Describe how differences in ion distribution and permeability contribute to the resting membrane potential
- Describe how a cell's resting membrane potential is developed and maintained
- Explain the role of the Na⁺-K⁺-ATPase pump in the process of ion exchange across the cell membrane
- Distinguish between depolarization, hyperpolarization, and repolarization
- Compare and contrast graded potentials and action potentials
- Describe the process of local current flow
- Explain the mechanism by which action potentials are generated
- Understand the function of sodium and potassium voltage-gated channels
- Distinguish between the absolute refractory period and the relative refractory period
- Describe the process of saltatory conduction
- Explain the functional significance of myelin
- Explain why the conduction of the action potential is unidirectional
- Describe the mechanism by which chemical synapses function
- Describe the effects of a neurotransmitter binding to its receptors on the postsynaptic neuron
- Compare and contrast excitatory synapses and inhibitory synapses
- Distinguish between an EPSP and an IPSP
- Describe how neurotransmitters are removed from the synaptic cleft
- Explain how temporal summation and spatial summation take place
- Distinguish between convergence and divergence

- Understand how pH and hypoxia affect synaptic transmission
- Describe the potential mechanisms by which drugs, toxins and diseases affect synaptic transmission
- Explain why synaptic transmission is unidirectional
- Distinguish between an agonist and an antagonist
- Compare and contrast the various forms of cellular adaptation. What is the purpose of these adaptive changes?
- Discuss the underlying mechanisms by which cellular injury can occur
- Describe the major manifestations that present when cells are injured. Why does each of these manifestations occur?
- Define apoptosis and necrotic cell death. How do they differ?
- List the specific types of cellular necrosis that may occur and their distinct characteristics
- Define gangrene and gas gangrene
- Discuss the two mechanisms by which tissue repair occurs. Give examples of specific cell types that will utilize each repair mechanism
- List the steps involved in wound repair along with the key features of each step
- List various factors that can impair wound healing
- What is a keloid scar? Why does it occur?

1.1 *Plasma membrane*

Each cell is enclosed within a plasma membrane that separates the cytoplasmic contents of the cell, or the intracellular fluid (ICF), from the fluid outside of the cell, the extracellular fluid (ECF). An important homeostatic function of this plasma membrane is to serve as a *permeability barrier* that insulates or protects the cytoplasm from immediate changes in the surrounding environment. Furthermore, it allows the cell to maintain a cytoplasmic composition that is very different from that of the ECF. The functions of neurons (nerve cells) and muscle cells depend on this difference. The plasma membrane also contains many enzymes and other components such as antigens and receptors. These structures allow cells to interact with other cells, neurotransmitters, blood-borne substances such as hormones, and various other chemical substances, such as drugs.

1.1.1 *Structure and function of the plasma membrane*

The major components of the plasma membrane include:

- Phospholipids
- Cholesterol
- Proteins
- Carbohydrates

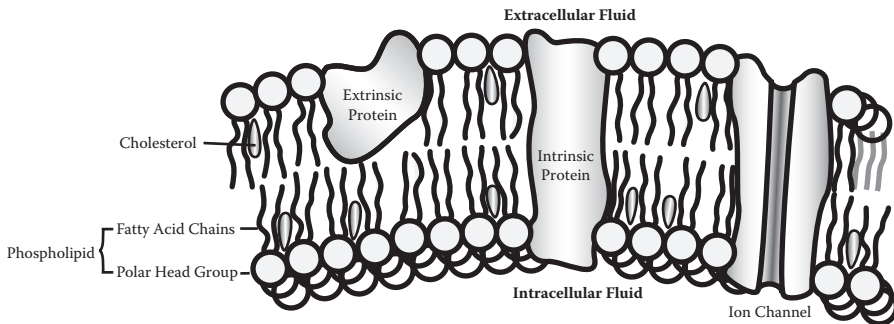


Figure 1.1 Structure of the plasma membrane. The plasma membrane is composed of a bilayer of phospholipid molecules. Associated with this bilayer are intrinsic proteins, which are embedded within and span the membrane, and extrinsic proteins, which are found on the external or internal surface of the membrane. Molecules of cholesterol are found in the inner, nonpolar region of the membrane.

The basic structure of the plasma membrane is formed by *phospholipids* (see [Figure 1.1](#)). These molecules are one of the more abundant of the membrane components. Phospholipids are *amphipathic* molecules that have both polar (water-soluble) and nonpolar (water-insoluble) regions. They are composed of a phosphorylated glycerol backbone, which forms a polar head group that is hydrophilic, and a nonpolar region containing two hydrophobic fatty acid chains. In an aqueous environment, such as the *lipid bilayer* consisting of two layers of phospholipids. The polar region of the molecule is oriented toward the outer surface of the membrane where it can interact with water; and the nonpolar, hydrophobic fatty acids are in the center of the membrane away from the water. The functional significance of this lipid bilayer is that it creates a *semipermeable barrier*. Lipophilic, or non-water-soluble, substances can readily cross the membrane by simply passing through its lipid core. Important examples of these substances include gases, such as oxygen and carbon dioxide, and fatty acid molecules, which are used to form energy within muscle cells.

Most hydrophilic, or water-soluble, substances are repelled by this hydrophobic interior and cannot simply diffuse through the membrane. Instead, these substances must cross the membrane using specialized transport mechanisms. Examples of lipid-insoluble substances that require such mechanisms include proteins, nutrient molecules such as glucose and amino acids, and all species of ions (Na^+ , Ca^{++} , H^+ , Cl^- , and HCO_3^-). Therefore, the plasma membrane plays a very important role in determining the composition of the ICF by selectively permitting substances to move in and out of the cell.

PHARMACY APPLICATION: LIPID SOLUBILITY AND DRUG ELIMINATION

The lipid solubility of many substances can change when physiological conditions vary. For example, the surrounding pH can determine whether a molecule is in a protonated form (positively charged, lipid-insoluble) or in an unprotonated form (uncharged, lipid-soluble). As discussed, charged substances do not readily cross the membrane, as do uncharged substances. This principle regarding lipid solubility is used in the treatment of an overdose of phenobarbital, a barbiturate used for sedation and seizure disorders. Phenobarbital is normally 30% removed by urinary excretion. In the case of an overdose, it would be advantageous to enhance urinary excretion. Alkalinization of the urine to a pH of 7.5–8 helps to promote excretion. In fact, by alkalinizing the urine, the amount of phenobarbital excreted increases 5- to 10-fold. After alkalinization, more phenobarbital would be ionized in the urine and, therefore, become lipid-insoluble and, therefore, the drug would not be reabsorbed from the kidney, but would instead be eliminated in the urine.

Another important aspect of the lipid bilayer is that the phospholipids are not held together by chemical bonds. This enables the molecules to move about freely within the membrane, resulting in a structure that is not rigid in nature, but instead, is very fluid and pliable. Another substance contributing to membrane fluidity is *cholesterol*. Cholesterol has a steroid nucleus that is lipid-soluble. Therefore, these molecules are found in the interior of the membrane lying parallel to the fatty acid chains of the phospholipids (see [Figure 1.1](#)). As such, they prevent the fatty acid chains from packing together and crystallizing, which would decrease membrane fluidity.

Membrane fluidity is very important in terms of function in many cell types. For example, skeletal muscle activity involves the shortening and lengthening of the muscle fibers. Furthermore, as white blood cells leave the blood vessels and enter the tissue spaces to fight infection, they must squeeze through tiny pores in the wall of the capillary, requiring significant deformation of the cell and its membrane. Finally, in all cells, many processes that transport substances across the plasma membrane require the embedded proteins to change their conformation and move about within the bilayer. In each case, for the cell membrane, or the entire cell, to change its shape, the membrane must be very fluid and flexible.

Proteins are also associated with the lipid bilayer and essentially float within it. Intrinsic, or transmembrane, proteins are embedded within and span the membrane. These proteins are like phospholipids in that they

are amphipathic with the polar regions of the molecule extending beyond the lipid bilayer and the nonpolar region embedded within it. Extrinsic, or peripheral, proteins are found on either the internal or the external surface of the membrane (see [Figure 1.1](#)). These proteins are not amphipathic and do not associate with the internal region of the membrane. The membrane proteins provide a variety of important cellular functions by forming the following structures:

- Channels
- Carrier molecules
- Enzymes
- Chemical receptors
- Antigens

Some proteins may form *channels* through the cell membrane, which allow small water-soluble substances, such as ions, to enter or leave the cell. These channels are quite specific and allow only one type of ion to pass through it (e.g., sodium channels, calcium channels). Other proteins may serve as *carrier molecules* that selectively transport larger water-soluble molecules, such as glucose or cellular products, across the membrane. *Enzymes*, which regulate specific chemical reactions, are extrinsic proteins and are found on either the internal (e.g., adenylate cyclase) or the external (e.g., acetylcholinesterase) surfaces of the membrane. *Chemical receptors* are found on the outer surface of the cell membrane and selectively bind with various endogenous molecules such as neurotransmitters and hormones as well as drugs. Many substances that are unable to enter the cell and cause a direct intracellular effect may indirectly influence intracellular activity without crossing the membrane through receptor activation. Other proteins found on the external surface of the plasma membrane are *antigens*. These molecules serve as cell “markers” that allow the body’s immune system to distinguish between our own cells and foreign cells or organisms, such as bacteria and viruses.

The plasma membrane contains a small amount of *carbohydrate* (2%–10% of the mass of the membrane) found predominantly on the outer surface. This carbohydrate is found attached to most of the protein molecules, forming glycoproteins, and to some of the phospholipid molecules (<10%), forming glycolipids. Consequently, the external surface of the cell has a carbohydrate coat, or glycocalyx.

These carbohydrate moieties have several important functions including the following:

- *Repel negatively charged substances*: many of the carbohydrates are negatively charged creating an overall negative charge on the surface of the cell that repels negatively charged extracellular molecules and helps to keep red blood cells apart from each other

- *Cell-to-cell attachment*: the glycocalyx of one cell may attach to the glycocalyx of another cell, which causes the cells themselves to become attached
- *Receptors*: carbohydrates may also serve as specific membrane receptors for extracellular substances, such as hormones
- *Immune reactions*: carbohydrates play a role in the ability of cells to distinguish between “self” cells and foreign cells

PHARMACY APPLICATION: HYDROPHILIC DRUGS BIND TO RECEPTORS

Many substances within the body, including neurotransmitters and hormones, are hydrophilic and, therefore, are incapable of entering the cells to carry out their effects directly. Instead, they bind to their specific receptors on the cell surface. This receptor binding then elicits a series of intracellular events that alter cell function and cell metabolism. As such, there are many instances where it would be clinically advantageous to either enhance or inhibit these activities. Therefore, drugs may be designed to bind to these specific receptors. A drug that binds to and stimulates a receptor, mimicking the action of the endogenous chemical substance, is referred to as a receptor *agonist*. An example is albuterol sulfate, a selective β_2 -adrenergic receptor agonist. Stimulation of β_2 -adrenergic receptors on airway smooth muscle causes dilation of the airways in a patient experiencing an asthmatic attack and relieves the patient’s wheezing. Conversely, a drug that binds to and blocks a receptor, preventing the action of the endogenous substance, is referred to as a receptor *antagonist*. An example in this case is cimetidine hydrochloride, which inhibits histamine H_2 receptors on parietal cells in the stomach. Because histamine H_2 receptor stimulation leads to gastric acid secretion, blockade of these receptors with an antagonist reduces acid secretion. While cimetidine hydrochloride is the active ingredient in Pepcid®, ranitidine hydrochloride, another histamine H_2 receptor antagonist, is found in Zantac® and works in much the same way. These drugs may be used to treat patients with a peptic ulcer or gastroesophageal reflux disease (GERD).

1.1.2 Membrane transport

The lipid bilayer arrangement of the plasma membrane renders it semipermeable. Uncharged or nonpolar molecules, such as oxygen, carbon dioxide and fatty acids, are lipid soluble and may permeate through the membrane quite readily. Charged or polar molecules, such as glucose, proteins, and ions, are water soluble and are impermeable and unable to cross the membrane unassisted. These substances require protein channels or carrier molecules to enter or leave the cell.