

Note: Page numbers followed by "b," "f," and "t" refer to boxes, figures, and tables, respectively.

A

- A-bands: muscle, 305
- ABC transporters, 174, 181, 816, 816–817
- Abdomen
 - abdominal aorta, 698, 699
 - abdominal cavity, 625
 - forceful expiration, 626
 - prevertebral ganglia, 475
- Absolute refractory periods, 268
- Accessory muscles: breathing mechanics, 626
- ACE inhibitors, 617
- Acetoacetate, 245
- Acetone, 245
- Acetyl Coenzyme A, 218, 227
- Acetylcholine, 168
 - autonomic nervous system, 479
 - degradation, 322–323
 - muscarinic receptors, 382, 479–480
 - muscle excitation, 321–322
 - nicotinic receptor binding, 382
 - pacemaker potential, 530
 - recycling, 322–323
 - stomach, 791
- Acetylcholine receptor (AChR), 331
- Acetylcholine signal
 - muscle fiber membrane, 331
- Acetylcholinesterase (AChE), 331
- Achalasia, 783b
- AChE. *See* Acetylcholinesterase (AChE)
- AChR. *See* Acetylcholine receptor (AChR)
- Acid reflux, 783
- Acid secretion, 727, 791–794, 794
- Acid–base balance, 752, 765
- Acid–base physiology, 665
- Acidemia, 665
- Acidic amino acids, 130
- Acidosis, 665, 669
 - ammonium, 762
 - hydrogen carbonate, 759
 - hyperventilation, 668
 - hypoventilation, 668
 - kidneys, 759
 - lungs, 760
 - renal tubular acidosis, 763b
 - respiratory acidosis, 668
 - ventilatory drive, 678–679
- Acids: bile, 814–816
- Acinar cells, 810
- Acinar secretion, mechanism of, 812f
- ACTH
 - pituitary–hypothalamus axis, 907–908
 - steroid secretion, 908–909
 - zona glomerulosa, 911
- Actin
 - cardiac contractility, 548
 - cell structure, 105, 107
 - myosin ATPase, 549
 - skeletal muscle, 309–310
 - smooth muscle, 356
- Action potentials, 265
 - axons, 280, 319
 - cardiac action potentials, 528
 - channels, 269–270
 - cutaneous sensory systems, 390–391
 - motor neuron synaptic inputs, 319
 - muscle fiber intracellular calcium, 324
 - muscle membranes, 323
 - origin, 319
 - problem sets, 289
 - propagation, 280
 - axons, 280
 - cable properties, 283–285
 - current, 280
 - electrotonic spread, 280–281
 - nerve cable properties, 280–281
 - nerve conduction velocity, 280
 - nodal movement, 286
 - saltatory conduction, 286
 - space constants, 283–285
 - time constants, 283–285
- Activation energies
 - enzyme effects, 64f
 - path, 70
 - rates of chemical reactions and, 64
 - transition state theory, 67–70
- Activation gates: action potentials, 270
- Active transport
 - antiports, 175–176
 - cell structure, 102
 - electrochemical potentials, 170–172
 - energetics, 170–172
 - exchangers, 170
 - ion permeation, 170–172
 - material transport, 172
 - metabolic energy, 172
 - phosphorylated intermediates, 173
 - pumps, 170
 - sodium, potassium-ATPase, 172–173
 - sodium, potassium-ATPase as electrogenic, 173–174
 - sodium–calcium exchangers, 174–175
 - symports, 176
- Active zones, 329–330
- Actomyosin cross-bridge cycling, 549
- Acyl chains, 143–145
- Adaptation to stimuli, 392
- Adaptive functions: autonomic nervous system, 473
- Addison's disease, 914b
- Adenine, 120
- Adenosine, 594
- Adenosine diphosphate (ADP): equilibrium concentrations, 92
- Adenosine triphosphate (ATP)
 - as energy currency of the cell, 218–219, 220f
 - enzymes, 108, 549, 794
 - equilibrium concentrations, 92
 - exercise duration/intensity, 334–335
 - hydrolysis, 90–92
- muscular activity, 312–313, 334
- production
 - amino acid oxidation, 241
 - fatty acid oxidation, 241
 - glycolysis, 218
 - oxidative phosphorylation, 227
 - TCA cycle, 227
- regeneration, 336
- Adenylyl cyclase, 591
- ADH. *See* Antidiuretic hormone (ADH)
- Adherens junctions, 111, 547
- Adipocyte lipolysis, 242f
- Adipose triglyceride lipase (ATGL), 242, 242f
- Adiposity signals, 843–844
- ADP. *See* Adenosine diphosphate (ADP)
- Adrenal cortex, 702, 906
- Adrenal medulla, 475, 596, 916
- Adrenaline, 475
- Adrenergic receptors
 - catecholamine action, 919–920
 - norepinephrine release, 480–482
 - pharmacology-based classification, 383
- Adrenergic stimulation
 - smooth muscles, 358
- Afferent arterioles, 699, 700–701
 - glomerular hydrostatic pressure, 740–741
 - renin release, 701–702, 748
- Afferent fibers: gut extrinsic innervation, 799
- Afferent sensory neurons, 419
- Affinity of a chemical for electrons, 229
- Afterload: cardiovascular system, 556, 558–559, 599
- Ageusia, 437
- Agglutinins, 503
- Agglutinogens, 503
- Agouti-related protein (AgRP), 842–843
- Agranular white blood cells, 507
- Agrin, 331
- AgRP. *See* Agouti-related protein (AgRP)
- A-intercalated cells, 757
 - acid secretion by, 761
- Air molecules: speed of sound, 451–452
- Air movement: lung volumes, 625
- Air pressure waves: hearing, 441–442
- Air transport: breathing, 623–624
- Airway mechanoreceptors, 679–680
- Airway resistance, 630–631, 633, 653
- Airy disk, 113–114
- Albumin, 498
- Aldosterone, 702, 912. *See also*
 - Renin–angiotensin–aldosterone (RAA) system
- perfusion regulation, 596–597
- zona glomerulosa, 911
- Alkalemia, 665
- Alkaline phosphatase, 939
- Alkaline solution secretion, 811–812
- Alkaloids, 506
- Alkalosis, 665, 669
 - hydrogen carbonate, 760

- Alkalosis (*Continued*)
 hyperventilation, 668
 kidneys, 760, 761
 lungs, 760
 respiratory compensation, 668
- Alleles, 956
- Allergies, 509–510
- α dystroglycan, 314–315
- α melanocyte stimulating hormone (α MSH), 842–843
- α -actinin, 105, 310
- α -helix, 134–135, 136f
- α -Klotho (KL), 931
- α_1 -antitrypsin, 496
- Alpha₂ adrenergic stimulation, 209–210
- Alveoli
 anatomic dead space, 647
 carbon dioxide production rates, 648
 duct mechanics, 624
 gas equations, 648, 651–652
 gas exchange, 645–646, 651, 653
 Law of Laplace, 627
 pressure, 627b
 surfactants, 627–628
- Amacrine cells, 463
- Ambient temperature and pressure, saturated (ATPS), 645
- Amiloride, 434–435, 733
- Amino acids
 ammonium origin, 755–756
 antidiuretic hormone, 870
 ATP production, 241
 basolateral membranes, 824–825, 825
 brush border membranes, 824–825
 insulin secretion, 898
 oxidation, 241
 oxytocin, 870
 protein structure, 139
 peptide bonds, 131–133
 primary protein structure, 134
 secondary protein structure, 134–136
 tertiary protein structure, 136–137
 proximal convoluted tubule, 725
 structure, 139
 transfer RNA, 123
- Aminoacyl (A) binding sites, 123
- Aminopeptidase A, 823–824
- Aminopeptidase N, 823–824
- Aminopeptidase P, 823–824
- Aminopeptidase W, 823–824
- Ammonium, 754, 755–756, 762
- Amphipathic molecules, 147–149, 149
 lowering of the surface energy by, 150f
- AMPK (AMP-activated protein kinase), 761
- Amylase, 811
- Amylolytic enzymes, 810
- Anaerobic metabolism, 222
 lactic acid
 glycolytic flux, 338
- Anaerobic thresholds: lactic acid, 340
- Anaphase, 957–958
- Anatomic dead space, 647
- Anemias, 501, 505
- Angiotensin, 702. *See also*
 Renin–angiotensin–aldosterone (RAA) system
 effects, 911–912
 perfusion regulation, 596–597
 zona glomerulosa, 911
- Angiotensin converting enzyme (ACE), 748
- Angiotensin II, 748
- Angiotensin-converting enzyme (ACE) 1 and 2, 823–824
- Angiotensinogen, 498–499
- Anionic amino acid system, 825
- Anions, 53
- Ankyrin, 314–315, 501f
- Annulus fibrosus, 516, 520
- ANP. *See* Atrial natriuretic peptide (ANP)
- ANS. *See* Autonomic nervous system (ANS)
- Anterior olfactory nucleus (AON), 433f
- Anterior pituitary, 857, 857, 874, 961–962, 962–963
- Anterior pyriform cortex (APC), 433f
- Anterolateral tract, 395
- Antibodies, 499, 514–515
- Anticipatory control systems, 11
- Anticoagulant therapy, 496b
- Antidiuretic hormone (ADH)
 amino acids, 870
 blood pressure, 616–617
 blood volume, 873
 collecting duct, 733
 diabetes insipidus, 739b
 distal nephron permeability, 738, 745
 feedback loops, 745–746
 hyperosmolarity, 744–745
 hypothalamus, 870
 hypovolemia, 744–745
 inner medullary collecting duct, 733
 late distal tubule, 733
 perfusion regulation, 596–597
 plasmaosmolarity, 873
 urine concentration, 730
 water balance, 744
- Antigens, 499f, 503
- Antiparallel beta sheets, 135
- Antiports, 175–176
- Antithrombin III, 496
- Antithromboplastin, 496
- Antrum, 952
- AON. *See* Anterior olfactory nucleus (AON)
- Aorta, 519–520
- Aortic arch: arterial pressure regulation, 609–610
- Aortic bodies: ventilation control, 676
- Aortic regurgitation, 520, 563
- Aortic valve, 519–520
- APC. *See* Anterior pyriform cortex (APC)
- Apex beat, 516
- Apical membranes, 725, 779f
- Aplastic anemia, 506
- Apnea, 680b
- Apolipoproteins, 498, 829–831
- Aquaporins, 168, 181, 198, 727, 731, 751
- Arcuate arteries, 700–701, 700f
- Arcuate arterioles, 700–701
- Arcuate veins, 701
- Arginine vasopressin (AVP), 730. *See also*
 Antidiuretic hormone (ADH)
- Aristotle, 5
- Aromatic amino acids, 825
- Arrhythmias, 544b, 563
- Arterial tree: hemodynamics, 570, 572
- Arteries
 arcuate arteries, 699, 700–701
 circulatory system overview, 489
 compliance, 570–571
 disease, 563
 interlobar arteries, 699, 700–701
 pressure, 573–574, 608
 stroke volume, 570–571
 vascular function curves, 602–603
 ventilation control, 676
- Arterioles
 afferent arterioles, 699, 700–701, 740–741, 748
 arcuate arterioles, 700–701
 branching, 573–574
 circulatory system overview, 489
 efferent arterioles, 701, 740–741
 perfusion regulation, 589, 593
 pressure drops, 573–574
 solute exchange, 578
 terminal arterioles, 578
 vascular function, 604
- Arteriosclerosis, 571
- Aspartate, 383
- Aspiration reflexes, 680
- Association constants, 666
- Asthma, 650b, 669
- ATGL. *See* Adipose triglyceride lipase (ATGL)
- Atherosclerosis, 571
- Atomic mass, 59
- Atomic number, 46
- Atomic orbitals, 47–48
- Atoms
 electrical charges, 46
 molecule formation, 48
 movement, 56f
- ATP synthase, 233
- ATP synthetase, 108
- ATPase, 549, 550, 794
 ABC transporters, 174
 F-type ATPases, 174
 P-type ATPases, 174
 V-type ATPases, 174
- ATP-driven ion pumps, 181
- ATPS. *See* Ambient temperature and pressure, saturated (ATPS)
- Atresia, 948
- Atria, 518, 519. *See also* Sinoatrial (SA) node
 cardiac action potential, 528
 electrocardiograms, 540, 544
 vascular function curves, 603–604
 ventricular function curves, 558
- Atrial natriuretic peptide (ANP)
 blood pressure, 617
 hypervolemia, 749
 perfusion regulation, 596–597
- Atrioventricular (AV) conduction blocks, 544
- Atrioventricular (AV) impulse transmission, 523
- Atropine nerve gas antidote, 484
- Atropine poison, 485
- Auditory cortex, 446–447
- Auditory systems. *See* Hearing
- Augmented unipolar limb leads, 543
- Auscultation, 520
- Autonomic nervous system (ANS), 473
 acetylcholine, 479
 adaptive functions, 473
 cardiac action potential, 529–530
 efferent functions, 473–474, 478–479
 emotional state, 473–474
 homeostasis, 473
 micturition, 483–485
 nerve terminals, 482
 neurotransmitters, 479
 norepinephrine, 479
 reflexes, 473
 target cell receptors, 482
- Autoregulation: GFR/RF, 742
- Autosomes, 956
- AV. *See* Atrioventricular (AV)...
- Avogadro's number, 59
- AVP. *See* Arginine vasopressin (AVP)
- Axons
 action potentials, 265, 280, 319
 cervical ganglia, 476
 neuropeptides, 384–385
 olfactory receptor cells, 427–428, 429
 Axoplasmic resistance: action potentials, 282

B

- Back pressure: bleeding restriction, 494
- Balance of movement, 409
- Baroreceptors, 609–610
- Baroreflex, 610–611
- Barrett's esophagus, 783
- Barrier function, 110
- Bartter syndrome, 732
- Barttin, 732
- Basal ganglia, 372, 413–415
- Basal metabolic rate (BMR), 837–838
- Base-acid balance, 752, 765
- Base-acid physiology, 665
- Basement membranes, 708
- Basic amino acids, 130
- Basolateral membrane, 779f
- Basolateral membrane (BLM), 825
 - amino acid absorption, 825
- Basolateral membranes, 725, 824–825
- Basophils, 507, 508–509
- Bellini ducts. *See* Ducts of Bellini
- Bending of light, 467–468
- Beta adrenergic stimulation, 212, 213f
 - cell signaling, 209
- Beta blockers: hypertension, 617
- β dystroglycan, 314–315
- Beta oxidation: fatty acids, 243–245
- Beta sheet, 135, 136f
- β -hydroxybutyric acid, 245
- Between brain. *See* Diencephalon
- Bicarbonate absorption: acid secretion, 727
- Bicarbonate buffer systems, 665
- Bicarbonate reabsorption, 756–757
- Bile, 773, 817–819, 833
- Bile acids, 814–815, 815, 815–816
 - enterohepatic circulation of, 817f
- Biliary secretion, 810
- Bilirubin, 502–503
- Biliverdin, 502–503
- B-intercalated cells, 757
- Bioassays: hormones, 861–862
- Biological membranes. *See* Membranes
- Bipolar cells, 462–463
- Bipolar electrodes, 542–543
- Bitter taste, 432, 436
- Bladder, 698
- BLM. *See* Basolateral membrane (BLM)
- Blood
 - acid excretion, 753
 - ATP production, 221–222
 - back pressure, 494
 - bleeding disorders, 496b
 - blood substitutes, 663b
 - blood–brain barrier, 370, 678
 - carbon dioxide transport, 661
 - coagulation, 494–495
 - activation, 495–496
 - anticoagulant therapy, 496b
 - inhibition, 495–496
 - concentration, 61b
 - dissolved oxygen content, 656
 - ejection by heart, 570
 - endocrine glands, 853
 - exercise intensity, 338
 - gas exchange, 642, 647
 - glucocorticoids, 909–910
 - glucose, 895
 - heart chambers, 518–520
 - hemoglobin, 656–657
 - hormones, 858–859
 - hydrogen carbonate (HCO_3), 661–662
 - inflammation, 511
 - kidneys, 698
 - lungs, 648
 - overview, 487
 - oxygen
 - carrying capacity, 657b
 - consumption, 657
 - delivery, 661
 - diffusion, 659
 - hemoglobin, 656–657
 - plasma, 494, 498
 - pressure
 - arterial pressure regulation, 609, 613–615
 - hormonal regulation, 615–617
 - long-term blood volume regulation, 613–615
 - sphygmomanometers, 572–573
 - pressure-driven flow, 493
 - problem sets, 525
 - red cells, 498
 - solute exchange, 585
 - type classification, 503–504
 - vasoconstriction, 494
- vessels
 - branching, 573–574
 - compliance, 493–494, 570–571
 - disease, 563
 - overview, 489
 - perfusion regulation, 589–590, 592, 593, 596–597
 - pressure, 572–573, 608
 - solute exchange, 578, 584–585
 - stroke volume, 570–571
 - vascular function, 569–570, 602–603, 604
 - ventilation control, 676
- volume
 - antidiuretic hormone, 873
 - integrated response, 749
 - long-term blood pressure regulation, 613–615
 - vascular function curves, 605
 - white cells, 507
- B-lymphocytes, 499–500, 510
- Body fluid compartments, 687
- Body temperature and pressure, saturated (BTSP), 644, 645, 652
- Bohr effect, 660–661
- Boltzmann's constant, 85
- Bonds
 - amino acids, 123
 - angles, 50
 - energies, 50
 - enthalpy, 50–51
 - hydrogen bonds, 53–54, 54
 - deoxyribonucleic acid, 121, 121
 - secondary protein structure, 134–136
 - water, 54
 - isomerism, 51
 - length, 50
 - movement, 56f
 - protein structure, 131–133
 - rotation, 50
 - unequal sharing, 51–53
 - water, 53–54
- Bone
 - erythrocyte formation, 502
 - hormones, 935–937
 - hypocalcemia, 927
 - osteoblasts, 933, 934–935
 - osteoclasts, 934, 935, 935
 - osteocytes, 933–934
 - remodeling, 934
 - vitamin D mineralization, 931
- Bone cells
 - fibroblast growth factor 23 (FGF23), 931
- Bovine spongiform encephalopathy (BSE), 139
- Bowman's capsule, 698–699, 700–701
- Bowman's glands, 428
- Bowman's space, 701, 705
- Bradycardia, 610
- Bradykinin: paracrine secretions, 595
- Brain, 370
 - adrenal cortex, 702, 906
 - adrenal medulla, 475, 596, 916
 - anterior pituitary, 857, 874, 961–962, 962–963
 - auditory cortex, 446–447
 - blood–brain barrier, 370, 678
 - brain stem
 - auditory cortex, 446–447
 - function, 373
 - ventilation control, 677
 - cerebellum
 - control of movement, 413–415
 - function, 373
 - movement accuracy, 415
 - cerebral cortex, 372, 411
 - cerebrospinal fluid, 691
 - brain surface features, 367
 - cushioning effect, 369–370
 - ventilation control, 678
 - ventricles, 369–370
 - consciousness, 366
 - cortex
 - hearing, 446–447
 - kidney function, 698–699
 - olfactory output, 429–431
 - taste receptors, 438
 - vision, 464–465
 - diencephalon function, 373
 - feeding behavior, 839
 - flavor in, 438
 - forebrain function, 372
 - gray matter organization, 371
 - hearing, 442–444, 446–447
 - hindbrain function, 373
 - hyperosmolarity, 744–745
 - hypothalamus, 870
 - diabetes insipidus, 739b
 - feeding behavior, 839
 - function, 373
 - sensory afferents, 611–612
 - testicular function, 961–963
 - thyroid stimulating hormone, 885
 - hypovolemia, 744–745
 - medulla
 - adrenal medulla, 475, 596, 916
 - baroreflex, 611–612
 - function, 373
 - kidney function, 698–699
 - reticulospinal tract, 406
 - salivary nuclei, 777–778
 - swallowing centers, 780
 - urea, 733, 736
 - vestibular nuclei, 419
 - motor cortex, 411
 - orbitofrontal cortex, 431
 - pituitary gland, 870
 - pons, 373
 - posterior pituitary, 857, 870
 - sensory cortex, 395
 - somatosensory information, 394–395
 - strength gains, 343
 - surface features, 367–369
 - testicular function, 961–963
 - thalamus
 - function, 373
 - olfactory output, 431
 - taste receptors, 438
 - ventilation control, 678
 - vision, 464
- Breasts: myoepithelial cell contraction, 871
- Breathing. *See* Respiratory systems
- Bronchi, 624

Bronchiectasis, 640
 Bronchioles, 624
 Bronchitis, 640
 Bronsted–Lowry theory, 665–666
 Brush border membranes
 amino acids, 824–825
 protein digestion, 822–824
 starch digestion, 825–826
 Bruxism, 775
 BSE. *See* Bovine spongiform encephalopathy (BSE)
 BTPS. *See* Body temperature and pressure, saturated (BTPS)
 Buffers, 500, 665, 752–753. *See also* Bicarbonate buffer systems
 Bundles of His, 523

C

C peptide, 895
 CA. *See* Carbonic anhydrase
 Ca-ATPase pump, 550
 Calcitonin (CT), 935, 937f, 941–942
 Calcitropic hormones, 924
 Calcium. *See also* Calcitropic hormones
 actomyosin cross-bridge cycling, 549
 ATP production, 239
 bone mineralization, 942
 cardiac action potential, 528, 532–533
 cardiac contraction
 calsequestrin, 551–552
 glycosides, 553–554
 induced, 552–553
 cardiac relaxation, 550–551
 cell signaling, 206–207, 211
 chemical neurotransmission initiation, 379
 cross-bridge cycling, 325–326
 excitation-contraction coupling, 324
 homeostasis, 924, 933
 hypertension channel blockers, 617
 induced cardiac contraction, 552–553
 intestine, 939
 mitochondria, 551
 muscle fiber action potentials, 324
 negative feedback loops, 942–943
 1,25(OH)₂-D hormone, 937–939
 osteoclasts, 934
 parathyroid hormone, 941
 perfusion regulation, 591
 presynaptic cells, 322, 380
 regulation, via membrane potential, 354
 by altering BK_{Ca} channels, 354
 repetitive stimulation effects, 327
 sarcoplasmic reticulum, 324
 smooth muscle, 354–356
 contraction, 353–354
 force production, 356–357
 relaxation, 358
 urinary excretion, 940–941
 Calcium Release Unit
 multiple proteins on T-tubules and sarcoplasmic reticulum membranes, 331–333
 Calcium-induced calcium release (CICR), 549–550
 Calmodulin, 332
 Calmodulin-dependent activation of enzymes, 206
 Calmodulin-dependent protein kinase (CAM kinase II), 332
 Calorimeters, 834, 836–837, 837
 Calsequestrin (CASQ), 332, 551–552
 cAMP. *See* Cyclic AMP (cAMP)
 Cancellous bone, 933
 Capacitance, 31, 281–282
 action potential propagation, 281–282
 coaxial cables, 288
 coaxial capacitors, 287
 Gauss' law, 287
 parallel plate capacitors, 35–36
 pressure-driven flow, 18
 Capacitive current, 39–40
 Capacitors, 36, 282
 charging of, time constant, 39–40
 Capillaries
 branching, 573–574
 circulatory system overview, 489
 inflammation, 511
 perfusion regulation, vasoconstriction, 589–590
 solute exchange, 578
 bulk fluid movement, 584
 lymphatics, 585
 net filtration pressure, 584–585
 passive mechanisms, 579
 transcytosis, 584
 types, 578–579
 Carbamates, 662
 Carbaminohemoglobin, 662
 Carbohydrates
 biological membranes, 142
 dietary fiber, 825
 digestion, 825
 glucose, 220–221
 Carbon
 bond rotation, 50
 geometries, 48–49
 rotation, 50
 surface, 48–49
 Carbon dioxide (CO₂)
 acid secretion, 759
 alveolar ventilation calculations, 648
 ATP production, 227–229
 breathing mechanics, 623
 carbaminohemoglobin, 662
 hydrogen carbonate reabsorption, 757–759
 hydrogen ion secretion, 757–759
 metabolic acidosis, 760
 metabolic alkalosis, 760–761
 pH regulation, 668
 respiratory system, 623
 transport, 656
 ventilation control, 677
 Carbon monoxide (CO) poisoning, 662b
 Carbonic acid (H₂CO₃), 667–668
 Carbonic anhydrase (CA), 662, 667, 727, 752, 753
 Carbonic anhydrase on the apical membrane (CAIV), 727
 Carboxyhemoglobin, 662
 Carboxypeptidase A, 822–823
 Carboxypeptidase P, 823–824
 Cardiac action potential, 528
 Cardiac contractility, 516–518
 cardiac cycle, 520–522
 cardiac glycosides, 553–554
 cellular basis, 547
 myofibrils, 548–549
 parasympathetic stimulation, 553
 regulation, 552
 stretch-based modulation, 554–555
 Cardiac cycle
 contractile events, 520–522
 electrocardiograms, 544–545
 Cardiac function curves, 556
 cardiac output, 599
 steady-state operating points, 604, 605
 Cardiac glycosides: cardiac contraction, 553–554
 Cardiac muscle
 calcium-induced calcium release, 549–550
 contraction, 516–518
 features, 547
 Cardiac myofibrils: contractility, 548–549
 Cardiac output (CO), 556, 599
 distribution by vascular system, 568
 Fick's principle, 560–561
 indicator dilution method, 561–563
 Cardiolipin: biological membranes, 146–147
 Cardiomyocyte coupling, 547
 Cardiomyopathy, 563
 Cardiovascular system. *See also* Blood; Heart; Inflammation; Vascular system
 hemodynamics, 568
 overview, 487
 Carnitine carrier substances, 243
 Carotid bodies: ventilation control, 676
 Carotid chemoreceptors: ventilation control, 676
 Carotid sinus: arterial pressure regulation, 609
 Carrier classifications, 179
 CART. *See* Cocaine–amphetamine regulated transcript (CART)
 CASQ. *See* Calsequestrin (CASQ)
 Catalysts
 cell structure, 101
 posttranslational modification, 137–138
 tricarboxylic acid cycle, 230–231
 Cataracts, 466b
 Catecholamines, 382
 adrenergic receptor types, 919–920
 degradation, 918–919
 fight or flight, 920–921
 sympathetic stimulation, 916–917
 Cationic amino acid system, 825
 Cations, 53
 Caudal ventrolateral medulla (CVLM), 611–612
 Causal link, 6
 Caveolae, 153f
 and integral proteins, 153
 Caveolae vesicles, 578–579
 Caveolin, 578–579
 Cavins, 153
 CCK. *See* Cholecystokinin (CCK)
 Celiac ganglia, 475, 799
 Cell bodies: motor neurons, 265
 Cell cortex, 105
 Cells
 action potentials, 265
 blood, 494, 498, 507
 body fluid compartments, 692
 cardiac action potential, 528–529
 cardiac contractility, 528–529, 547
 cell theory, 6–7
 complement systems, 514f
 core principles, 6–7
 cell theory, 6–7
 diversity, 7
 forms, 7
 genome, 7
 cortisol, 910–911
 diffusion coefficients, 79–80
 follicular development, 949–953
 fractionation problem sets, 156
 gametes, 946, 947, 956, 958, 960–961
 glucagon release, 899–900
 glycolysis, 218, 222
 gut, 782
 insulin synthesis, 895
 membranes
 cell forms, 7

- cell structure, 101–102
- cell theory, 6–7
- smooth muscle contractile filaments, 352
- motor neurons, 265, 318, 318
- myoepithelial cells, 777, 871
- nervous system, 318, 375
- osmotic pressure, 192–193
- ovarian steroidogenesis, 953
- oxygen diffusion, 659
- red blood cells, 498
- signaling, 205
 - cellular response classes, 206
 - channels, 206–207, 207–209
 - chemical signaling, 205, 207–209, 212
 - effectors, 212
 - electrical signals, 205, 206
 - endocrine signals, 206
 - event transduction, 205
 - gene expression, 213, 215
 - heterotrimeric G-protein-coupled receptors, 209
 - ligand-gated ion channels, 207–209
 - mechanical signals, 205
 - membrane-bound enzymes, 212
 - neurotransmitters, 206
 - nuclear receptors, 213
 - receptors, 212, 213
 - gene transcription, 213
 - histone acetylase, 214
 - transcription factors, 214–215
 - voltage-gated ion channels, 206
- skeletal muscle contractile mechanisms, 306
- smooth muscle coupling, 352–353
- solute exchange, 581–582
- structure, 99
 - attachment, 110–111
 - cell membranes, 101–102
 - centrifugation separation analyses, 116–117
 - cytoskeleton, 103
 - cytosol, 103
 - electron microscopy, 114
 - endoplasmic reticulum, 108
 - form, 101
 - function, 101
 - Golgi apparatus, 108
 - lipid processing/synthesis, 108
 - lysosomes, 109
 - microscopy, 113
 - mitochondria, 108–109
 - nuclei, 107–108
 - organelles, 101, 115
 - peroxisomes, 109
 - proteasomes, 110
 - protein processing/synthesis, 108
 - protein synthesis, 108
 - ribosomes, 108
 - study methods, 113
 - subcellular fractionation, 115
 - thyroglobulin precursors, 883, 885
 - types, 7, 125–126
- Cellular pacemakers, 675
- Cellular respiration, 623
- Central chemosensors, 677–678
- Central nervous system (CNS). *See also* Brain; Spinal cord
 - cutaneous sensory systems, 389
 - depression, 669
 - feeding behavior, 838–839
 - integrative centers, behavioral response, 366
 - major area functions, 372–373
 - odor adaptation, 431
 - organization, 367
 - preganglionic neurons, 474
 - serotonin, 384
 - thoracolumbar spinal cord, 475–477
- Central pattern generator (CPG), 773–774
- Central sleep disorders, 680
- Central venous pressure. *See* Preload
- Centrifugation: cell structure, 115–116
- Centrioles, 104–105
- Centripetal acceleration, 117
- Cephalic acid secretion phases, 791–794
- Cephalic enzyme secretion phases, 812–813
- Ceramide, 146
- Cerebellum
 - control of movement, 413–415
 - function, 373
 - movement accuracy, 415
- Cerebral cortex
 - function, 372
 - purposeful movement, 411
- Cerebrosides, 146, 146
- Cerebrospinal fluid (CSF), 691
 - brain surface features, 367
 - cushioning of brain, 369–370
 - ventilation control, 678
 - ventricles, 369–370
- Cervical ganglia, 476
- CFTR. *See* Cystic fibrosis transmembrane conductance regulator (CFTR)
- Chaperones: protein structure, 137
- Chaperonins: protein structure, 137
- Charge
 - action potential propagation, 282
 - atoms, 46
 - electrical potential, 31–32
 - light, 467
 - movement, 37
 - pressure-driven flow, 18
 - vision, 467
- Chemical potentials: osmotic pressure, 184
- Chemical reactions, rates of
 - and activation energy, 64
- Chemical signals, 205
 - circulatory system overview, 489–490
 - ligand-gated ion channels, 207–209
 - membrane-bound enzymes, 212
 - smooth muscle, 354–356
- Chemical species, aggregate of, 72
- Chemical synapses. *See* Synapses
- Chemical trigger zones (CTZ), 804
- Chemiosmotic coupling, 233
- Chemokines, 512
- Chemoreceptors, 676f, 677, 791–793, 797–798
- Chemosensors, 676, 677–678, 840–841
- Chemotactic compounds, 513–514
- Chenodeoxycholic acid, 814–815
- Chest wall, 626, 628–630
- Chewing, 773
- Chloride ion secretion
 - acid–base balance, 757
- Cholecystectomy, 819
- Cholecystokinin (CCK), 788–789, 812–813, 841
- Cholesterol
 - bile, 814, 816–817
 - biological membranes, 146–147
 - steroid hormones, 857, 906–907
- Cholic acid, 814–815
- Chord conductance, 259–260, 269
- Chordae tendinae, 518
- Chorionic gonadotropin (hCG), 963
- Choroid plexuses, 678
- Chromaffin cells, 475, 596
- Chromatin, 122
- Chromatography, 862
- Chromosomes, 120, 122, 956, 958–959
- Chronaxie, 268
- Chronic acidosis, 762
- Chronic bronchitis, 640
- Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, 724
- Chronic obstructive pulmonary disease (COPD), 640b
- Chronotropic effects: cardiac action potential, 529–530
- Chylomicrons, 585, 829–831
- Chyme, 800–801
- Chymotrypsin, 822–823
- CICR. *See* Calcium-induced calcium release (CICR)
- Cilia. *See also* Follicles
 - cell structure, 104
- Ciliary body: pupillary light reflex, 482–483
- Circular esophageal smooth muscle, 781
- Circulatory pressure, 601
- Circulatory systems. *See also* Cardiovascular system; Respiratory systems
 - diapedesis, 513–514
- Circus arrhythmia, 544
- Cisternae, 108
- Citric acid cycle. *See* tricarboxylic acid (TCA) cycle
- CJD. *See* CREUTZFELDT–Jakob disease (CJD)
- Clathrin-coated pits, 153f
 - and integral proteins, 153
- Clitoris, 946
- Clotting
 - inflammation, 511
 - plasmin, 495
 - retraction, 495
- CO. *See* Carbon monoxide (CO)
- poisoningCardiac output (CO)
- Coagulation, 494–495
 - activation, 495–496
 - anticoagulant therapy, 496b
 - inhibition, 495–496
- Coaxial capacitors, 287
- Cobalamin, 506
- Cocaine–amphetamine regulated transcript (CART), 842–843
- Cochlea
 - cochlear microphonic, 448–450
 - hair cells, 444–445
 - implants, 449b
 - sound frequency tonotopic mapping, 445–446
- Codons, 123
- Cold receptors, 393
- Collagen, 627, 710
- Collecting ducts
 - acid–base balance, 757
 - kidney function, 698–699
 - urea transport, 733
 - water permeability, 733
- Colligative properties
 - osmotic pressure, 185
- Colloid osmotic pressure. *See* Oncotic pressure
- Colon
 - content reflux, 802
 - diverticular disease, 808b
 - motility, 796
- Command systems, 10
- Compartmental analysis, 72–74
 - chemical species, aggregate of, 72
 - turnover, 72–74
- Compensatory pause, 544
- Competitive inhibition
 - facilitated diffusion, 165
 - ligand binding, 868–869
- Compliance
 - circulatory systems, 601–602
 - lung expansion, 626, 627

Compliance (*Continued*)
 pulse pressure, 570–571
 vascular function, 568, 569–570, 602–603
 Compton effect, 114
 Concave lenses, 468
 Concentration, 59
 definition, 60
 facilitated diffusion, 164–165
 osmotic pressure, 182–184
 urine, 730
 Concentric contractions, 300, 300
 Conductance, 39
 Conductance potentials, 258–259, 269–270, 271
 Conductors, 39
 Confocal microscopy, 119
 Connecting ducts: salt, 732–733
 Consensual pupillary light reflex, 482–483
 Conservation of energy
 electrical potential, 32–33
 pressure-driven flow, 17
 Conservation of matter, 17
 Conservation of solute calculations, 61
 Conservative forces
 electrical potential, 32–33
 work, 33
 Constipation, opioid-induced, 807b
 Continence, 483, 803
 Continuity equations, 17, 83–84
 diffusion, 75
 pressure-driven flow, 17
 Continuous capillaries, 578, 578–579
 Continuous positive airway pressure (CPAP), 640
 Contractile behavior
 muscle fibers, 297–298
 Contractile mechanisms
 airway resistance, 639
 colonic motility, 802–803
 excitation-contraction coupling, 206, 318
 frequency codes, 409
 heart, 516–518, 547
 action potentials, 528–529
 cardiac cycle, 520–522
 cardiac glycosides, 553–554
 cellular basis, 547
 cycle, 520–522
 electrical systems, 522–523
 myofibrils, 548–549
 parasympathetic stimulation, 553
 regulation, 552
 stretch-based modulation, 554–555
 perfusion regulation, 592–593
 physically-based, 351
 population codes, 409
 skeletal muscle, 293, 300, 305
 slow wave activity, 799
 smooth muscle, 351, 352
 stomach, 787–788
 stroke volume, 556
 Control systems
 cell structure, 101
 core principles, 10
 anticipatory control systems, 11
 cyclical systems, 11
 developmental control systems, 11
 feed-forward control systems, 11
 negative feedback loops, 10–11
 noncyclical systems, 11
 threshold control systems, 11
 movement, 409
 Convection–diffusion equations, 81
 Convergence of light, 468
 Convex lenses, 468
 Cooperativity of oxygen binding, 656–657

Cooperativity plots, 867–868
 Coordinated command and control, 10
 COPD. *See* Chronic obstructive pulmonary disease (COPD)
 Cori cycle, 223
 Coronary artery disease, 563
 Coronary sinus, 518
 Corpus albicans, 949
 Corpus cavernosa, 965
 Corpus luteum, 949, 954–955
 Cortex. *See also* Cerebral cortex
 hearing, 446–447
 kidney function, 698–699
 olfactory output, 429–431
 taste receptors, 438
 vision, 464–465
 Cortical masticatory area (CMA), 773–774
 Cortical nephrons, 701
 Cortical neurons, 396–397
 Corticospinal tract, 405
 Cortisol, 909–910, 911
 Costameres, 314–315
 Cotransporters. *See* Symports
 Cough reflexes, 680
 Coulomb's law, 31, 34–35
 Countercurrent exchangers, 736
 Counter-transporters. *See* Exchangers
 Covalent bonds, 51–53, 123
 COX. *See* Cyclooxygenase (COX) enzyme
 CPAP. *See* Continuous positive airway pressure (CPAP)
 Cranial nerve VII, 773
 Cranial nerves, 373, 477–478
 Creatinine, 723
 Creutzfeldt–Jakob disease (CJD), 139
 Cribriform areas, 427–428, 698–699
 Cristae, 109f
 Cross-bridge cycle, 312
 Cross-bridges, 312–313, 325, 549
 Crossed-extensor reflexes, 400–401
 Crossing-over: genetics, 958–959
 Cross-striations: muscle, 548–549
 Crystallins, 466
 Crystalloids, 584
 CSF. *See* Cerebrospinal fluid (CSF)
 CT polypeptide hormone
 hypercalcemia, 928
 plasma ion concentration, 928
 CTZ. *See* Chemical trigger zones (CTZ)
 Current, 31, 39
 action potentials, 265, 280, 282, 286
 ion movement, 37–38
 Ohm's law, 39
 resting membrane potential, 260–261
 Current–voltage relationship, 271–272
 Cushing's disease/syndrome, 913b
 Cutaneous sensory systems, 389
 action potentials, 390–391
 anatomical connection, 391
 anterolateral tract, 395
 central nervous system pathways, 390
 dorsal column pathways, 394–395
 exteroceptors, 389
 interoceptors, 389
 long receptors, 390–391
 pain information, 395
 perception, 390
 receptive fields, 392, 396–397
 receptor types, 392–393
 sensation disorders, 395–396
 sense organs, 390
 sensory cortex, 395
 sensory neurons, 392
 sensory receptors, 390
 sensory stimuli, 391

short receptors, 390–391
 somatosensory information, 394–395, 396–397
 temperature information, 395
 Weber–Fechner law of psychology, 391–392
 C–X bonds: isomerism, 51
 Cyclic AMP (cAMP), 529–530
 Cyclooxygenase (COX) enzyme, 593, 596, 795
 Cysteine aminopeptidase, 739
 Cystic fibrosis, 623–624
 Cystic fibrosis transmembrane conductance regulator (CFTR), 624, 812
 Cytokines, 502, 510, 512
 Cytoplasm
 actomyosin cross-bridge cycling, 549
 cell structure, 103
 Cytosine, 120
 Cytoskeletal units
 tensegrity, 106
 Cytoskeleton
 cell structure, 103
 actin, 105
 intermediate filaments, 105–106
 microtubules, 103–105
 myosin, 107
 skeletal muscle contractile mechanisms, 314–315
 Cytosol
 ATP production, 235–236
 cell structure, 103
 smooth muscle, 354, 358
 taste receptor cells, 435
 Cytosolic carbonic anhydrase (CAII), 727
 Cytotoxic T cells, 510

D

D (diffuse) subshells, 47–48
 Da. *See* Dalton (Da)
 Dalton (Da), 59
 Darrow–Yannet diagrams, 694–696
 Darwin, Charles, 8
 Davenport diagrams, 669
 Deamination, 247–251
 Decoding, 6
 Defecation, 803–804
 nervous control of, 805f
 Degrees of freedom, 25
 Dehydration, 740
 Dehydrogenation reactions, 247
 Deiodinase type I, 886–888
 Delayed rectifying potassium ion channels, 532, 533
 Dendrites, 265
 Density gradient centrifugation, 116, 116
 Deoxycholic acid, 815
 Deoxyribonucleic acid (DNA)
 cell diversity, 7
 cell signaling, 214
 genetic code, 123–125
 genomes, 120
 nucleotides, 121–122
 protein synthesis, 120
 replication, 122
 transcription regulation, 125–126
 Dephosphorylation, 221–222
 Depolarization
 action potentials, 269
 electrocardiograms, 541–542, 544
 Depolarizing current, 265
 Depolarizing stimuli, 266
 Depot fat, 241–242
 Desmosomes, 111, 547
 Detergents, 153
 Detrusor muscles, 483

Deuterium oxide, 689
 Developmental control systems, 11
 DGC. *See* Dystrophin–glycoprotein complex (DGC)
 DHPR. *See* Dihydropyridine receptors (DHPR)
 Di- and tri-peptide transport systems, 825
 Diabetes insipidus, 739*b*
 Diabetes mellitus, 176, 668, 721, 904*b*
 Diapedesis, 513–514
 Diaphragm: breathing mechanics, 625
 Diaphysis, 933
 Diarrhea, 668
 Diastereomers, 51
 Diastole relaxation, 516
 Diastolic pressure, 520–522, 556–557, 570, 571–572
 Diastolic volume, 556–557
 Dicrotic pressure, 570
 Dictyosomes, 108
 Dielectric constants, 281–282
 Diencephalon, 373
 Dietary fiber, 825, 831*b*
 Differential centrifugation, 115–116
 Differential expression of the genome, 7
 Differential interference microscopy, 119
 Differentiation: cell structure, 101
 Diffusion, 75, 579, 580, 645–646, 755–756
 alveolar membranes, 645–646
 electrochemical potential, 87–88
 equilibrium potentials, 255–257
 muscle, 353, 659–660
 oxygen, 659–660, 661
 problem sets, 94
 solute exchange, 581–582
 Diffusional permeability
 by dissolution–diffusion mechanism, 197–198
 of microporous membranes, 195–196
 Digastric muscle, 773
 Digestion, 773, 821. *See also* Gastrointestinal (GI) system
 bile, 817
 chewing, 773
 exocrine pancreas, 810
 saliva, 775–776
 Digoxin, 749
 Digoxin drugs, 553–554
 Dihydropyridine receptors (DHPR), 331, 549
 Dihydroxyacetone phosphate, 242–243
 Dilator muscles, 482–483
 Dilution
 conservation of solute calculations, 61
 fluid volume calculations, 62
 urine, 730
 Dipeptidyl peptidase 4, 823–824
 Dipeptidylcarboxypeptidases, 823–824
 2,3-diphosphoglycerate (DPG), 660
 Dipole moment, 57–58
 Dipoles
 dipole–dipole interactions, 54–55
 electrocardiograms, 537, 541
 Direct pupillary reflex, 482–483
 Discontinuous capillaries, 578
 Dissociation constants, 666
 Dissolution
 cytosol, 103
 lipid bilayers, 163–164
 Dissolution–diffusion mechanism
 diffusional permeability by, 197–198
 Distal nephrons
 acid–base balance, 757
 antidiuretic hormone, 738, 745
 osmotic diuresis, 738
 urinary excretion, 940–941

Distal tubules, 701, 732–733
 Disulfide exchange, 137
 Disulfide isomerase, 137
 Diuretics, 617
 Divergence of light, 468
 Diverticular disease, 808*b*
 Diving reflexes, 679
 Dixon plots, 869
 DNA. *See* Deoxyribonucleic acid (DNA)
 DNA methylation, 128
 DOK7, 329
 Dominant ovarian follicle, 949
 Donors: universal, 504
 Dopamine, 382–383
 Dorsal column pathway, 394–395
 Dorsal motor nuclei, 612
 Dorsal respiratory group (DRG), 672
 Dose–response curves: hormones, 859–860
 Double carbon–carbon bonds, 50
 Double helical structure, 122
 Double-reciprocal plots, 66
 Downregulated dose–response curves:
 hormones, 860–861
 DPG. *See* 2,3-Diphosphoglycerate (DPG)
 Drag force, 85
 DRG. *See* Dorsal respiratory group (DRG)
 Duchenne muscular dystrophy, 314–315
 Duct cells: pancreas, 811–812, 817–819
 Ductal cells, 810
 Ducts of Bellini, 698–699
 Duodenum, 788, 788, 796
 Duty cycle, 335
 Dyads, 549
 Dye: body fluid compartments, 689
 Dynamic compression: lungs, 639
 Dynamic pressure: breathing mechanics, 630–631
 Dynamic response phenomena: arterial pressure regulation, 610
 Dynamins, 153
 Dystrophin, 314–315
 Dystrophin–glycoprotein complex (DGC), 314–315

E

E neurons, 673–674
 Ear parts. *See also* Hearing
 inner ear, 441–444
 middle ear, 441–444
 air pressure waves, 441–442
 fluid pressure waves, 441–442
 sound channeling, 441
 outer ear, 441–444
 Eccentric contractions: skeletal muscle mechanics, 300
 ECF. *See* Extracellular fluid (ECF)
 ECG. *See* Electrocardiograms (ECG)
 ECL. *See* Enterochromaffin-like (ECL) cells
 Essential light chain (ECL)
 Ectopic beat, 544
 Ectopic focus, 544
 Ectopic pregnancy, 948
 Edema, 508–509
 Edinger–Westphal nuclei, 482–483
 EDP. *See* End-diastolic pressure (EDP)
 EDV. *See* End-diastolic volume (EDV)
 Effective renal plasma flow (ERPF), 707
 Effectors
 behavior, 367
 cell signaling, 209, 212
 Efferent arterioles, 701, 740–741
 Efferent autonomic nervous system, 473–474
 Efferent fibers, 367
 Efferent stimulation: inner hair cell tuning, 445
 Einstein's frictional coefficient, derivation of
 from momentum transfer in solution, 82–86
 Einthoven's triangle, 537–539, 543–544
 Ejaculation, 965
 Ejection cardiac cycle phase, 522
 Elastic fibers: lung expansion, 627
 Elastin fibers, 627
 Electric dipoles. *See* Dipoles
 Electric fields, 34
 Electrical activities: smooth muscle, 351–352
 Electrical axis definition, 541–542
 Electrical capacitors, 36, 282
 Electrical charge. *See* Charge
 Electrical force. *See* Force
 Electrical polarizability, 55*f*
 Electrical potentials, 31
 conservative forces, 32–33
 electric fields, 34
 energy, 34
 force, 34
 work per unit charge, 31–32
 Electrical signals, 205, 206
 heart contraction, 522–523
 voltage-gated ion channels, 206
 Electrical synapses, 378–379
 Electrically coupled cardiomyocytes, 547
 Electrically coupled smooth muscle cells, 352–353
 Electrocardiograms (ECG), 537
 Electrochemical gradients: ATP production, 234–235
 Electrochemical potentials, 87–88
 active transport, 170–172
 definition, 88
 diffusive forces, 87–88
 electrical forces, 87–88
 flux, 88
 force, 88
 Gibbs free energy, 89
 negative gradients, 88
 Electrodes: electrocardiograms, 542–543
 Electrodifusion equations, 257–258
 Electrogenic
 sodium, potassium-ATPase as, 173–174
 Electrolytes
 bile, 814
 plasma blood cells, 498–500
 problem sets, 765
 Electromagnetic radiation, 467
 Electromechanical coupling, 590–591
 Electron transport chain (ETC), 108, 231
 Electron negativity
 ionic bonds, 53
 Electronic orbits, 47*f*
 Electrons
 affinity of a chemical for, 229
 atomic structure, 46
 ATP production, 233
 electronegativity, 51, 54
 microscopy, 114
 quantized energies, 46
 Electrophoretic uniport, 239, 551
 Electrostatic interactions, 54
 dipole–dipole interactions, 54–55
 hydrogen bonding, 54
 induced dipoles, 55
 London dispersion forces, 55
 secondary protein structure, 136
 Electrotonic spread, 280–281
 Electrotonus, 284
 Emesis, 804
 Emotional states: autonomic nervous system, 473–474
 Emphysema, 640, 669
 Emulsification, 828

- Enantiomers, 51
 - Encoding, 6
 - End-diastolic pressure (EDP), 520–522
 - End-diastolic volume (EDV), 520–522
 - cardiac output, 556
 - pressure–volume loops, 556–557
 - Endergonic reactions, 90, 91f
 - Endocardium: electrocardiograms, 540–541
 - Endochondral bone formation, 879f
 - Endocrine and autocrine signals
 - and muscle size, 345–346
 - Endocrine pancreas, 810, 895
 - Endocrinology, 851. *See also* Hormones
 - Endocytosis, 578–579
 - cell structure, 102
 - proximal tubules, 728
 - Endogenous creatinine clearance, 723
 - Endogenous digitalis-like substances, 749
 - Endogenous ligands: taste, 437b
 - Endometrium, 947–948
 - Endoplasmic reticulum, 116
 - Endoplasmic reticulum (ER), 108, 154
 - Endosteum, 933
 - Endosymbiotic hypothesis, 108–109
 - Endothelial cells, 510–511
 - glomerular filtration, 708
 - perfusion regulation, 593
 - Endothelin, 593
 - Endothermic reactions, 250–251
 - End-systolic volume (ESV), 556, 561
 - Endurance training, 343–345
 - Energy. *See also* Adenosine triphosphate (ATP)
 - active transport, 170–172
 - antiports, 175–176
 - electrochemical potentials, 170–172
 - exchangers, 170
 - material transport, 172
 - phosphorylated intermediates, 173
 - sodium, potassium-ATPase, 172–173
 - sodium, potassium-ATPase as electrogenic, 173–174
 - symports, 176
 - balance, 834, 847
 - conservation of, 17, 32–33
 - core principles, 9
 - electrical potential, 34
 - enthalpy definition, 51
 - free energy, 87
 - hydrogen ion pumps, 231–232
 - hydrolysis, 90–92
 - kinetics, 59
 - heart total work, 557–558
 - Michaelis–Menten formulations, 65–66
 - problem sets, 94
 - muscle, 334, 349
 - pressure-driven flow, conservation, 17
 - transition state theory, 67–70
 - Energy currency of the cell
 - adenosine triphosphate (ATP) as, 218–219, 220f
 - Enhancers of gene expression, 125–126
 - Enteric nervous system, 473, 797, 799
 - Enterochromaffin-like (ECL) cells, 791
 - Enterocytes, 937
 - Enteroendocrine cells (EECs), 797–798
 - chemoreception by, 798f
 - in gastrointestinal tract, 800t
 - Enterogastric inhibitory reflex, 788, 804
 - Enthalpy: definition, 51
 - Environmental challenges, robustness and, 9
 - Enzymes. *See also*
 - Renin–angiotensin–aldosterone (RAA) system
 - acetylcholine recycling, 322–323
 - acid–base balance, 752, 753
 - activation energy, 64f
 - ATP production, 222, 227, 243, 246
 - biliary secretion, 810
 - calmodulin-dependent activation, 206
 - carbonic anhydrase, 662, 667, 752, 753
 - cell signaling, 207, 212, 214
 - cell structure, 109
 - deoxyribonucleic acid, 120, 121–122
 - diabetes insipidus, 739b
 - exocrine pancreas, 810
 - flippase enzymes, 152
 - histone code, 126
 - hormone immunosorbent assays, 863
 - kidneys, 701–702
 - lipid bilayers, 152–153
 - lipolytic enzymes, 810, 811, 828–829
 - messenger RNA, 122
 - Michaelis–Menten formulations, 65–66
 - pancreatic secretion, 810
 - posttranslational modification, 137–138
 - ribosomal RNA, 122
 - single nephron GFR, 743
 - speeding up reactions, 64
 - starch digestion, 825–826
 - stomach, 790, 794
 - transfer RNA, 123
 - tyrosine kinases, 212, 899
- Eosinophils, 507, 509–510
- Ependymal cells, 678
- Epicardium, 540–541
- Epinephrine, 221, 242, 242f, 382, 475, 480–481
 - adrenal medulla, 916
 - cardiac action potential, 534
 - metabolic control, 922
 - perfusion regulation, 596–597
- Epiphysis, 933
- Epithelial cell attachments, 111
- EPO. *See* Erythropoietin (EPO)
- EPSP. *See* Excitatory postsynaptic potentials (EPSP)
- Equilibrium centrifugation, 116
- Equilibrium concentrations, 92
- Equilibrium constants, 63
- Equilibrium potentials, 255–257, 269–270
- Equipartition theorem, 85
- ER. *See* Endoplasmic reticulum (ER)
- Erection of penis, 964–965
- ERV. *See* Expiratory reserve volume (ERV)
- Erythroblastosis fetalis, 505b
- Erythrocytes
 - abundance, 500
 - cell forms, 7
 - destruction of, 502–503
 - formation, 502
 - hemoglobin, 500
- Erythropoietin (EPO), 498–499, 502, 507, 679, 703
- Esophageal manometry, 783
- Esophagitis, 783
- Esophagus, 769
- Essential light chain (ECL), 356
- Estrogen reducing adult height, 879–880
- ESV. *See* End-systolic volume (ESV)
- ETC. *See* Electron transport chain (ETC)
- Ethane, 50
- Ethanolamine, 143
- Ethylene, 50
- Euchromatin, 214
- Evan's blue dye, 689
- Evolution
 - core principles, 8–9
 - cause and effect, 8
 - comparative genomics, 8
 - diversity, 8
 - genome, 9
 - phenotypes, 8
 - preexisting forms, 8
 - robustness, 9
- Exchangers, 736
 - active transport, 170
 - ATP production, 239
 - cardiac action potential, 533–534
- Excitation-contraction coupling, 206, 318
- Excitatory neurotransmitters
 - aspartate, 383
 - glutamate, 383
- Excitatory postsynaptic potentials (EPSP), 318–319, 327–328
- Exercise, 635
 - duration/intensity
 - aggregate rates, 334–335
 - ATP consumption, 334–335
 - blood lactate levels, 338
 - metabolic pathways, 336
 - glucose, 340, 902
 - maximum voluntary ventilation, 635
 - metabolism, 838
 - oxygen delivery, 660–661
 - ventilation, 635, 680
- Exergonic reactions, 90
- Exhalation, 625
- Exit (E) binding sites, 125f
- Exocrine pancreas, 810, 895
- Exocytosis, 102
- Exons, 126f
- Exothermic reactions, 250–251
- Expiration, 625
- Expiration (E) neurons, 673–674
- Expiratory reserve volume (ERV), 633
- Expired air: steady-state gas exchange equations, 651
- Expired oxygen: oxygen consumption calculations, 658–659
- Exponential decay
 - first-order rate equations and, 63
- External intercostal muscles, 672
- External sphincter muscles, 484
- Exteroreceptors, 10, 389
- Extracellular fluid (ECF), 614–615
 - body fluid compartments, 690, 694–695, 694, 695
 - homeostasis, 7–8
- Extracellular resistance: action potential propagation, 282–283
- Extracellular volume: body fluid compartments, 689
- Extracorporeal shockwave lithotripsy, 819
- Extrasystole beat, 544
- Extravasation, 511
- Extrinsic nerves: stomach, 786
- Extrinsic nervous innervation: ileal motility, 803
- Extrinsic proteins, 151
- Exudation: inflammation, 511
- Eyes. *See also* Vision
 - shape, vitreous body, 458
 - structure, 456–458

F

- Facial nerve, 477–478, 773
- Facilitated diffusion, 161
 - competitive inhibition, 165
 - membrane-bound carriers, 164
 - proximal convoluted tubules, 725
 - saturation, 164–165
 - specificity, 165
- F-actin. *See* Filamentous actin (F-actin)
- FADH₂: ATP production, 235
- Fallopian tubes, 946, 947

- Far-sightedness, 459–460
Fasting, 789, 801–802
Fatigue, 303, 334, 341–343, 342, 342–343
Fats: ATP production, 219–220, 241
Fatty acids
 ATP production, 241
 beta oxidation, 243–245
 biological membranes, 143
 depot fat breaking down, 241–242
 mitochondria, 243
 oxidation, 241
 peroxisomes, 243
Fatty acyl chains, 143–145
Fatty alcohols
 plasmalanyl phospholipid and plasmaleny
 phospholipids using, 146
Feedback loops, 10–11
 antidiuretic hormone-renal system, 745–746
 growth hormone, 876
 plasma calcium ions, 942–943
 plasma PI, 942–943
 ventilation control, 677, 677f, 679f
Feedforward mechanisms, 11, 680
Feeding center, 839
Female reproductive systems, 946
Fence function, 110–111
Fenestrae, 709
Fenestrated capillaries, 578, 579
Ferguson reflex, 871
Ferritin, 503
Fetus, 948
Fiber, 825, 831b
Fibrillation, 544
Fibrinogen, 494–495
Fibroblast growth factor 23 (FGF23)
 and hyperphosphatemia, 942
Fick's dilution principle
 body fluid compartments, 689–690
 fluid volume calculations, 62
Fick's law: solute exchange, 580
Fick's law of diffusion, 75, 75
Fick's principle: cardiac output, 560–561
Fight or flight, 920–921
Filamentous actin (F-actin), 105, 548–549
Filamin, 105
Filling pressure, 558
Filtered loads, 719, 725
Filtering of air: breathing, 623–624
Filtration coefficient, 183f, 186–187
Filtration permeability, 196
Filtration pressure: solute exchange, 584–585
Fimbriae, 947
Fimbrin, 105
First degree heart blocks, 544
First Korotkoff sound, 572–573
First Law of Thermodynamics, 32–33
First pain production by nociceptors, 393
First-order rate equations and exponential
 decay, 63
FKBP-12 (FK506 binding protein),
 332
Flat bones, 933
Flatulation, 803
Flavor in the brain, 438
Flippase enzymes, 152
Flow
 arterial pressure regulation, 608–609
 pressure-driven flow, 15
 problem sets, 43
 solute exchange, 581–582
Flow through a pipe
 Poiseuille's law, 23–24
Flow waves: arterial tree, 572
Flow-induced vasodilation: perfusion
 regulation, 593
Flow–volume loops: airway resistance,
 635–636
Fluid balance, 740, 765
Fluid mosaic model, 153
Fluid pressure waves: hearing, 441–442
Fluid volumes, 62, 715
Fluorescence microscopy, 119
Fluorophore, 119
Flux
 alveolar membranes, 646
 diffusion, 80–81
 electrochemical potentials, 88
 glucose flux, 902
 pressure-driven flow, 15
 conjugate force, 16
 flow per unit area, 15
 movement, 16
fMRI. *See* Functional magnetic resonance
 imaging (fMRI)
Focal adhesion complex, 314–315
Focal lengths: vision, 468, 469–470
Focal points: vision, 468
Folic acid, 506
Follicle stimulating hormone (FSH), 948–949,
 954, 961–962, 963
Follicles
 cellular development, 949–953
 corpus luteum formation, 954–955
 hormones, 948–949, 954, 961–962, 963
 ovarian development, 949
 ovulation, 947
 thyroid gland, 883
 thyroglobulin precursor, 883, 885
 thyroxine, 883
 triiodothyronine, 883
Food, 771, 834. *See also* Gastrointestinal (GI)
 system
 thermic effect of, 838, 838f
Force
 actin/myosin interactions, 107, 356,
 548–549
 cardiac contraction
 force–frequency relations, 552
 stretch-based modulation, 554–555
 sympathetic stimulation, 552–553
 conservative forces, 33–34
 diffusive flux, 80–81
 electric charge movement, 37
 electrical force, 31
 Coulomb's law, 31
 current, 37–38
 electric charge movement, 37
 electrochemical potential, 87–88
 equilibrium potentials, 255–257
 problem sets, 43
 solute flux, 37–38
 electrical potential, 34
 electrochemical potential, 88
 frequency codes, 409
 hair cells, 419
 heart beat, 552
 intermolecular forces, 46
 inverse myotatic reflexes, 403
 London dispersion forces, 55
 myosin/actin interactions, 107, 356,
 548–549
 population codes, 409
 pressure-driven flow, 15–16
 repulsive force, 55
 skeletal muscle, 292, 293–295, 295–296,
 296–297, 308–309
 architecture, 300–302
 eccentric contractions, 300
 fatigue, 303
 force–velocity curves, 313–314
 isometric force, 293
 motor neuron firing, 295–296
 motor unit activation, 293–295
 muscle length, 296–297
 muscle velocity, 298–299
 smooth muscle, 351–352
 actin–myosin interaction, 356
 calcium ions, 356–357
 myosin light chain phosphorylation, 356
 van der Waals force, 55
“Force” of friction, 3
Forced vital capacity (FVC), 635
Force–frequency relations, 552
Forceful expiration, 626, 639
Forceful inspiration, 626
Force–velocity curves, 313–314
Forebrain, 372
Foreign chemicals: taste, 437b
Forward rate constants, 62–63
Fossil genes, 8
Fourier's law of heat transfer, 75
Frank–Starling law, 558
FRC. *See* Functional residual capacity (FRC)
Free diffusion coefficients, 79–80
Free energy, 87
Free water clearance, 746–748
Frequency codes, 409
Frequency vibrations, 448–450
Frictional coefficient, 85
Fructose, 827
FSH. *See* Follicle stimulating hormone (FSH)
F-type ATPases, 174
Functional hyperemia, 594
Functional magnetic resonance imaging (fMRI),
 594
Functional residual capacity (FRC), 630–631,
 633, 649–650
Fundamental (f) subshells, 47–48
Fusiform muscle fibers, 301
FVC. *See* Forced vital capacity (FVC)
- ## G
- GABA. *See* Gamma amino butyric acid (GABA)
G-actin. *See* Globular actin (G-actin)
Gag reflexes, 804
Galactose, 827
Gallbladder, 814, 817
Gallstones, 818b
Gametes, 946, 947, 956, 958, 960–961
Gamma amino butyric acid (GABA), 383–384
Gamma motor systems, 403
 γ -tubulin ring complex (γ -TuRC), 104–105
Ganglia
 adrenal medulla, 475
 cervix, 476
 postganglionic neurons, 474
 vision, 462–463, 464
Ganglionic plexuses of nerve cells: gut, 782
Gangliosides, 146, 146
Gap junctions, 111, 534, 547
Gases
 breathing mechanics, 624
 exchange, 623, 642, 653
 Henry's law, 644–645
 problem sets, 653, 682
Gastric accommodation, 787
Gastric acid secretion phases, 791–794
Gastric emptying, 788, 804
Gastric lipase, 790–791
Gastric phases, 812–813, 822–824
Gastric slow waves, 785–786
Gastrin, 787, 789, 791, 808
Gastrin-releasing peptide (GRP), 791
Gastrocolic reflex, 803, 804

Gastroesophageal reflux disease (GERD), 783b
 Gastroileal reflex, 803, 804
 Gastrointestinal (GI) system, 691, 857, 928
 biliary secretion, 810
 body fluid compartments, 697f
 colonic motility, 796
 esophagus, 769
 growth, 771
 ileum, 796, 802, 833
 intestinal motility, 796
 mouth, 769
 pancreas, 810
 small intestine, 785, 796, 825, 828–829
 stomach, 785
 Gastroparesis, 789b
 Gating. Ligand-gated ion channels LGICs. *See* Voltage-gated ion channels
 Gaussian surfaces, 35f, 35f
 Gauss's law, 34–35, 287
 Genes
 definition, 956
 DNA, 120
 expression
 cell signaling, 213, 215
 thyroid hormones, 888
 genetic code, 123–125
 transcription
 cell signaling, 213
 histone code, 126–127
 Genome, 958
 aldosterone, 912
 deoxyribonucleic acid, 120
 differential expression, 7
 evolution, 9
 immune response, 511–512
 Genomics, comparative
 revealing pedigree, 8
 Genotypes, 956
 blood groups, 503
 cell diversity, 7
 DNA, 120
 Geometric isomers, 51
 GERD. *See* Gastroesophageal reflux disease (GERD)
 Germ cells. *See* Gametes
 GFR. *See* Glomeruli—filtration
 Ghrelin, 787, 789, 842, 877
 GHRH. *See* Growth hormone releasing hormone (GHRH)
 GI. *See* Gastrointestinal (GI) system
 Gibbs free energy, 89
 Gibbs–Donnan equilibria, 692–693
 GIP. *See* Glucose-dependent insulinotropic peptide (GIP)
 Glaucoma, 457b
 Glial cells, 375–376
 Globin components: erythrocytes, 500
 Globular actin (G-actin), 309
 cardiac contractility, 548–549
 cell structure, 105
 Globulins, 496, 498–499
 Glomeruli, 429, 698–699
 blood flow, 742–743
 filtration, 705
 autoregulation, 742
 creatinine concentration, 723–724
 endogenous creatinine clearance, 723
 nephron adjustment, 743–744
 oncotic pressure, 740
 problem sets, 715
 tubuloglomerular feedback, 742
 urine output, 740–741
 hydrostatic pressure, 740, 740–741
 Glomerulotubular balance, 743–744, 758–759
 Glossopharyngeal nerve, 478, 673, 676

Glottis, 625
 GLP-1. *See* Glucagon-like peptide (GLP-1)
 Glucagon, 897
 exocrine pancreas, 810
 islets of Langerhans, 899–900
 liver glycogenolysis, 900
 metabolic control, 921
 Glucagon-like peptide (GLP-1), 842, 897
 Glucocorticoids, 909–910, 921–922
 Glucogenic amino acids, 247
 Gluconeogenesis, 221, 224, 226f, 703, 900–902
 Glucose. *See also* Adenosine triphosphate (ATP)—production
 absorption, 827
 blood, 895
 diabetes mellitus, 721
 flux, 902
 high intensity exercise, 336–338
 kidneys, 703
 muscle sarcolemma, 340
 renal titration, 720–721
 Glucose-dependent insulinotropic peptide (GIP), 897
 Glucostatic hypothesis, 841–842
 Glucosuria, 721
 Glutamate, 383
 Glycerol
 biological membranes, 143–145
 depot fat, 241–242
 glycolysis intermediates, 242–243
 metabolism, 242–243
 phosphate shuttles, 222–223, 235
 Glycerol kinase, 242–243
 Glycerolipids, 146
 Glycerophosphates, 242–243
 Glycocalyx, 710
 Glycogen, 219–220, 338
 Glycogenolysis, 900–902
 Glycogenoses, 343
 Glycolysis, 218, 242–243
 Glycolytic flux
 lactic acid, anaerobic metabolism, 338
 Glycophorin, 501f
 Glycoproteins. *See* Follicle stimulating hormone (FSH) Luteinizing hormone (LH)
 Glycosides, 553–554
 GnRH secretion, 962–963
 Goblet cells, 623–624
 Goitrogens, 892
 Goldman–Hodgkin–Katz (GHK) equation, 257–258, 262–264
 Golgi apparatus, 108
 Golgi stack, 108
 Gonadotropin-releasing hormone, 961–962
 Gonadotropins, 952–953, 963. *See also* Follicle stimulating hormone (FSH); Luteinizing hormone (LH)
 Gonads, 947
 GPCRs. *See* G-protein-coupled receptors (GPCRs)
 G-proteincoupled receptors (GPCR family), 797–798
 G-protein-coupled receptors (GPCRs), 381–382
 bitter taste, 436
 cell signaling, 209
 sweet taste, 436
 umami taste, 436
 G-proteins
 ATP production, 221
 perfusion regulation, 591
 Graafian follicle, 949, 952–953
 Gradient, 41
 Granular white blood cells, 507. *See also* Basophils; Eosinophils; Neutrophils

Granule cells
 renin release, 701–702, 748
 single nephron GFR, 743
 Granulocytes, 511
 Grave's disease, 893–894
 Gravity
 hair cells, 419
 heart total work, 557–558
 lung blood flow, 649
 Gray matter, 371
 Growth
 gastrointestinal system, 771
 thyroid hormone, 888
 Growth factors: white blood cell formation, 507
 Growth hormone (GH), 875, 881b, 921
 mechanisms of action of, 878f
 Growth hormone releasing hormone (GHRH), 875
 Growth plates, 877–879
 skeletal growth at, 877–879
 GRP. *See* Gastrin-releasing peptide (GRP)
 GS mechanisms, 591
 GTPases, 211–212
 Guanine, 120
 Guanylate cyclase, 357, 591–592
 Guanylyl cyclase receptors, 212
 Gut. *See* Stomach

H

Hair cells. *See also* Follicles
 balance, 415–419
 hearing, 444–445
 inner hair cell tuning, 445
 sacculles, 419
 utricle, 419
 Haldane effect, 662
 Half-life: hormones, 861
 hCG. *See* Human chorionic gonadotropin (hCG)
 HCV. *See* Hepatitis C virus (HCV)
 HDL. *See* High-density lipoproteins (HDL)
 Head rotation: vestibular apparatuses, 419
 Hearing, 440
 auditory cortex, 446–447
 delay differences, 441
 ear infections, 444b
 ear parts, 441–444
 ear tubes, 444b
 intensity, 440–441
 pitch perception, 447–448
 sound physics, 451–455
 sources of noise, 441
 tests for newborns, 449b
 timbre, 440–441
 tone, 440–441
 Heart, 516
 action potential, 528
 arterial pressure, 570, 608
 attack, 563
 calcium-induced calcium release, 549–550
 cardiac cycle, 520–522, 544–545
 cardiomyocyte coupling, 547
 cardiomyopathy, 563
 chambers, 518–520
 circulatory system overview, 489
 contraction, 516–518, 547
 cardiac glycosides, 553–554
 cellular basis, 547
 cycle, 520–522
 electrical systems, 522–523
 myofibrils, 548–549
 parasympathetic stimulation, 553
 regulation, 552
 stretch-based modulation, 554–555

- coronary artery disease, 563
 - coronary sinus, 518
 - ejection of blood, 570
 - electrocardiograms, 537
 - failure, 563*b*
 - faulty valves, 563
 - force–frequency relations, 552
 - function curves, 556, 599, 599–600, 604, 605
 - glycosides, 553–554
 - heartburn, 783
 - location, 516
 - murmurs, 520
 - muscle features, 547
 - myofibrils, 548–549
 - output, 556, 599
 - distribution by vascular system, 568
 - Fick's principle, 560–561
 - indicator dilution method, 561–563
 - rate
 - cardiac output, 556
 - nucleus tractus solitarius, 611–612
 - parasympathetic withdrawal, 612
 - respiratory sinus arrhythmia, 612–613
 - rostral ventrolateral medulla, 612
 - total work
 - gravitational terms, 557–558
 - kinetic terms, 557–558
 - pressure, 557–558
 - valves, 520
 - venous return, 599
 - work problem sets, 565
- Heat**
- circulatory system overview, 489–490
 - of combustion, 834–835
 - diffusion, 75
 - pressure-driven flow, 18
- Helper T cells, 510**
- Hematocrit, 708**
- Hematocrits, 501, 656**
- Hematopoietic growth factors, 507**
- Heme groups, 500–501**
- Heme recycling, 503**
- Hemodynamics, 568, 619**
- Hemoglobin, 61*b*, 656–657**
 - erythrocytes, 500
 - heme groups, 500–501
 - oxygen delivery, 659
 - oxygen dissociation curves, 659–660
 - polypeptide chains, 500–501
- Hemophilia, 496**
- Hemorrhage, 605, 610**
- Hemostasis: vascular volume, 494–495**
- Henderson–Hasselbalch equations, 666**
 - carbonic acid, 667–668
 - isohydric principle, 667
 - pH, 669, 753
- Henle loops. *See* Loops of Henle**
- Henry's law, 644–645**
- Heparin, 496, 508–509**
- Hepatitis C virus (HCV), 663**
- Hepatocytes, 221, 814**
- Hereditary spherocytosis, 506**
- Hering–Breuer inflation reflex, 680**
- Hernia, 783*b***
- Heterochromatin, 214**
- Heterotrimeric G-proteins**
 - ATP production, 221
 - cell signaling, 209
- Hiatal hernia, 783*b***
- High-density lipoproteins (HDL), 498**
- Hill equation, 656–657**
- Hill plots, 859, 867–868**
- Hindbrain, 373**
- Hippuric acid, 707–708**
- Histamine**
 - basophils, 508–509
 - perfusion regulation, 595–596
 - stomach, 791
- Histone acetylase, 214**
- Histone code, 126–127**
- Histones, 122, 214**
- HIV. *See* Human immunodeficiency virus (HIV)**
- Hodgkin–Huxley model, 276**
- Homeostasis, 924**
 - autonomic nervous system, 473
 - calcium, 933
 - core principles, 7–8, 13–14, 13
 - extracellular fluid, 7–8
 - somatic cells, 7–8
 - phosphorus, 933
 - weight regulation, 838
- Homologous chromosomes, 958–959**
- Horizontal cells: vision, 463**
- Hormones. *See also* Antidiuretic hormone (ADH)**
 - adrenal cortex, 906
 - adrenal medulla, 916
 - anterior pituitary, 857, 874
 - arterial pressure regulation, 609
 - ATP production, 221, 242
 - blood pressure, 615–617
 - blood transport, 858–859
 - bone, 935–937
 - calcitropic hormones, 924
 - cell signaling, 213
 - classification, 854–857
 - definitions, 853, 853
 - dose–response curves, 859–860
 - endocrine hormones, 796
 - endocrine pancreas, 810, 895
 - exocrine pancreas, 810, 895
 - follicle stimulating hormone, 948–949, 954, 961–962, 963
 - gastrointestinal hormones, 857
 - half-life, 861
 - hypothalamus, 870
 - kidneys, 703
 - level measurements, 861–863
 - luteinizing hormone, 948–949, 954, 961–962, 963, 963
 - menstrual cycle, 953–954
 - metabolic clearance rates, 861
 - muscle size, 343
 - ovarian steroidogenesis, 953
 - pancreas, 810, 895
 - paracrine secretions, 595–596
 - perfusion regulation, 596–597
 - pituitary gland, 857, 870
 - polypeptide hormones, 854, 857–858
 - posterior pituitary, 857, 870
 - receptors, 859
 - smooth muscle, 353
 - steroid hormones, 854, 857, 858
 - stomach, 788–789, 791
 - target cells, 859, 861
 - testicles, 960–961, 961–962
 - testosterone, 960–961
 - thyroid gland, 883, 921, 963
 - urine concentration, 730
- Hormone-sensitive lipase (HSL), 242, 242*f***
- Hot taste, 436–437**
- How? questions, 5**
- HSL. *See* Hormone-sensitive lipase (HSL)**
- HUGO. *See* Human Gene Organization (HUGO)**
- Human chorionic gonadotropin (hCG), 963**
- Human Gene Organization (HUGO), 179, 179**
- Human immunodeficiency virus (HIV), 663**
- Humidifying of air: breathing, 623–624**
- Hyaline membrane disease, 630**
- Hydraulic conductivity, 183*f*, 186–187**
- Hydraulic permeability, 183*f*, 186–187**
- Hydrochloric acid secretion, 790, 794**
- Hydrogen bonds, 53, 54**
 - deoxyribonucleic acid, 121
 - secondary protein structure, 134–136
 - water, 54
- Hydrogen carbonate, 661–662, 758–759**
 - acid–base balance, 753–754, 757–759
 - bile duct cells, 817–819
 - exocrine pancreas, 810
 - metabolic acidosis, 760
 - metabolic alkalosis, 760–761
 - proximal tubules, 727
 - respiratory acidosis, 759
 - respiratory alkalosis, 760
 - ventilation control, 678
- Hydrogen ions, 757–759**
 - acid–base balance, 757–759
 - electron transport chain, 231–232
 - isohydric principle, 667
 - pH definition, 665
 - stomach, 791–793, 794
- Hydrogen/sodium exchangers: ATP production, 239**
- Hydrolysis, 90–92, 108, 829–832**
- Hydrophilic groups, 136, 143–145**
- Hydrophobic groups, 136, 143**
- Hydrophobic interactions, 130–131**
- Hydroxylation, 929**
- Hygiene hypothesis, 650**
- Hyperbaric oxygen, 662**
- Hypercalcemia, 928**
- Hypercapnia, 677, 678**
- Hyperemia, 594**
- Hyperosmolarity, 744–745**
- Hyperphosphatemia**
 - fibroblast growth factor 23 (FGF23) and, 942
- Hyperpolarization, 266**
- Hypertension, 563, 617*b***
- Hyperthyroidism, 893–894**
- Hypertonic solutions, 191, 192*f***
- Hypertrophy, 343, 542**
- Hyperventilation, 668, 760**
- Hypervolemia, 749**
- Hypocalcemia, 926–927**
- Hypochromic anemias, 502, 506**
- Hypokalemic metabolic alkalosis, 762**
- Hypopnea, 680**
- Hypothalamus, 870**
 - diabetes insipidus, 739*b*
 - feeding behavior, 839
 - function, 373
 - sensory afferents, 611–612
 - testicular function, 961–963
 - thyroid stimulating hormone, 885
- Hypothesis testing, 26–27**
- Hypothyroidism, 889–890**
- Hypotonic solutions, 191, 192*f***
- Hypoventilation, 668, 760**
- Hypovolemia, 744–745**
- Hypoxia, 502, 678–679**
- Hypoxic vasoconstriction, 650**
- H-zone: muscle, 306**

I

- I neurons, 673–674
- I-bands: muscle, 305
- IC. *See* Inspiratory capacity (IC)
- ICCs. *See* Interstitial cells of Cajal (ICCs)
- ICF. *See* Intracellular fluid (ICF)
- Ideal gas equations, 642–643
- IGF. *See* Insulin-like growth factor (IGF)

- IGF-I. *See* Insulin-like growth factor (IGF-I)
- IgG antibodies, 514
- IgM antibodies, 514
- Ileal brake, 804
- Ileal motility, 803
- Ileocecal sphincter, 802, 803
- Ileogastric reflex, 804
- Ileum, 796, 802, 833
- Immune response. *See* Inflammation
- White blood cells
- Immunoglobulins, 499
- Impermeant ions, 692–693
- Inactivation gates, 270–271, 270
- Inappropriate antidiuretic hormone secretion (SIADH), 739b
- Incisura pressure, 570
- Incontinence, 803
- Incus, 441–442
- Indicator dilution method, 561–563
- Indigestible carbohydrates, 825
- Induced dipoles, 55
- Infant respiratory distress syndrome, 630
- Inference, 6
- Inferior cervical ganglia, 476
- Inferior mesenteric ganglia, 475, 799
- Inferior vena cava, 518, 698
- Inflammation, 507, 595–596
- Inflation reflexes, 680
- Infundibulum, 947
- Inhalation, 625
- Inhibin, 948
- Inhibitory postsynaptic potentials (IPSP), 318–319, 327–328
- Initial segment: action potential origin, 319
- Initial training gains, 343
- Inner ear, 441–444
- Inner hair cells: ear, 445, 448–450
- Inner medulla osmotic gradients, 736
- Inner medullary collecting duct, 733
- Inner mitochondrial membrane, 108
- Innervation ratio, 320
- of motor units, 298
- Inositol, 143
- Inositol triphosphate (IP₃) receptors, 354–356
- Inotropic agents: cardiac function curves, 559
- Inotropic effects: drugs, 553–554
- Inscriptions: muscle, 301
- Inspiration, 625
- Inspiration (I) neurons, 673–674
- Inspiratory capacity (IC), 633
- Inspiratory (Insp) neurons, 675
- Inspiratory motor neurons, 673
- Inspiratory reserve volume (IRV), 633
- Inspired air: steady-state gas exchange equations, 651
- Inspired oxygen: oxygen consumption calculations, 658–659
- Insulators, 39
- Insulin, 222, 242, 242
- amino acids, 898
- β cells, 895
- exocrine pancreas, 810
- glucagon-like peptide, 897
- glucose-dependent insulinotropic peptide, 897
- metabolic control, 921
- parasympathetic stimulation, 897–898
- plasma glucose, 895–897
- pulsatile release, 898–899
- somatostatin, 897
- sulfonylurease, 898
- sympathetic stimulation, 897–898
- tyrosine kinases, 899
- Insulin-like growth factor (IGF), 876–877, 877
- Insulin-like growth factor (IGF-I), 345
- Integral proteins, 151
- caveolae and clathrin-coated pits, 153
- Integrin, 314–315
- Integrins, 314–315
- Intercalated cells, 733, 757, 761
- Intercalated disks, 523, 534, 547
- Intercostal muscles, 625, 672
- Interlobar arteries, 699
- Interlobar veins, 699, 701
- Intermediate filaments, 105–106
- classification of, 107t
- structure of, 106f
- Intermolecular forces, 46
- Internal intercostal muscles, 672
- Interoceptors, 10, 389
- Interphase, 956–957
- Interstitial cells of Cajal (ICCs), 785–786, 796, 796–798. *See also* Pacemakers
- Interstitial fluid (ISF)
- body fluid compartments, 690, 692
- circulatory system overview, 489
- oxygen diffusion, 659
- solute exchange, 582–583
- Interstitial space clotting, 511
- Intestine
- acid secretion phases, 791–794
- calcium ions, 939
- colon
- content reflux, 802
- diverticular disease, 808b
- motility, 796
- lining renewal, 821
- migrating motility complex, 789
- motility, 796
- 1,25(OH)₂-D hormone, 937–939
- pancreatic enzyme secretion, 813
- PI, 939
- postprandial pancreatic enzyme secretion, 812–813
- protein digestion phases, 822–824
- small intestine, 785
- carbohydrate digestion, 825
- lipolytic activity, 828–829
- stomach acid secretion, 794
- surface area, 821
- Intracellular calcium, 206–207
- action potentials, 324
- cell signaling, 211
- smooth muscle contraction, 353–354
- Intracellular fluid (ICF): body fluid
- compartments, 690–691, 694, 695
- Intracellular organelles: biological membranes, 142
- Intracellular protein digestion phases, 822–824
- Intrafusal fiber tension: gamma motor systems, 403
- Intraocular fluid, 691
- Intrapleural pressure: breathing mechanics, 628–630, 630
- Intrapleural space: breathing mechanics, 630
- Intrinsic factor, 506, 790–791
- Intrinsic nerves: stomach, 786
- Intrinsic proteins, 151
- Introns, 126f
- Inulin, 690, 706–707
- body fluid compartments, 689, 690
- filtered loads, 725
- renal titration curves, 719–720
- water reabsorption, 724–725
- Inverse myotatic reflexes, 403
- Involuntary ventilation control, 672
- Inward ion current, 532–533
- Inward rectifying potassium ion channels, 528–529, 532
- Iodine deficiency disorders, 893b
- Ionic bonds, 53
- Ionophores: ion transport, 166–167
- Ionotropic receptors, 381–382
- Ions, 757. *See also* Acid–base balance; Action potentials; Electrical potentials; Electrochemical potentials; Resting membrane potentials
- active transport, 170–172
- actomyosin cross-bridge cycling, 549
- aldosterone, 912
- body fluid compartments, 692–693
- bone mineralization, 942
- cardiac
- contraction, 551f
- relaxation, 550–551
- cell signaling, 206–207, 207–209
- chemical neurotransmission initiation, 379
- cross-bridge cycling, 325–326
- current, 37–38
- delayed rectifying potassium ion channels, 532, 533
- excitation-contraction coupling, 324
- hypervolemia, 749
- induced cardiac contraction, 552–553
- intestine, 939
- inward rectifying potassium ion channels, 528–529, 532
- ligand-gated channels, 167, 207–209, 381–382
- negative feedback loops, 942–943
- 1,25(OH)₂-D hormone, 937–939
- osteoclasts, 934
- parathyroid hormone, 941–942
- plasma blood cells, pH, 500
- presynaptic cells, 322, 380
- relaxation, 358
- release, 324
- repetitive stimulation effects, 327
- reuptake, 324–325
- sensitization, 591
- signals, 324
- smooth muscle, 356–357
- contraction, 353–354
- solute flux, 37–38
- stomach, 791–793
- transport, 166–167
- uptake, 324, 551
- urinary excretion, 940–941
- ventricular cardiomyocyte action potential, 530–534
- voltage-gated ion channels, 167, 206
- zona glomerulosa, 911
- IP₃. *See* Inositol triphosphate (IP₃) receptors
- IPSP. *See* Inhibitory postsynaptic potentials (IPSP)
- Iris: pupillary light reflex, 482–483
- Iron: heme recycling, 503
- Iron-deficiency anemia, 506
- Irregular bones, 933
- IRV. *See* Inspiratory reserve volume (IRV)
- ISF. *See* Interstitial fluid (ISF)
- Islets of Langerhans, 810, 899–900
- Isobars, 669
- Isoforms, 111
- Isohydric principle, 667
- Isomerism, 51
- Isometric contractions, 293, 300
- Isometric force, 293
- Isosmotic solution reabsorption, 731
- Isotonic fluid, 776–777
- Isotonic muscle contractions, 298–299
- Isotonic saline infusion, 696
- Isotopes, 59
- Isovolumetric heart contraction, 522
- Isovolumetric heart relaxation, 522

J

Jejunum, 796
 JGA. *See* Juxtaglomerular apparatus (JGA)
 Juxtaglomerular apparatus (JGA), 701–703, 743, 748
 Juxtaglomerular cells, 748
 Juxtamedullary nephrons, 701

K

Ketogenic amino acids, 247
 Ketone bodies, 245
 Ketosis, 245–246
 Kidneys, 699*f*, 700–701
 acid–base balance, 752
 adrenal cortex, 906
 anatomy, 698
 body fluid compartments, 696
 concentration mechanisms, 730
 deiodinase type I, 886–888
 dilution mechanisms, 730
 failure, 703*b*
 fluid balance regulation, 740
 free water clearance, 746–748
 function, 698
 glomerular filtration, 705
 hypocalcemia, 927
 nephrons
 acid–base balance, 757
 antidiuretic hormone, 738, 745
 glomerular filtration, 705
 osmotic diuresis, 738
 osmotic gradients, 733–736
 salt reabsorption, 743–744
 splay, 720
 tubular transport mechanisms, 731–736
 tubuloglomerular feedback, 742
 urinary excretion, 940–941
 water reabsorption, 724, 743–744
 osmotic gradients, 733–736
 pressure-driven flow, 20
 vitamin D, 929
 Kinase activation, 590
 Kinetics, 59
 heart total work, 557–558
 problem sets, 94
 Kirchhoff's Current Law, 39
 Kirchhoff's Voltage Law, 39
 Korotkoff sound, 572–573
 KREBS cycle. *See* Tricarboxylic acid (TCA) cycle
 Kuru disease, 139–140

L

L system, 825
 Labia majora, 946
 Labia minora, 946
 Lactate dehydrogenase (LDH), 223
 Lactate shuttling
 liver, 339
 mitochondria, 339
 oxidative fibers, 339
 Lacteals, 829–831
 Lactic acid
 anaerobic metabolism
 glycolytic flux, 338
 anaerobic thresholds, 340
 NADH oxidation carrier systems, 339
 Lactose intolerance, 830*b*
 Lagging DNA strands, 123*f*
 Lamellar bone, 934
 Laminar flow: airway resistance, 636–637, 638
 Laminin, 710
 Langmuir adsorption isotherms, 864
 Langmuir troughs, 149

Language processing, 447
 Laplace law. *See* Law of Laplace
 Large intestine. *See* Colon
 Late distal tubule, 733. *See also* Connecting ducts
 Late proximal tubule
 salt absorption, 728
 water absorption, 728
 Latency: action potentials, 267
 Lateral corticospinal tract, 405
 Lateral hypothalamic area (LHA), 839
 Lateral vestibulospinal tract, 405–406
 Law of Laplace, 21, 516–517, 627
 LBM. *See* Lean body mass (LBM)
 LDH. *See* Lactate dehydrogenase (LDH)
 LDL. *See* Low-density lipoproteins (LDL)
 Le Chatelier's principle, 753
 Leading DNA strands, 123*f*
 Lean body mass (LBM), 691
 Learning: ventilation control, 680
 Least squares linear regression, 29–30
 Left electrical axis deviations, 542
 Length–tension curves, 296, 306–308
 Lennard–Jones potential, 55, 56*f*
 repulsive force
 van der Waals forces, 55
 Lenses
 focal lengths/object distance relationships, 469–470
 image formation/refractive power, 468–469
 light convergence, 468
 light divergence, 468
 near object focus, 459
 thin lens formula, 467–470
 Leptin, 843
 Leukocytes. *See* White blood cells
 Level of significance of the test, 27
 Leydig cells, 961, 963
 LGICs. *See* Ligand-gated ion channels (LGICs)
 LH. *See* Luteinizing hormone (LH)
 LHA. *See* Lateral hypothalamic area (LHA)
 Ligament of Treitz, 796
 Ligand binding, 864, 967
 Ligand-gated ion channels (LGICs), 167, 207–209, 381–382
 Ligandins, 815–816
 Light chain kinase activation, 590
 Light convergence, 468
 Light divergence, 468
 Light focus, 456–458, 467–470
 Limbic system, 372
 Liminal length, 273
 Limiting pH, 757–758
 Linear regression, 29–30
 Lineweaver–Burk plots, 66
 Lipase, 241–242
 Lipases, 242
 Lipids. Fats. *See also* Fatty acids
 bilayers/biological membranes, 36, 142
 dynamic motion, 152–153
 extraction, 142
 lipid rafts, 153
 liposome formation, 150
 passive transport, 163–164
 structure, 36*f*
 cell structure, 108
 digestion, 828
 hydrolysis products, 829–832
 Lipolysis, 242
 Lipolytic enzymes, 810, 811, 828–829
 Lipopolysaccharide (LPS) receptors, 512
 Lipoproteins, 241–242, 829–832
 Liposome formation, 150
 Lipostatic hypothesis, 843
 Lithocholic acid, 815

Liver

absorption of nutrients, 773
 ATP production, 221, 247
 bile, 814, 814–816, 816
 deiodinase type I, 886–888
 digestion, 773
 glycogenolysis, 900
 lactate shuttling, 339
 substrate packaging, 245–246
 vitamin D, 929
 xenobiotics, 816
 Local nervous innervation, 803
 Local testosterone effects, 963
 Locomotor pattern generators, 404–405
 London dispersion forces, 55
 Lone electron pairs, 53
 Long bones, 933
 Long receptors, 390–391
 Longitudinal esophageal smooth muscle, 781
 Longitudinal sarcoplasmic reticulum, 306
 Loops of Henle, 701
 permeability, 730, 732
 vasa recta, 736–738
 Low-density lipoproteins (LDL), 499
 Lower esophageal sphincter (LES), 772–773, 782, 785
 Lower pons, 672
 LPS. *See* Lipopolysaccharide (LPS) receptors
 LRP4, 331
 L-type enteroendocrine cells, 798
 L-type ion channels, 528–529, 532–533
 epinephrine, 534
 Luminal protein digestion phases, 822–824
 Lungs
 body fluid compartments, 697*f*
 breathing patterns, 679–680
 circulatory system overview, 491–493
 collapse, 630
 compliance, 626, 627
 gas equilibration, 649*f*
 gas exchange, 642
 metabolic acidosis, 760
 pleura, 626
 ventilation pressure, 628–630
 volume, 633
 air movement, 625
 airway resistance, 638–639
 anatomic dead space, 647
 body size, 634
 capacity, 633–634
 spirometry, 633
 Lusitropic effect phenomena, 553
 Luteinizing hormone (LH), 948–949, 954, 961–962, 963, 963
 Lymphatic system, 585, 585–586
 Lymphedema, 585
 Lymphocytes, 499–500, 507, 510
 Lymphoid progenitors, 507
 Lysis, 514*f*
 Lysosomes, 109, 116

M

M2 receptors: pacemaker potential, 530
 Macrocytic anemias, 501
 Macroglobulin, 496, 498–499
 Macronutrients. *See* Nutrients
 Macrophages, 510–511
 chemokine secretion, 512*f*
 cytokine secretion, 512*f*
 erythrocyte destruction, 502
 monocytes, 508
 Macroscopic electroneutrality, 692
 Macula densa cells, 743
 MAG. *See* Monoacylglycerol (MAG)

- Magnocellular pathway, 463
Malaria, 506
Malate/aspartate shuttles, 222–223, 235
Male reproductive systems, 956
Malleus, 441–442
Mannan-binding lectin (MBL), 514
Mannose receptors, 512
Manometry, 783
MAPs. *See* Microtubule-associated proteins (MAPs)
Marker enzymes, 116
Markers: body fluid compartments, 689, 690
Mass spectrometry, 862
Matrices: mitochondria, 108–109
Maximum effort exercise, 335–336
Maximum voluntary ventilation, 635
MBL. *See* Mannan-binding lectin (MBL)
McArdle's disease, 346
MCR. *See* Metabolic clearance rates (MCR)
Mean, 25
 standard error of, 25
Mean arterial pressure, 571–572
Mean circulatory pressure, 601
Mean electrical axis definition, 541–542
Mean systemic pressure, 601, 602, 609
Mechanical signals, 205
Mechanically coupled smooth muscle cells, 352–353
Mechanoreceptors, 392–393, 679–680, 840–841
Medial pterygoideus, 773
Medial vestibulospinal tract, 406
Medulla
 adrenal medulla, 475, 596, 916
 baroreflex, 611–612
 function, 373
 kidney function, 698–699
 reticulospinal tract, 406
 salivary nuclei, 777–778
 swallowing centers, 780
 urea, 733, 736
 ventilation control, 672
 vestibular nuclei, 419
Meiosis, 956, 958
Melanopsin photoreceptors, 482–483
Membrane potential
 problem sets, 289
Membrane potential, calcium regulation via, 354
 by altering BK_{Ca} channels, 354
Membrane proteins, 150–151
Membrane surface tension
 problem sets, 156
Membranes, 142
 action potentials, 266, 323
 chord conductance equation, 269
 depolarization, 269
 threshold, 267–268
 transmembrane resistance, 282
 active transport, 170
 amphiphatic molecules, 149
 attack complexes, 515
 cardiolipin, 146–147
 cell signaling, 213
 cell theory, 6–7
 cholesterol, 146–147
 dynamic motion, 152–153
 electrical capacitors, 36
 facilitated diffusion, 164
 fatty acyl chains, 143–145
 gas diffusion, 645–646
 glycerol, 143–145
 hydrophilic groups, 143–145
 intracellular organelles, 142
 ion transport, 166–167
 lipid rafts, 153
 liposome formation, 150
 organic solvents, 142
 passive transport, 161–163
 phosphate, 143–145
 phospholipids, 142–143, 143–145, 146–147, 149–150
 plasmalyl phospholipids, 146
 plasmeyl phospholipids, 146
 problem sets, 156, 199
 protein bonding affinities, 151–152
 resting potentials, 253
 secreted proteins, 154
 smooth muscle contractile filaments, 352
 sphingolipids, 146, 146–147
 surface pressure, 149
 surface tension, 149
 transport mechanisms, 161
Menarche, 948
Menses, 948
Menstrual cycle, 946–947, 948–949, 953–954
Mentalism, 5
Mesangial cells, 740, 743
Mesenteric ganglia, 475, 799
Messenger ribonucleic acid (mRNA), 122
Metabolic acidosis, 678–679, 760
Metabolic alkalosis, 760–761, 762
Metabolic clearance rates (MCR), 861
Metabolic control, 916
Metabolic hyperemia: perfusion regulation, 594
Metabolism, 336. *See also* Adenosine triphosphate (ATP)—production
 active transport, 172
 endurance training, 343–345
 energy expenditure, 837
 exercise duration/intensity, 336
 food intake, 838–839
 hormones, 861
 muscle fibers, 338
 perfusion regulation, 594–595
 thyroid hormone, 888
Metabotropic receptors, 381–382
Metalloproteinases, 783
Metaphase, 957
Metastable complexes, 68
Methane, 48–49
Methemoglobin, 502f
MGL. *See* Monoacylglycerol lipase (MGL)
Michaelis–Menten formulations, 65–66
Microbiota, 11–13
Microcirculation, 578, 619
Microcytic anemias, 501, 506
Micronutrients
 absorption, 821
 digestion, 821
Microporous membrane
 diffusional permeability of, 195–196
 mechanism of osmosis for, 189–190
 microscopic characteristics, 188
 physical origin of osmotic pressure across, 194–195
Micropuncture studies
 glomerular filtration, 705
 proximal tubule, 725
 ultrafiltrate reabsorption, 725
Microscopic characteristics
 microporous membrane, 188
Microscopy
 cell structure, 113
 problem sets, 156
Microsomal triglyceride transfer protein (MTP), 829–831
Microtubule organizing centers (MTOC), 104–105
Microtubule-associated proteins (MAPs), 103–104
Microtubules
 cell structure, 103–105
 motor proteins, 103–104
Microvilli. *See* Villi
Micturition, 483–485
Midbrain, 373
Middle cervical ganglia, 476
Middle ear, 441–444
 air pressure waves, 441–442
 fluid pressure waves, 441–442
 sound channeling, 441
Midmyocardium: electrocardiograms, 540–541
Migrating motility complex (MMC), 789
Migrating motor complex (MMC), 801–802
Migrating myoelectric complex (MMC), 801–802
Mineralization: vitamin D, 931
Minerolocorticoids. *See* Aldosterone
Mitochondria, 116
 calcium ion uptake, 551
 cell structure, 108–109
 fatty acid metabolism, 243
 hydrogen ion pumps, 231–232
 lactate shuttling, 339
 NADH oxidation carrier systems, 339
 oxygen diffusion, 659
 TCA cycle, 227
 transport mechanisms, 238–239
Mitosis, 956
Mitotic spindles, 104–105
Mitral valve, 519
Mixed sleep disorders, 680
MLCK. *See* Myosin light chain kinase (MLCK)
MLCP. *See* Myosin light chain phosphatase (MLCP)
M-line/M-band
 myomesin joins thick filaments at, 310–311
 muscle, 306
MMC. *See* Migrating motility complex (MMC)
 migrating motor complex (MMC)
 migrating myoelectric complex (MMC)
Modeling relation, 6, 6f
Modification of Diet in Renal Disease (MDRD)
 Study equation, 724
Modified amino acids, 854
Molecules
 atom binding, 48
 atom movement, 56f
 bond movement, 56f
 bonding of atoms, 48
 potential energy/separation graphs, 67
 size
 diffusion coefficients, 81–82
 Stokes–Einstein equation, 81–82
Moles
 Avogadro's number, 59
 concentration calculations, 60b
 definition, 59
 electrochemical potential, 89
 gas partial pressure, 642–643
Momentum transfer in solution
 derivation of Einstein's frictional coefficient from, 82–86
Monoacylglycerol lipase (MGL), 242f
Monoacylglycerol (MAG), 242, 242f
Monocytes, 507, 510–511
 diapedesis, 513–514
 inflammation, 511
 tissue macrophages formation, 508
Monoglycerol lipase, 242
Monomeric GTPases: cell signaling, 211–212
Monooxygenases, 816
Monosynaptic reflexes, 402–403

- Mono-unsaturated fatty acid, 144f
 Motilin, 787, 789
 Motion sickness, 804
 Motoneuron activity, 409–410
 Motor activity
 premotor areas, 411–412
 sensory areas, 411–412
 Motor control
 hierarchical control, 412–413
 serial control, 412–413
 spinal reflexes, 410–411
 Motor cortex: somatotopic organization, 411
 Motor efferents: autonomic reflexes, 478–479
 Motor end plate, 320
 Motor external behavioral responses, 366–367
 Motor nerves: myotomes, 410
 Motor neurons
 action potentials, 265
 synaptic inputs, 319
 muscle excitation, 321–322
 respiratory muscle control, 672, 673
 skeletal muscle, 295–296, 318
 spinal reflexes
 descending tracks, 405–406
 integrated response, 407
 myotatic reflexes, 402–403
 ventilation control, 673
 Motor proteins: cell structure, 104f
 Motor units
 innervation ratio of, 298
 muscle fiber, 298
 Motor units: skeletal muscle mechanics, 293–295
 Mouth, 769
 Movement
 balance/control, 409
 cell structure, 101
 gastrointestinal system, 771
 mRNA. *See* Messenger ribonucleic acid (mRNA)
 MS. *See* Multiple sclerosis (MS)
 MTOC. *See* Microtubule organizing centers (MTOC)
 MTP. *See* Microsomal triglyceride transfer protein (MTP)
 Mucin, 814
 Mucus, 775, 790–791
 Multiple sclerosis (MS), 386b
 Munc-18, 329–330
 Muscarine poisoning, 485b
 Muscarinic receptors, 382, 479–480
 Muscle, sphincters. *See also* Heart; Skeletal muscle; Smooth muscle
 action potentials, 323, 528
 airway resistance, 639
 autonomic nervous systems, 483
 breathing mechanics, 625–626
 defecation, 803–804
 dystrophy, 316b
 endurance training, 343–345
 energetics, 334, 349
 excitation
 acetylcholine, 321–322
 contraction coupling, 318
 motor neurons, 321–322
 exercise
 duration/intensity, 336
 glucose, 336–338
 glycogen, 336–338
 fibers
 action potentials, 324
 metabolic properties, 338
 muscle spindle, 401–402
 types, 346–347
 gamma motor systems, 403
 heart, 516
 hypertrophy, 343
 inverse myotatic reflexes, 403
 micturition, 484
 myosin light chain kinase activation, 590
 of Oddi, 773
 oxygen, 659–660, 660–661
 problem sets, 349
 pupillary light reflex, 482–483
 relaxation, 803
 size, 345–346
 solute exchange, 585–586
 sphincters, 773, 802
 micturition, 484
 pupillary light reflex, 482–483
 relaxation, 804
 upper esophageal, 772–773
 spinal cord circuitry, 410
 training, 334
 twitch waveforms, 326–327
 ventilation control, 672
 Muscle fibers, 297–298
 and metabolic ability, 297–298
 motor units, 298
 Muscle size
 endocrine and autocrine signals regulating, 345–346
 Muscle spindle, 401–402
 Muscle strength
 depending on muscle size, 343
 Muscular activity, 334
 Muscular dystrophy
 clinical applications, 316b
 Music processing, 447
 MUSK (Muscle-specific kinase), 331
 Myelinated axons, 265
 Myelinated baroreceptor A fibers, 610
 Myeloid progenitors, 507
 Myenteric plexus, 782, 796–798
 Myocardial contractility, 610
 Myoepithelial cells, 777, 871
 Myofibrils, 305, 548
 Myogenic mechanisms, 592–593, 742, 742–743
 Myoglobin, 659–660
 Myomesin, 310–311
 Myoplasmic calcium ions, 325–326, 326
 Myosin
 actomyosin cross-bridge cycling, 549
 ATPase, 549
 cardiac contractility, 548
 cell structure, 105, 107
 skeletal muscle, 308–309
 smooth muscle, 356
 Myosin light chain kinase (MLCK)
 perfusion regulation, 590–591
 vascular smooth muscle, 590
 Myosin light chain phosphatase (MLCP), 356, 590–591
 Myosin light chain phosphorylation, 356
 Myostatin, 345–346
 Myotatic reflexes, 401, 402–403
 Myotomes, 410
- N**
 NAD⁺: ATP production, 222–224
 NADH. *See* Nicotinamide adenine dinucleotide (NADH)
 NANC. *See* Nonadrenergic noncholinergic (NANC) neurons
 Narrow tubes: pressure-driven flow, 19–20
 Nasal cavities, 427
 Natriuretic peptide, 242, 242f
 Natural killer cells, 510
 Natural selection, 8
- Nausea, 804–806
 Near object focus, 459
 Near-sightedness, 459–460
 Nebulin, 309–310
 Negative feedback loops, 10–11
 antidiuretic hormone-renal system, 745–746
 growth hormone, 877
 plasma calcium ions, 942–943
 plasma PI, 942–943
 ventilation control, 677
 Negative free energies, 90–92
 Negative gradients
 electric fields, 34
 electrochemical potentials, 88
 Negative intrapleural pressure, 628–630
 Nephrogenic diabetes insipidus, 739
 Nephrons, 698–699, 699
 acid–base balance, 757
 antidiuretic hormone, 738, 745
 glomerular filtration, 706
 osmotic diuresis, 738
 osmotic gradients, 733–736
 salt reabsorption, 743–744
 splay, 720
 tubular transport mechanisms, 731–736
 tubuloglomerular feedback, 743
 urinary excretion, 940–941
 water reabsorption, 724, 743–744
 Nernst–Planck electrodiffusion equation, 257–258
 Nerve conduction
 problem sets, 289
 Nerve gases, 484b
 Nerves
 action potentials, 268, 280, 280, 280, 280–281
 autonomic nervous system, 474, 482
 gut, 782
 hearing, 442–444
 problem sets, 422
 smooth muscle, 353
 stomach, 782, 785, 788–789
 ventilation control, 672, 673
 Nervous innervation: ileal motility, 803
 Nervous system
 autonomic nervous system, 473
 balance of movement, 409
 cells, 375
 central nervous system
 cutaneous sensory systems, 389
 depression, 669
 feeding behavior, 838–839
 integrative centers, 366
 major area functions, 372–373
 odor adaptation, 431
 organization, 367
 preganglionic neurons, 474
 serotonin, 384
 thoracolumbar spinal cord, 475–477
 chemical senses, 427
 control of movement, 409
 cutaneous sensory systems, 389
 enteric, 797
 gut extrinsic innervation, 799
 neurotransmitters, 375
 organization, 363
 behavior, 365–366
 blood-brain barrier, 370
 brain internal structures, 370–371
 brain surface features, 367–369
 central nervous system divisions, 367
 cerebral spinal fluid, 369–370
 component cells, 371–372
 consciousness, 366
 external behavioral responses, 366–367

- Nervous system (*Continued*)
- gray matter, 371
 - major area functions, 372–373
 - neuroendocrine system, 365
 - peripheral nervous system divisions, 367
- parasympathetic nervous system, 473
- baroreflex, 611–612
 - cardiac contraction, 553
 - gut extrinsic innervation, 799
 - heart rate, 612
 - insulin secretion, 897–898
 - micturition, 484
 - muscarinic receptors, 479–480
 - origin, 477–478
 - pacemaker potential, 530
 - pupillary light reflex, 482–483
 - target tissue stimulation effects, 482
- somatic nervous system, 474*f*
- spinal reflexes, 400
- sympathetic nervous system, 473
- adrenal medulla, 916
 - baroreflex, 611–612
 - calcium ion induced cardiac contraction, 552–553
 - gut extrinsic innervation, 799
 - insulin secretion, 897–898
 - micturition, 484
 - origin, 475–477
 - pacemaker potential, 529–530
 - rostral ventrolateral medulla, 612
 - target tissue stimulation effects, 482
 - vascular system control, 596
- synapses, 375
- Nervous tissue
- neurons, 375
 - supporting cells, 375
- Net filtration pressure, 584–585
- Net fluxes
- unidirectional fluxes and, 70–72
- Neuroendocrine system. *See* Hormones
- Nervous system
- Neuromuscular junction, 318
- complex array of interacting proteins, 329–331
 - molecular machinery of, 329–331
 - multiple enlargements connected by axon segments, 320
 - muscle fiber membrane, 331
- Neuromuscular transmission problem sets, 349
- Neurons
- action potentials, 265
 - autonomic nervous system, 474
 - cutaneous sensory systems, 392, 396–397
 - gamma amino butyric acid, 383–384
 - nervous tissue, 375
 - receptive fields, 396–397
 - shape, 376–377
 - size, 376–377
 - ventilation control, 673
 - vestibular nuclei, 419
- Neuropathic pain, 397
- Neuropeptide Y (NPY), 842–843
- Neuropeptides, 384–385
- Neurotransmission, 320–321, 379
- Neurotransmitters, 205, 375
- acetylcholine, 168
 - autonomic nervous system, 479
 - degradation, 322–323
 - muscarinic receptors, 382, 479–480
 - muscle excitation, 321–322
 - nicotinic receptor binding, 382
 - pacemaker potential, 530
 - recycling, 322–323
 - stomach, 791
 - aspartate, 383
 - autonomic nervous system, 479
 - catecholamines, 382
 - cell signaling, 206
 - destruction of, 380–381
 - glutamate, 383
 - recycling, 322–323, 381
 - removal of, 380–381
 - serotonin, 384, 494
 - central nervous system, 384
 - perfusion regulation, 595
 - peripheral nervous system, 384
 - smooth muscle, 353
- Neutral amino acid system, 825
- Neutrons, 46
- Neutrophils, 507, 508, 513–514
- Nicotinic receptor binding, 382
- Nicotinamide adenine dinucleotide (NADH), 218
- ATP production, 227–229, 234–235, 235–236
 - lactic acid, 339
- Nidogen, 710, 710
- Nitric oxide (NO)
- perfusion regulation, 591–592, 593
 - smooth muscle relaxation, 357
- Nitrogen, 837
- NO. *See* Nitric oxide (NO)
- Noble gases, 48
- Nociceptors, 393
- Nodes of Ranvier, 265
- Nonadrenergic noncholinergic (NANC) neurons, 482
- Noncyclical control systems, 11
- Nonpolar amino acids, 130
- Nonshivering thermogenesis, 250*b*
- Nonspontaneous spontaneous process coupling, 90*f*
- Nonsteroidal anti-inflammatory drugs (NSAIDs), 596, 794
- Norepinephrine, 382, 479, 480–482
- Normal probability density function, 27–29
- Normochromic anemias, 502
- Nose
- odors
 - binding proteins, 428–429
 - central nervous system, 431
 - detection limits, 431
 - recognition, 428
 - trigeminal nerve, 431–432
 - olfactory bulb, 429
 - olfactory epithelium, 427
 - olfactory output, 431
 - olfactory receptors, 427–428, 429
- NPY. *See* Neuropeptide Y (NPY)
- NSAIDs. *See* Nonsteroidal anti-inflammatory drugs (NSAIDs)
- NTS. *See* Nucleus tractus solitarius (NTS)
- Nuclear domain, 346
- Nuclear envelopes, 107–108
- Nuclear pores, 107–108
- Nuclear receptors, 213
- Nucleation sites, 105
- Nuclei
- atomic structure, 46
 - cell structure, 107–108
 - nuclei separation, 67–68
- Nucleolus
- cell structure, 107–108
 - ribosomal RNA assembly, 122–123
- Nucleolytic enzymes, 810, 811
- Nucleosomes, 126, 214
- Nucleotides, 121–122
- Nucleus ambiguus, 611–612
- Nucleus tractus solitarius (NTS), 611–612, 840–841
- Numerical aperture, 113–114
- Nutrients
- absorption, 772–773, 821
 - catabolism, 837
 - circulatory system overview, 489–490
 - digestion, 821
 - filtered load, 719
 - gastrointestinal system, 771, 771–772
 - glomerular filtration, 705
 - intestine, 794
 - pancreatic enzyme secretion, 813
- O**
- Obscurin, 312
- Obstructive sleep apnea, 681, 681
- Oculomotor nerve, 477
- Odorant binding proteins, 428
- Odors
- binding proteins, 428–429
 - central nervous system, 431
 - detection limits, 431
 - recognition, 428
 - trigeminal nerve, 431–432
- Off-center bipolar cells, 462
- Off-center ganglion cells, 462–463
- 1,25(OH)₂-D hormone, 937
- 25(OH)₂-D vitamin D, 930–931
- Ohm's law, 39
- Okazaki fragments, 123*f*
- Olfaction, 429
- Olfactory bulb, 429
- Olfactory epithelium, 427
- Olfactory output, 431
- Olfactory receptors, 427
- cribriform plate, 427–428
 - glomeruli, 429
 - second-order neurons, 429
- Olfactory sensory neurons (OSN), 427, 433*f*
- On-center bipolar cells, 462
- On-center ganglion cells, 462–463
- Oncotic pressure
- plasma proteins, 500
 - solute exchange, 584
- One-dimensional diffusion, 79
- One-dimensional random walk, 76–79
- Onsager reciprocity, 16
- Oogenesis, 948
- Opioid-induced constipation, 807*b*
- Optical isomers, 51
- Orad stomach, 787
- Oral dissolution therapy, 819
- Oral rehydration therapy (ORT), 177
- Orbitals, 46, 47–48
- Orbitofrontal cortex, 431
- Organ systems of the body, 4*t*
- Organelles, 116. *See also* Mitochondria
- biological membranes, 142
 - calcium ion uptake, 551
 - cell structure, 101, 109, 115
 - fatty acid metabolism, 243
 - hydrogen ion pumps, 231–232
 - lactate shuttling, 339
 - NADH oxidation carrier systems, 339
 - transport mechanisms, 238–239
 - tricarboxylic acid cycle, 227
- Organic anions: sodium cotransporters, 725–727
- Organic solvents: biological membranes, 142
- ORT. *See* Oral rehydration therapy (ORT)
- Orthostasis, 610
- OSA. *See* Obstructive sleep apnea
- Osmolarity, 184
- Osmolytes, 184

- Osmometers, cells behaving like, 192–193
 Osmoreceptor cells: antidiuretic hormone secretion, 744
 Osmosis, 182, 191–192, 194–198. *See also* Osmotic...
 aquaporins, 198
 dissolution–diffusion mechanism, diffusional permeability by, 197–198
 filtration permeability, 196
 for microporous membranes, 189–190
 microporous membranes, diffusional permeability of, 195–196
 physical origin of osmotic pressure across a microporous membrane, 194–195
 pressure- and osmosis-driven flow, 196–197
 Osmotic and hydrostatic pressures, equivalence of, 186–187
 Osmotic diuresis: distal nephron, 738
 Osmotic gradients
 inner medulla, 736
 urine concentration, 730–731
 Osmotic pressure, 182, 187, 191–192, 727–728
 cells, 192–193
 colligative properties, 185
 hypertonic solutions, 191, 192f
 hypotonic solutions, 191, 192f
 microporous membranes, 194–195
 mechanism of osmosis for, 189–190
 microscopic characteristics, 188
 nonideal solutions, 185
 osmometers, cells behaving like, 192–193
 osmotic and hydrostatic pressures, equivalence of, 186–187
 osmotic coefficients, 185
 permeable solutes, 187
 physical origin of, across a microporous membrane, 194–195
 rational osmotic coefficient, 186
 reflection coefficients, 187
 regulatory volume decrease (RVD), 193
 regulatory volume increase (RVI), 193
 solute exchange, 584, 584
 solutions, 185
 units for the calculation of, 187t
 van't Hoff equations, 182–184
 Osmotically inactive, 194
 OSN. *See* Olfactory sensory neurons (OSN)
 Osteoblasts, 933, 934–935
 Osteocalcin, 934
 Osteoclastic osteolysis, 935–936
 Osteoclasts, 934, 935
 Osteocytes, 933–934
 Osteocytic osteolysis, 935
 Osteoid, 933, 934–935
 Osteoprogenitor cells, 934
 Osteoprotegerin (OPG), 935
 Otitis media, 444
 Ouabain, 749
 Ouabain drugs, 553–554
 Outer ear, 441–444
 Outer hair cells: ear structure, 445
 Outer mitochondrial membrane, 109f
 Outward potassium ion current, 532
 Ova, 948, 958
 Ovaries, 946, 947, 949
 Overpressure-induced renal damage, 742–743
 Overshoot: action potentials, 268
 Oviducts. *See* Fallopian tubes
 Ovulation, 947, 948, 949, 954–955
 Oxidation
 anaerobic thresholds, 340
 ATP production, 236–238, 241
 acetyl CoA, 218
 pyruvate, 227
 carrier systems, 339
 Oxidation potentials, 39
 Oxidative fibers: lactate shuttling, 339
 Oxidative muscle: oxygen storage, 659–660
 Oxidative phosphorylation: ATP production, 227
 Oxygen
 consumption, 657
 calculations, 659b
 cardiac output, 560–561
 delivery
 in exercise, 661
 to tissue, 659
 dissociation curves, 656, 656–657, 660–661
 electron transport chain, 233
 hemoglobin, 656–657
 myoglobin, 659–660
 respiratory system, 623
 saturation curves, 656
 transport, 623, 656
 ventilation control, 677
 Oxytocin, 872–873
 amino acids, 870
 hypothalamus, 870
 myoepithelial cell contraction, 871
 uterine contraction, 871
- P**
 P (principle) subshells, 47–48
 P wave atrial depolarization, 540
 Pacemakers, 522, 528–529, 675, 675–676, 785–786
 Pain production by nociceptors, 393
 Pain receptors: taste, 436–437
 Painful stimuli, 400
 Pancreas, 810, 895
 absorption of nutrients, 773
 digestion, 773
 endocrine pancreas, 810, 895
 exocrine pancreas, 810, 895
 secretory cells, 109f
 Pancreatic acinar secretion, mechanism of, 812f
 Papillary muscles, 518
 Para-amino hippuric (PAH) acid, 707
 clearance, 723
 renal titration, 722–723
 Paracellular pathways: intestinal calcium ions, 937
 Paracrine secretions, 595–596
 Parallel beta sheets, 135
 Parallel muscle fibers, 301
 Parallel plate capacitors, 35–36
 Parasitic infections, 509–510
 Parasympathetic nervous system, 473
 baroreflex, 611–612
 cardiac contraction, 553
 gut extrinsic innervation, 799
 heart rate, 612
 insulin secretion, 897–898
 micturition, 484
 muscarinic receptors, 479–480
 origin, 477–478
 pacemaker potential, 530
 pupillary light reflex, 482–483
 target tissue stimulation effects, 482
 Parathyroid hormone (PTH), 703
 derivative control, 927
 destruction of, 927
 goals, 941–942
 hypocalcemia, 926–927
 osteoclastic osteolysis, 935–936
 osteocytic osteolysis, 937
 plasma phosphate regulation, 722
 vitamin D, 929–930
- Paraventricular nuclei, 744
 Paravertebral ganglia, 475
 Parietal lobes: vision, 465
 Parietal pleura, 625f
 Parkinson's disease, 420
 Parotid glands, 775
 Paroxysmal supraventricular tachycardia (PSVT), 544
 Partial molar volume, 184
 Partial pressures, 642–643, 652
 alveolar air and blood, 657, 658f
 diffusing capacity, 646–647
 Partial volumes, 652
 Particle number in moles, 59
 Partition coefficients, 130–131
 Parturition, 947–948
 Parvocellular pathway, 462–463
 Passive mechanisms, 161. *See also* Diffusion
 cell structure, 102
 reabsorption of urea, 728
 resting expiration, 626
 solute exchange, 579
 water, 168
 Patch clamp experiments, 271
 Pauling units, 51
 PBC. *See* Pre-Botzinger complex (PBC)
 Peak expiratory flow rate (PEFR), 635–636
 Pedigrees: evolution, 8
 PEEP (positive end-expiratory pressure), 640
 PEFR. *See* Peak expiratory flow rate (PEFR)
 Peltier effect, 16
 Pelvic nerve, 803
 Pendred's syndrome, 892b
 Penis: erection, 964–965
 Pepsinogen secretion, 790–791
 Peptic ulcers, 794b
 Peptide bonds, 131–133
 Peptidyl (P) binding sites, 125f
 Perception, 390
 Perfusion, 589. *See also* Ventilation/perfusion ratios
 pulmonary circulation, 650
 solute exchange, 583–584
 Pericardium, 516
 Pericytes, 578–579
 Perikaryons, 265
 Perilipin, 242
 Periodic table, 47f
 Periodicity, 47–48
 Periosteum, 933
 Peripheral chemosensors, 677
 Peripheral nervous system (PNS)
 connection to CNS, 373
 organization, 367
 serotonin, 384
 Peripheral proteins, 151
 Peristalsis, 698, 780–781
 intestinal motility, 800–802
 vomiting, 809
 Peritoneum, 698
 Peritubular capillaries, 701
 Permeable solutes: osmotic pressure, 187
 Pernicious anemia, 506
 Peroxisomes, 109, 116, 243
 Perturbations
 positive feedback control systems and, 11
 pH. *See also* Acid–base balance
 chemical buffers, 665
 definition, 665
 Henderson–Hasselbach equations, 667–668
 oxygen dissociation curves, 660, 660
 plasma blood cells, 500
 problem sets, 682
 renal system, 665
 respiratory system, 665, 668

- pH (*Continued*)
 taste receptor cells, 435
 ventilation control, 676
 Phagocytes, 502–503, 508
 Phagocytosis, 102
 Pharmacomechanical coupling, 590–591
 Pharyngeal swallowing phases, 780–781
 Phase locking: pitch perception, 447–448
 Phase-contrast microscopy, 119
 Physically-based contractile activity, 351
 Phenotypes, 956
 cell diversity, 7
 DNA, 120
 evolution, 8
 Phenoxymethylamine, 481
 Pheochromocytoma, 922*b*
 pH–hydrogen carbonate diagrams, 669–670
 Phonocardiograms, 520
 Phosphate
 biological membranes, 143–145
 proximal convoluted tubules, 725–727
 Phosphatidylinositol 3-kinase (PI-3K), 345
 Phospholamban
 cardiac relaxation, 550
 smooth muscle, 354
 Phospholamban (PLN), 333
 Phospholipase C, 211
 Phospholipids
 bile, 814
 biological membranes, 142–143, 143–145,
 146–147, 149–150
 water squeezing out, 149*f*
 Phosphorus homeostasis, 924, 933
 Phosphorylated intermediates: active transport,
 173
 Phosphorylation: smooth muscle, 354, 356
 Photoreceptor cells, 460
 Phrenic nerve, 625, 672
 Physiologic dead space, 647–648
 Physiology, 66
 Physiology, core principles of, 6
 PI
 bone mineralization, 942
 equilibrium concentrations, 92
 intestine, 937–939
 negative feedback loops, 942–943
 1,25(OH)₂-D hormone, 937–939
 osteoclasts, 933–934
 urinary excretion, 940–941
 Pigments: bile, 814
 PI-3K. *See* Phosphatidylinositol 3-kinase (PI-3K)
 Pinnate muscle fibers, 301
 Pinocytosis, 102
 Pitch perception, 447–448
 Pituitary gland, 857, 870
 Pituitary–hypothalamus axis, 907–908
 PKA. *See* Protein kinase A (PKA)
 PKG. *See* Protein kinase G (PKG)
 Placenta, 948
 Planar lipid bilayer capacitance, 37*b*
 Plasma, 494, 498
 antidiuretic hormone, 873
 body fluid compartments, 689, 690–691,
 692, 693–694, 696
 buffer lines, 669
 calcitropic hormones, 924–925, 928
 creatinine concentration, 723–724
 dehydration, 740
 electrolytes, 498–500
 glomerular filtration, 707–708
 glucose
 absorption, 900–902
 excretion, 720
 glycogenolysis, 900–902
 insulin secretion, 895–897
 hepatocytes, 814
 kidneys, 697*f*, 702
 membrane cell forms, 7
 parathyroid hormone, 941
 pH, 500, 665
 phosphate, 722
 thyroid hormone, 885–886
 volume estimations, 62*b*
 water, 498–500
 Plasma membrane, 116
 Plasmalogens, 146
 Plasmalyl glycerol phospholipids, 146, 146*f*
 Plasmalyl phospholipids
 using fatty alcohols, 146
 Plasmenyl glycerol phospholipids, 146, 146*f*
 Plasmenyl phospholipids
 using fatty alcohols, 146
 Plasmin, 495
 Plasminogen, 495
 Platelets, 507
 pluripotent stem cells, 507
 vascular hole sealing, 494
 Pleura, 626
 PLN. *See* Phospholamban (PLN)
 Pluripotent stem cells, 502, 507–508
 Pneumothorax condition, 630
 Podocytes, 708, 709*f*
 Poiseuille equation, 637–638
 Poiseuille's law, 19–20, 189, 574–576
 derivation of, 22–24
 pressure-driven flow through a cylindrical
 pipe, 22
 flow through a pipe, 23–24
 shear stress, 22–23
 Polar amino acids, 130
 Polar bonds, 53, 53–54, 57
 Polar groups, 143
 Polarizable atoms, 55
 Polycythemia, 501, 679
 Polydipsia, 721
 Polypeptide chains, 500–501
 Polypeptide hormones, 854, 857–858
 Polyuria, 721, 738
 POMC. *See* Proopiomelanocortin (POMC)
 Pons, 373, 672
 Pontine respiratory group (PRG), 672, 674*f*
 Pontine reticulospinal tract, 406
 Population codes: contractile force, 409
 Population variance, 25
 Positive chronotropy, 552
 Positive feedback control systems, 11
 Positive inotropic agents, 559
 Positive pressure breathing, 640*b*
 Positive staircase phenomena, 552
 Posterior pituitary, 857, 870
 Postganglionic neurons, 474
 Postganglionic sympathetic nerves, 799
 Postganglionic sympathetic neurons, 480–482
 Postprandial pancreatic enzyme secretion,
 812–813
 Postsynaptic potentials
 decay over time, 319
 electronical spread, 319
 excitatory types, 318–319
 graded, 319
 inhibitory types, 318–319
 Posttranslational modification, 126, 137–138
 Potassium
 acid–base balance, 757, 762
 action potentials, 269–270, 528–529, 532,
 533
 aldosterone, 749, 912
 equilibrium potentials, 257
 stomach, 794
 zona glomerulosa, 911
 Potential, current and
 Ohm's law, 39
 Pre-Botzinger complex (PBC), 673
 Preganglionic axons, 477
 Preganglionic fibers, 475, 476
 Preganglionic neurons, 474
 Pregnancy, 948
 "Preinspiratory" (Pre-I) neurons, 675
 Preload: cardiovascular system, 556, 558–559,
 599
 Premature depolarization, 544
 Premotor areas, 411–412
 Preosteoblasts, 934
 Pressure
 alveoli, 627*b*
 arteries, 571–572, 573–574
 blood flow, 493, 494
 breathing mechanics, 624–625, 625,
 628–630
 circulatory, 601
 heart
 muscle contraction, 516–518
 total work, 557–558
 valve closure, 520
 mole fractions, 642–643
 osmotic, 182, 727–728
 partial, 642–643, 646–647, 652, 657, 658*f*
 perfusion regulation, 589–590
 pH regulation, 668
 plasma proteins, 500
 problem sets, 43
 solute exchange, 584–585
 sound, 454–455
 systemic, 601, 602, 609
 vapor pressure, 643, 644
 vascular flow, 568–569
 vascular function, 569–570, 603–604
 ventilation control, 677, 677
 Pressure- and osmosis-driven flow, 196–197
 Pressure-driven flow, 15
 blood, 493
 capacitance, 18
 charge, 18
 conservation of energy, 17
 conservation of matter, 17
 continuity equations, 17
 through a cylindrical pipe
 Poiseuille's law, 22
 force, 15–16
 heat, 18
 Laplace Law, 21
 Poiseuille's law, 19–20
 solute, 18
 steady-state flow
 linear gradients, 17–18
 Poiseuille's law, 19–20
 volume, 18
 Pressure–volume (PV) loops, 556–557
 Pre-synaptic cells, 380
 calcium ion efflux mechanisms, 322
 Pre-synaptic terminals, 381
 Prevertebral ganglia, 475
 PRG. *See* Pontine respiratory group (PRG)
 Primary active transport, 172–173
 Primary auditory cortex, 447
 Primary bile acids, 814–815
 Primary motor cortex, 411
 Primary peristalsis, 780
 Primary polydipsia, 739
 Primary protein structure, 134
 Primary spermatocytes, 960–961
 Primordial follicle, 949
 Principal cells, 733
 Probability, 26
 Problem sets

- acid–base balance, 765
 action potential, 289
 airway resistance, 653
 alveolar gas exchange, 653
 blood, 525
 cardiac work, 565
 cell fractionation, 156
 clearance, 715
 diffusion, 94
 electrical force, 43
 electrolyte balance, 765
 energy balance, 847
 fluid balance, 765
 fluid volumes, 715
 gas exchange, 653
 gas transport, 682
 glomerular filtration, 715
 hemodynamics, 619
 kinetics, 94
 ligand binding, 967
 membrane potential, 289
 membrane structure, 156
 membrane surface tension, 156
 membrane transport, 199
 microcirculation, 619
 microscopic resolution, 156
 muscle energetics, 349
 muscle force, 349
 nerve conduction, 289, 422
 neuromuscular transmission, 349
 pH, 682
 pressure forces and flows, 43
 sensory transduction, 471
 surface tension, 156
 Proliferation: cell structure, 101
 Proline and glycine transport system, 825
 Proline transport system, 825
 Prometaphase, 957
 Promoters of gene expression, 125
 Proopiomelanocortin (POMC), 842–843
 Propanolol, 481
 Prophase, 956–957
 Propulsion of stomach contents, 787–788
 Prostacyclin, 593, 596
 Prostaglandins, 595
 Prostate specific antigen (PSA), 965
 Proteasome, structure of, 110f
 Proteasomes, 110
 Protein. *See also* Follicle stimulating hormone (FSH); Luteinizing hormone (LH)
 aquaporins, 168, 727, 731, 751
 biliary secretion, 815–816
 biological membranes, 154
 bonding affinities, 151–152
 endoplasmic reticulum, 154
 lipid rafts, 153
 bitter taste, 436
 breathing mechanics, 624
 calcium ion release/reuptake, 324
 cardiac action potential, 529–530
 cell signaling, 209
 cell structure, 104f, 105, 110, 111
 endoplasmic reticulum, 108
 proteasomes, 110
 ribosomes, 108
 cortisol, 909–910
 dietary energy content, 241
 digestion, 822–824
 distal nephron permeability, 745
 endocytosis, 728
 erythrocytes, hemoglobin, 500
 folding diseases, 139b
 glomerular filtration, 710
 G-proteins, 209, 221, 381–382, 436, 591
 mannan-binding lectin, 514
 odorant response, 428–429
 plasma blood cells, 498–500
 oncotic pressure, 500
 pH, 500
 reabsorption mechanisms, 728
 semen, 965
 skeletal muscle contractile mechanisms, 308–309, 314–315
 structure, 130
 activation, 139
 amino acids, 130, 134–136
 four levels of structure, 134–137
 hydrophobic interactions, 130–131
 inactivation, 139
 number of molecules, 139
 partition coefficients, 130–131
 peptide bonds, 131–133
 posttranslational modification, 137–138
 primary protein, structure, 134
 quaternary protein, structure, 137
 reactive surface formation, 133–134
 reversible activation/inactivation, 139
 secondary protein structure, 134–136
 tertiary protein structure, 136–137
 sweet taste, 436
 synthesis
 deoxyribonucleic acid, 120
 messenger RNA, 122
 thyroid hormones, 885–886
 umami taste, 436
 xenobiotics, 816
 Protein kinase A (PKA), 242, 332
 Protein kinase G (PKG), 332
 Protein phosphatases, 332
 Protein YY(3-36), 843
 Proteoglycans, 710, 710
 Proteolytic cleavage, 137, 514
 Proteolytic enzymes, 810–811
 Prothrombin, 498–499
 Proton electrochemical gradients, 234–235, 234
 Proton motive force, 234
 Proton pumps, 233, 794
 Protons, 46
 Proximal tubules, 701, 725–728
 acid–base balance, 753
 ammonium, 755–756
 endocytosis, 728
 isosmotic solution reabsorption, 731
 ultrafiltrate reabsorption, 725
 PSA. *See* Prostate specific antigen (PSA)
 P-selectin protein, 513–514
 PSVT. *See* Paroxysmal supraventricular tachycardia (PSVT)
 PTH. *See* Parathyroid hormone (PTH)
 P-type ATPases, 174
 Puberty, 948
 Pudendal nerve, 803
 Pulmonary artery, 518–519
 Pulmonary chemoreflex, 680
 Pulmonary surfactants, 627–628
 Pulmonary valve, 518–519
 Pulmonary ventilation, 623, 635. *See also* Alveoli; Respiratory systems
 exercise, 635
 Pulse pressure
 artery compliance/stroke volume, 570–571
 mean arterial pressure, 571–572
 Pupillary light reflex, 482–483
 Purkinje fibers, 523
 Pursed-lip breathing, 639–641, 641f
 PV. *See* Pressure–volume (PV) loops
 Pyloric sphincter, 772–773, 785
 Pyruvate, 227
- Q**
 QRS complexes, 540
 Quantized energies: electron orbitals, 46
 Quaternary protein structure, 137
 Quinine alkaloids, 506
- R**
 RAA. *See* Renin–angiotensin–aldosterone (RAA) system
 Radial arteries, 699, 700–701
 Radial veins, 699, 701
 Radioimmunoassays, 862–863
 Random coils, 135
 Rapsyn, 331
 Rate constants: transition state theory, 68–70
 Rational osmotic coefficient, 186
 RBF. *See* Renal blood flow (RBF)
 RDS. *See* Respiratory distress syndrome (RDS)
 Reaction rates: transition state theory, 67–70
 Reactive oxygen species (ROS), 508
 Receptors, 859, 860
 adrenergic receptors, 383
 arterial pressure regulation, 609–610
 autonomic nervous system, 482
 baroreceptors, 609–610
 catecholamine action, 919–920
 cell signaling, 209, 212, 213
 gene transcription, 213
 histone acetylase, 214
 transcription factors, 214–215
 colonic contraction, 803
 cutaneous sensory systems, 389, 390–391, 392–393
 receptive fields, 392
 types, 392–393
 G-proteins, 209, 221, 381–382, 436, 591
 guanylyl cyclase, 212
 immune response, 511–512
 metabotropic receptors, 381–382
 muscarinic receptors, 382, 479–480
 nicotinic receptor binding, 382
 passive mechanisms
 cell structure, 102
 reabsorption of urea, 728
 resting expiration, 626
 solute exchange, 579
 water, 168
 smell, 427, 429
 smooth muscle, 354, 358
 steroid hormones, 125–126
 stomach, 791–793
 stretch receptors
 antidiuretic hormone secretion, 745
 colonic contraction, 803
 stomach, 791–793
 taste, 433–434, 438
 thermoreceptors, 393
 tyrosine kinase, 212
 warm receptors, 393
 Recipients: universal, 504
 Recoil tendency of lungs, 627, 630
 Recruitment
 muscle force, 297
 and muscle force, 297
 Rectoanal inhibitory reflex, 804
 Red blood cells, 494, 498
 Reduction potential, 229, 229–230
 Reentry arrhythmia, 544
 Referred pain, 478–479
 Reflection coefficients, 190–191
 osmotic pressure, 187
 Reflexes
 aspiration, 680
 autonomic nervous system, 473, 478–479

- Reflexes (*Continued*)
 diving, 679
 Hering–Breuer inflation, 680
 ileogastric, 804
 inflation, 680
 myotatic, 401, 402–403
 spinal, 400
 stomach distension, 803
 swallowing, 680
 ventilation control, 679–680
 Reflux, 783, 802
 Refraction
 light focusing, 458–459
 angles of incidence, 468
 refractive indices, 468
 speed of light, 467–468
 thin lens formulae, 467–470
 thin lens formulae, 467–470
 Refractive index, 113–114
 Refractory periods, 268
 Regulatory light chain (RLC): smooth muscle, 356
 Regulatory T cells, 510
 Regulatory volume decrease (RVD), 193
 osmotic pressure, 193
 Regulatory volume increase (RVI), 193
 osmotic pressure, 193
 Relative humidity, 644
 Relative refractory periods, 268
 Relaxation volume–pressure curves, 628–630
 Renal arteries, 698, 699, 700–701
 Renal blood flow (RBF): autoregulation, 741–743
 Renal capsule, 698–699
 Renal compensation
 acid–base balance, 759
 Renal corpuscles, 705
 Renal damage, 742–743
 Renal function curves, 614–615
 Renal plasma flow, 707–708
 Renal pyramids, 698–699
 Renal system. *See also* Kidneys
 pH regulation, 665, 752–753
 Renal titration, 719–720, 722–723
 Renal tubular acidosis, 668, 763*b*
 Renal veins, 698, 699, 701
 Renin, 701–702, 743, 748
 Renin–angiotensin–aldosterone (RAA) system, 749
 blood volume, 749
 hormonal regulation, blood pressure, 615–616
 perfusion regulation, 596–597
 sodium balance, 748–749
 Replication forks, 123*f*
 Repressors of gene expression, 125–126
 Reproductive systems, 946, 956
 Repulsive force
 van der Waals forces
 Lennard–Jones potential, 55
 Residual volume (RV), 633, 634*t*
 Resistive current, 39–40
 Resolution: cells structure/microscopy, 113–114
 Respiratory distress syndrome (RDS), 630
 Respiratory rate (RR), 635
 exercise, 635
 pulmonary ventilation, 635
 Respiratory systems, 621. *See also* Alveoli; Lungs
 acidosis, 669, 759
 airway resistance, 630–631, 633, 653
 alkalosis, 669, 760
 breathing mechanics, 621
 carbon dioxide transport, 656
 compensation, 665
 exchange ratios, 642
 gas exchange, 642
 muscle control, 672
 oxygen transport, 656
 pH regulation, 665, 668, 752–753
 quotients, 642
 sinus arrhythmia, 612–613
 ventilation control, 672
 Resting expiration, 626
 Resting membrane potentials, 253
 cardiac cells, 528
 contractile cells, 528–529
 sinoatrial node, 528–529
 ventricular cardiomyocyte action potentials, 530–532
 Rest time: intensity of exercise, 335–336
 Reticuloendothelial system, 510–511
 erythrocyte destruction, 502–503
 monocytes, 510–511
 tissue macrophages, 510–511
 Reticulospinal tract, 406, 484
 Retina, 456–458, 460–462
 far-sightedness, 459–460
 near-sightedness, 459–460
 photoreceptor cells, 460
 pupillary light reflex, 482–483
 visual signal processing, 460–462
 Retropulsion of stomach contents, 787–788
 Reverse peristalsis, 800–802, 804–806
 Reverse rate constants: chemical reactions, 62–63
 Reynolds number, 637
 Rheobase, 268
 RhoA G-proteins, 591
 Ribonucleic acid (RNA)
 cell structure, 108
 messenger RNA, 122
 ribosomal RNA, 108, 122–123
 transfer RNA, 123
 Ribosomal ribonucleic acid (rRNA), 108, 122–123
 Ribosomes: cell structure, 108
 RNA. *See* Ribonucleic acid (RNA)
 Robustness and environmental challenges, 9
 ROS. *See* Reactive oxygen species (ROS)
 Rostral ventrolateral medulla (RVLM), 612
 Rough endoplasmic reticulum, 108
 RR. *See* Respiratory rate (RR)
 RRNA. *See* Ribosomal ribonucleic acid (rRNA)
 Rubrospinal tract, 405
 RV. *See* Residual volume (RV)
 RVD. *See* Regulatory volume decrease (RVD)
 RVI. *See* Regulatory volume increase (RVI)
 RVLM. *See* Rostral ventrolateral medulla (RVLM)
 Ryanodine receptors (RyR), 331, 332, 332, 549
 RyR. *See* Ryanodine receptors
- S**
 s (sharp) subshells, 47–48
 SA. *See* Sinoatrial (SA) node
 Sacculi, 419
 Sacral nerves, 477–478
 Saliva, 775–776, 778–779
 Saliva production, 779–780, 779*f*, 780
 Salivary glands, 775
 Salivary nuclei, 777–778
 Salivation control, 777–778
 Salt
 body fluid compartments, 696*b*
 distal tubule, 732–733
 late proximal tubule, 728
 loop of Henle, 731, 732
 nephron adjustment, 743–744
 taste, 432, 434–435
 Saltatory conduction: action potential propagation, 286
 Sample standard deviation, 25
 Sample variance, 25
 Sarcolemma (SL), 306, 340, 550–551, 590–591
 Sarcomeres, 310, 311–312, 548
 Sarcoplasmic reticulum membranes, multiple proteins on
 Calcium Release Unit, 331–333
 Sarcoplasmic reticulum (SR), 306
 calcium ions
 excitation-contraction coupling, 324
 induced cardiac contraction, 549, 550, 551*f*
 induced cardiac relaxation, 550–551
 release, 324
 reuptake, 324–325
 phospholamban phosphorylation, 354
 repetitive stimulation, 327
 summation, 326
 tetany, 326
 Sarin nerve gas, 484
 Satiety center, 839
 Satiety signals, 840–843
 Saturated fatty acid, 144*f*
 Saturation
 facilitated diffusion, 164–165
 glucose, 720–721
 splay, 721
 Scatchard plots, 859, 864–866
 Scavenger receptors: immune response, 512
 Schwann cells, 265
 Scramblase enzymes, 152
 Scrapies, 139
 Scrotum, 960
 Second degree heart blocks, 544
 Second pain production by nociceptors, 393
 Secondary active amino acid transporters, 725
 Secondary active transport
 antiports, 175–176
 sodium–calcium exchangers, 174–175
 symports, 176
 Secondary bile acids, 815
 Secondary follicle, 951–952
 Secondary peristalsis, 780–781
 Secondary protein structure, 134–136
 Secondary sex characteristics development, 948
 Secondary spermatocytes, 960–961
 Second-order neurons, 429
 Secretin, 794, 808, 813–814
 Secretory cells, 108, 221
 Secretory materials: cell structure, 108
 Sedimentation, 115–116
 Sedimentation coefficient, 118
 Segmentations: intestinal motility, 800–802
 Self-identification, 5–6
 Self-replication, 4
 Semen, 965
 Semenogelin, 965
 Semi-lunar valves, 519–520
 Seminiferous tubules, 960–961
 Sensation disorders, 395–396
 Sense organs, 390
 Senses, 389, 427
 environmental condition appraisal, 366
 hearing, 440
 smell, 427
 taste, 427
 vision, 456
 Sensors: external behavioral responses, 366–367
 Sensory afferents: nucleus tractus solitarius, 611–612
 Sensory areas: motor activity, 411–412
 Sensory cortex: cutaneous sensory systems, 395

- Sensory input: autonomic reflexes, 478–479
- Sensory neurons: vestibular nuclei, 419
- Sensory receptors, 390
- Sensory systems: cutaneous sensory systems, 389
- Sensory transduction: problem sets, 471
- Septicemia, 585
- Septum, 518–519
- SERCA (smooth endoplasmic reticulum Ca-ATPase), 333
- Serine, 143
- Serine/threonine receptors, 212
- Serotonin, 384, 494
- central nervous system, 384
 - perfusion regulation, 595
 - peripheral nervous system, 384
- Serous glands, 775
- Sertoli cells, 961, 963
- Sex hormones, 213, 963
- Sexual reproduction. *See* Reproductive systems
- SGLT. *See* Sodium–glucose linked transporters (SGLT)
- Shear stress
- Poiseuille's law, 22–23
- Short bones, 933
- Short receptors, 390–391
- SIADH. *See* Syndrome of inappropriate antidiuretic hormone secretion (SIADH)
- Sickle cell anemia, 501
- Sickle cell disease, 506
- Sieving coefficients: glomerular filtration, 710
- Siggaard–Anderson nomograms, 669
- Sight. *See* Vision
- Signal function, 111
- Single carbon–carbon bonds, 49
- Sinoatrial (SA) node
- action potentials, 528–529, 530, 534
 - heart beat, 522
- Sinus arrhythmia, 544
- Sinus bradycardia, 544
- Sinus tachycardia, 544
- Sinusoidal capillaries. *See* Discontinuous capillaries
- Sister chromatids, 956–957
- Skeletal growth at growth plates, 877–879
- Skeletal muscle, 292
- anatomical arrangement, 292–293
 - architecture, 300–302
 - breathing mechanics, 625–626
 - classification, 292–293
 - concentric contractions, 300
 - contractile mechanisms, 300, 305
 - ATP splitting, 312–313
 - cell structure, 305–306
 - cross-bridges, 312–313
 - cytoskeleton, 314–315
 - fiber type dependence, 313–314
 - force, 308–309
 - force–velocity curves, 313–314
 - muscular dystrophy, 316b
 - proteins, 314–315
 - sliding filament hypotheses, 306–308
 - thick filaments, 308–309
 - thin filaments, 309–310
 - transmembrane proteins, 314–315 - eccentric contractions, 300
 - fine structure, 292–293
 - force, 292, 293–295, 295–296, 296–297, 308–309
 - eccentric contractions, 300
 - fatigue, 303
 - innervation ratio of motor units, 298
 - muscle length, 296–297
 - muscle velocity, 298–299
 - recruitment, 297 - function, 292
 - isometric contractions, 300
 - isometric force, 293
 - motor neurons, 295–296, 318
 - motor units, 293–295
 - neural control, 292–293
 - power, 299–300
 - shortening, 292
 - size principles, 295
 - velocity, 298–299, 300–302
 - voluntary activation, 293
- Skeleton. *See also* Bone
- form/support, 933
- Skin: vitamin D, 928–929
- SL. *See* Sarcolemma (SL)
- Sleep apnea, 640, 680b
- Sleep disorders, 680b
- Sliding filament hypotheses, 306–308
- Slit diaphragms, 710
- Slit membranes, 710
- Slope conductance: resting membrane potential, 258–259
- SM proteins, 329–330
- Small intestine, 785
- carbohydrate digestion, 825
 - lipolytic activity, 828–829
- Small nuclear RNAs (snRNA), 126f
- Smell. *See* Nose
- Smooth endoplasmic reticulum, 108
- Smooth muscle, 292, 351
- adrenergic stimulation, 358
 - airway resistance, 639
 - beta-adrenergic receptors, 358
 - cell coupling, 352–353
 - chemical signals, 354–356
 - contractile filaments, 352
 - cross-striations, 351
 - cytosolic calcium ions, 354, 358
 - electrical activities, 351–352
 - esophagus, 780
 - force, 351–352
 - actin–myosin interaction, 356
 - calcium ions, 356–357
 - myosin light chain phosphorylation, 356 - guanylate cyclase, 357
 - hormones, 353
 - intestinal contraction, 799
 - intracellular calcium ions, 353–354
 - intrinsic activity, 353
 - mechanism synopsis, 358–359
 - myosin light chain phosphatase, 356
 - nerves, 353
 - nitric oxide, 357
 - perfusion regulation, 591–592
 - phasically-based contractile activity, 351
 - sphincters, 772–773
 - tension, 351
 - tonically-based contractile activity, 351
- SNAP-25, 329–330
- SNARE proteins for SNAP receptor, 329–330
- Sneezing, 679
- Sodium
- action potentials, 269, 269–270, 532, 533–534
 - aldosterone, 749, 912
 - ATP production, 239
 - filtered load, 720b
 - hypervolemia, 749
 - integrated response, 749–750
 - organic anion cotransporters, 725–727
 - renin–angiotensin–aldosterone system, 748–749
- Sodium, potassium-ATPase, 172–173
- as electrogenic, 173–174
- Sodium chloride. *See also* Salt
- body fluid compartments, 695
 - loop of Henle, 732
- Sodium–calcium exchangers, 174–175, 533–534
- Sodium–glucose linked cotransporters (SGLT), 725
- Sodium–hydrogen carbonate cotransporters, 753–754
- Sodium–hydrogen exchangers, 239
- Solitary nuclei, 438
- Soluble adenylyl cyclase (sAC), 761
- Soluble NSF attachment protein, 329–330
- Solute carriers, 179–181
- Solute exchange, 578
- Solute flux, 37–38
- Solute loads, 738
- Solute osmotic pressure, 187
- Solute pressure-driven flow, 18
- Solutions
- dilution calculations, 61b
 - making up, 60b
 - osmotic pressure, 185, 191–192
- Solvents: biological membranes, 142
- Soma, 265, 384–385
- Somatic cells
- cell diversity, 7
 - homeostasis, 7–8
 - mitosis, 956
- Somatic nervous system, 474f
- Somatomedin. *See* Insulin-like growth factor (IGF-I)
- Somatosensory cortical neurons: receptive fields, 396–397
- Somatosensory information: dorsal column pathway, 394–395
- Somatosensory input: cutaneous sensory systems, pain reduction, 396
- Somatostatin (SST), 789, 808, 875
- exocrine pancreas, 810
 - insulin secretion, 897
 - stomach, 791
- Somatotopic organization/representation, 394, 411
- Sound. *See* Hearing
- Sour taste, 432, 435
- Space constants: action potential propagation, 283–285
- Specific activity, 71
- Specificity of facilitated diffusion, 165
- Spectrin, 105, 501f
- Spectrin-based filament network, 314–315
- Speed of light, 467–468
- Speed of sound, 451–452
- Sperm, 958, 960–961
- Spherical lenses, 468–469
- Sphincters, 772–773, 802
- micturition, 484
 - of Oddi, 773
 - pupillary light reflex, 482–483
 - relaxation, 803
 - upper esophageal, 772–773
- Sphingolipids, 146–147
- using sphingosine, 146
- Sphingomyelin, 146
- Sphingosine, 146
- sphingolipids using, 146
- Sphygmomanometers, 572–573
- Spinal cord
- muscle control, 410, 672
 - nerve function, 373
 - respiratory control, 672
 - reticulospinal tract, 406, 484
 - sympathetic nervous system, 475–477
 - ventilation control, 673

- Spinal reflexes, 400
 crossed-extensor reflexes, 400–401
 descending tracks, 405–406
 lateral corticospinal tract, 405
 lateral vestibulospinal tract, 405–406
 medial vestibulospinal tract, 406
 medullary reticulospinal tract, 406
 pontine reticulospinal tract, 406
 rubrospinal tract, 405
 tectospinal tract, 406
 ventral corticospinal tract, 405
 gamma motor systems, 403
 integrated response, 407
 intrafusal fiber tension, 403
 inverse myotatic reflexes, 403
 locomotor pattern generators, 404–405
 motor control, 410–411
 muscle spindle, 401–402
 myotatic reflexes, 402–403
 painful stimuli, 400
 reflex definition, 400
 withdrawal reflexes, 400–401
- Spirometry
 airway resistance, 635–636
 lung volumes, 633
 maximum voluntary ventilation, 635–636
- Splanchnic nerves, 799
- Splay, 721
- Spliceosomes, 126f
- Spongy bone, 933
- Spontaneous to nonspontaneous process
 coupling, 90f
- SR. *See* Sarcoplasmic reticulum (SR)
- SST. *See* Somatostatin (SST)
- Standard deviation, sample, 25
- Standard error of the mean, 25
- Standard Hydrogen Electrode, 229
- Standard redox potential, 229
- Standard reduction potential, 229
- Standard temperature and pressure, dry (STPD),
 643t, 645, 652
- Stapes, 441–442
- Starch, 811, 825–826
- Starling forces, 585, 711–713
- Starvation and estrogen reducing adult height,
 879–880
- Static forces of gravity, 419
- Static pressure: breathing mechanics, 628
- Static response phenomena, 610
- Steady-state flows: pressure-driven flow, 17–18,
 19–20
- Steady-state gas exchange equations, 651–652
- Steady-state operating points, 604, 605
- Stem cells, 502, 507–508
- Stenosis, 563
- Stercobilin, 502–503
- Stereocilia, 444–445
- Stereoisomers, 51
- Sternum, 625
- Steroid hormones, 125–126, 854, 857, 858,
 948
 ACTH, 908–909
 adrenal cortex, 906–907
- Steroidogenesis: ovarian, 953
- Stethoscopes, 520
- STIM1 (stromal interacting molecule), 333
- Stimuli awareness, 390
- Stimuli perception, 390
- Stimulus-secretion coupling, 206
- Stock solution dilutions, 61b
- Stoichiometry, 48–49
- Stokes equation, 119
- Stokes–Einstein equation, 81–82
- Stomach, 782, 785
 acid secretion, 790
 cephalic phases, 791
 chemoreceptors, 791–793
 colonic motility, 803
 contractions, 787–788
 emptying, 788, 804
 extrinsic innervation, 799
 food, 772–773
 gastric
 accommodation, 787
 lipase, 790–791
 motility, 785–786, 787
 phases, 791–794, 812–813, 822–824
 slow waves, 785–786
 grinding, 787–788
 hydrochloric acid secretion stomach, 790
 intestinal acid secretion phases, 791–794
 intrinsic factor secretion, 790–791
 lower esophageal sphincter, 782
 migrating motility complex, 789
 mucus secretion, 790–791
 nerve cell ganglionic plexuses, 782
 orad stomach, 787
 pacemaker cells, 785–786
 pepsinogen secretion, 790–791
 postprandial pancreatic enzyme secretion,
 812–813
 protein digestion, 822–824
 regions, 785
 small intestine, 785
 stretch receptors, 791–793
 vomiting, 804
- STPD. *See* Standard temperature and pressure,
 dry (STPD)
- Streamline flow. *See* Laminar flow
- Strength training, 343
- Strength–duration relationship, 268
 amount of charge necessary to reach
 threshold, 274
 threshold depolarization, 273
- Stressed volumes, 601–602, 608–609
- Stretch receptors
 antidiuretic hormone secretion, 745
 colonic contraction, 803
 stomach, 791–793
- Striated muscle, 292, 305, 548
- Stroke volume (SV)
 afterload, 556, 558–559
 cardiac output, 556
 contractility, 556
 Frank–Starling law, 558
 preload, 556, 558–559
 pulse pressure, 570–571
- Structural isomers, 51
- Subcellular fractionation, 115
- Subendocardium, 540–541
- Subepicardium, 540–541
- Sublingual glands, 775
- Submandibular glands, 775
- Submucosal plexus, 782, 796–798
- Substantia nigra, 415
- Sulfonylurease, 898
- Superior cervical ganglia, 476
- Superior mesenteric ganglia, 475, 799
- Superior vena cava, 518
- Supporting cells: nervous tissue, 375
- Suppressor T cells, 510
- Supraoptic nuclei, 744
- Surface membranes: smooth muscle, 354–356
- Surface pressure: biological membranes, 149
- Surface recognition: cell structure, 102
- Surface tension
 biological membranes, 149
 lung expansion, 627
 problem sets, 156
 pulmonary surfactants, 627–628
- Svedberg units, 118
- Swallowing, 680, 780
- Sweet taste, 432, 436
- Swelling, 508–509
- Sympathetic nervous system, 473
 adrenal medulla, 916
 baroreflex, 611–612
 calcium ion induced cardiac contraction,
 552–553
 gut extrinsic innervation, 799
 insulin secretion, 897–898
 micturition, 484
 origin, 475–477
 pacemaker potential, 529–530
 rostral ventrolateral medulla, 612
 target tissue stimulation effects, 482
 vascular system control, 596
- Sympathetic tetralogy, 615
- Symports, 176
- Synapses, 318, 375
- Synaptobrevin, 329–330
- Synaptotagmin, 329–330
- Syndrome of inappropriate antidiuretic
 hormone secretion (SIADH), 739b
- Synovial fluid, 691
- Syntaxin, 329–330
- System, understanding, 6
- Systemic circulation, 491–493
- Systemic perfusion regulation, 592
- Systemic pressure, 601
- Systemic testosterone effects, 963
- Systole contraction, 516
- Systolic pressure, 570, 572–573
- Systolic volume, 556, 561
- T**
- T wave subepicardium repolarization, 540–541
- TAARs. *See* Trace amine-associated receptors
 (TAARs)
- Talin, 314–315
- Target cells, 221
 autonomic nervous system, 482
 cortisol, 910–911
 hormones, 859, 861
 integrated control, 933
- Taste, 427
 bitter taste, 436
 hot taste, 436–437
 pain receptors, 436–437
 salty taste, 434–435
 sour taste, 435
 sweet taste, 436
 taste buds, 433–434
 types, 432
 umami taste, 436
- Taste receptor cells, 435
- TBW. *See* Total body water (TBW)
- TCA. *See* Tricarboxylic acid (TCA) cycle
- Tectorial membrane, 444–445
- Tectospinal tract, 406
- Teleology, 5
- Telophase, 958
- Temperature
 cutaneous sensory systems, 395
 oxygen dissociation curves, 660, 660
 speed of sound, 452–453
- Temporal lobes
 olfactory output, 429–431
 vision, 465
- Temporalis muscle, 773
- Temporomandibular joint syndrome, 775b
- Tendon muscle force sensors, 403
- Tensegrity
 cytoskeletal units, 106

- Terminal arterioles, 578
 Terminal bronchioles, 624
 Terminal cisternae, 306
 Terminal ileum, 833
 Tertiary follicle, 952
 Tertiary protein structure, 136–137
 Testicles, 960–961, 961–963
 Testosterone, 963
 Tetanus, 296
 Tetany, 326
 Tetralogy of Fallot heart defects, 523
 Thalamus
 function, 373
 olfactory output, 431
 taste receptors, 438
 Thecal layer, 951–952
 Thermal dilution method, 563
 Thermocouples, 16
 Thermodynamic derivation: van't Hoff's law, 184–185
 Thermogenesis, 250b
 Thermoreceptors, 393
 Thick filaments
 cardiac contractility, 548–549
 skeletal muscle contractility, 305, 308–309
 Thick-walled spheres: cardiac muscle
 contraction, 517–518
 Thin filaments
 cardiac contractility, 548–549
 skeletal muscle contractility, 305, 309–310
 Thin lens formulae, 467–470
 Thin-walled spheres: cardiac muscle
 contraction, 516–517
 Thiokinase, 243
 Thiolase, 246
 Third degree heart blocks, 544
 Thirst, 596–597
 Thoracic cage, 625
 Thoracic cavity, 516, 625
 Thoracic duct, 585, 829–831
 Thoracolumbar spinal cord, 475–477
 Thorax, 537–539
 Threshold depolarization
 strength–duration relationship, 273
 Thrombi, 494
 Thrombin, 494, 496
 Thrombopoietin (TPO), 507
 Thromboxane, 494, 593, 595, 596
 Thymine, 120
 Thyroglobulin, 883, 885
 Thyroid gland, 883, 921, 963
 Thyroid hormone: metabolic control, 921
 Thyroid stimulating hormone (TSH), 885, 963
 Thyroxine, 883, 884–885
 Tidal volume (TV), 633
 anatomic dead space, 647
 exercise, 635
 pulmonary ventilation, 635
 Timbre: hearing, 440–441
 Time constant, 40
 capacitor, charging of, 39–40
 Tissue factor pathway inhibitor (TFPI), 496
 Tissue plasminogen activator (tPA), 495
 Tissues
 cardiac output distribution, 568
 inflammation, 511
 integrated control, 933
 macrophages, 508, 510–511
 neurons, 375
 oxygen delivery, 659
 perfusion regulation, 589
 supporting cells, 375
 thyroid hormones, 886–888
 Titin filaments, 548
 Titratable acid, 754, 755
 Titration curve plots, 859, 860, 867–868
 T-lymphocytes, 510
 Tone: hearing, 440–441
 Tonically-based contractile activity, 351
 Tonicity, 191–192
 Tonotopic mapping of sound frequency, 445–446
 Total body water (TBW), 689, 691
 Total lung capacity (TLC), 634
 Total peripheral resistance (TPR), 602–603, 604, 610, 614
 Total peripheral resistance–cardiac output relationships, 614
 Toxins: action potentials, 270
 tPA. *See* Tissue plasminogen activator (tPA)
 TPO. *See* Thrombopoietin (TPO)
 TPR. *See* Total peripheral resistance (TPR)
 Trabeculae, 933
 Trace amine-associated receptors (TAARs), 428
 Trachea: breathing mechanics, 623–624
 Tracheae: breathing mechanics, 644
 Tracheobronchial tree, 624
 Training of muscle, 334
 Transamination reactions, 247
 Transcellular fluid compartments, 691
 Transcription, 123–125
 cell signaling, 213
 cortisol, 910–911
 histone code, 126–127
 Transcription factors, 125, 214–215
 Transcutaneous electrical neural stimulation, 397
 Transcytosis, 578–579, 584
 Transduction, 205
 Transfer ribonucleic acid (tRNA), 123
 Transferrin, 499
 Transient diabetes insipidus, 739
 Transition state theory, 67–70
 Translation, 122, 126f
 Translocon proteins, 108
 Transmembrane proteins, 151–152, 314–315
 Transmembrane resistance: action potential propagation, 282
 Transmissible spongiform encephalopathies (TSE), 139
 Transport mechanisms. *See also* Diffusion
 active transport
 antiports, 175–176
 cell structure, 102
 electrochemical potentials, 170–172
 energetics, 170–172
 exchangers, 170
 ion permeation, 170–172
 material transport, 172
 metabolic energy, 172
 phosphorylated intermediates, 173
 pumps, 170
 sodium, potassium-ATPase, 172–173
 sodium, potassium-ATPase as electrogenic, 173–174
 sodium–calcium exchangers, 174–175
 symports, 176
 cell structure, 101, 102
 cytosol, 103
 passive mechanisms, 161
 cell structure, 102
 reabsorption of urea, 728
 resting expiration, 626
 solute exchange, 579
 water, 168
 tubular, 731–736
 urea, 733
 Transport proteins, nomenclature of, 179
 ABC transporters, 181
 aquaporins, 181
 ATP-driven ion pumps, 181
 carrier classifications, 179
 HUGO nomenclature, 179
 solute carriers, 179–181
 Transverse (T) tubules, 306, 549, 550
 Treppe phenomena, 552
 TRIC-A (trimeric intracellular cationselective channel), 332–333
 Tricarboxylic acid (TCA) cycle, 227
 Tricuspid valve, 518
 Trigeminal nerve, 431–432, 773
 Triglycerides, 241–242
 Triiodothyronine, 883
 Tripalmitin, 246b
 Tropomyosin, 310, 548–549
 Troponin, 310
 TSE. *See* Transmissible spongiform encephalopathies (TSE)
 TSH. *See* Thyroid stimulating hormone (TSH)
 T-tubules, multiple proteins on
 Calcium Release Unit, 331–333
 T-type calcium ion channels, 528–529
 Tubules. *See also* Nephrons
 acid excretion, 753
 acidosis, 763b
 pH, 757–759
 reabsorption/secretion, 705, 719
 transport mechanisms, 736
 Tubulin, 103f
 Tubuloglomerular feedback, 742
 Tunic intima, 590
 Tunica adventitia, 590
 Tunica media, 590
 Tuning: pitch perception, 447–448
 Turbinates, 623
 Turbulent airflow, 636–637, 638
 Turnover
 compartmental analysis, 72–74
 TV. *See* Tidal volume (TV)
 Twitch waveforms, 326–327
 TXA₂. *See* Thromboxane
 Tympanostomy, 444
 Type I error, 27, 27
 Type II error, 27, 27
 Type IV collagen, 710
 Tyrosine, 212, 382, 916
 Tyrosine kinases, 212, 899
- ## U
- Ubiquitin, 110
 Ubiquitinylation reaction, 110f
 Ulcers, 794b
 Ultrafiltrate/ultrafiltration
 glomerular filtration, 705, 711–713
 barriers, 713
 pressure-driven flow, 20b
 proximal tubule, 725
 Umami taste, 432, 436
 Uncompensated metabolic acidosis, 670
 Uncompensated metabolic alkalosis, 670
 Understanding a system, 6
 Unidirectional fluxes, 70–72
 and net fluxes, 70–72
 Unipolar leads: electrocardiograms, 542–543
 Unitary conductances: action potentials, 271
 Universal donors/recipients, 504
 Unmyelinated axons, 265
 Unmyelinated baroreceptor C fibers, 610
 Unstressed volumes, 601–602, 608–609
 Upper esophageal sphincter, 772–773
 Upregulated dose–response curves: hormones, 860–861
 Uracil, 122

- Urea
elimination, 247–251
inner medulla
collecting duct, 733
osmotic gradients, 736
loop of Henle, 732
production, 247–251
proximal convoluted tubule, 727
reabsorption mechanisms, 727
- Urease, 794
- Ureters, 698, 698–699
- Urethra, 698
- Urinary system, 698. *See also* Kidneys
concentration mechanisms, 730
dilution mechanisms, 730
excretion
calcium ions, 940–941
PI, 940–941
glomerular filtration, 740–741
limiting pH, 757–758
metabolic acidosis, 760
metabolic alkalosis, 760–761
nitrogen, 837
- Urobilin, 502–503
- Ursodeoxycholic acid, 815
- Ussing flux ratio equation, derivation of, 178–179
- Uterus, 871, 946, 947–948
- Utricles, 419
- V**
- Vagal efferents, 612
- Vagina, 946
- Vagovagal reflexes, 780–781, 787, 813
- Vagus, 478
afferent fibers, 799
gut parasympathetic innervation, 799
pacemaker potential, 530
stomach, 791
ventilation control, 673, 675–676, 676f
- Van der Waals force, 55
repulsive force
Lennard–Jones potential, 55
- Van't Hoff equations, 182–184, 187
- Van't Hoff's law, 182, 184–185
- Vapor pressure, 643, 644
- Variance, population, 25
- Variance, sample, 25
- Vasa recta, 701, 736
- Vascular system
blood flow, 493
circulatory system overview, 489
function
arterial compliances, 602–603
arteriolar resistance, 604
blood volume, 605
cardiac function matching, 599–600
hemodynamics, 568
positive right atria pressures, 603–604
steady-state operating points, 604
venous compliances, 602–603
hemostasis, 494–495
paracrine secretions, 595–596
perfusion regulation, 590, 591–592
platelet plugs, 494
resistance, 576
sympathetic nervous system, 596
- Vasoactive intestinal peptide (VIP), 778–779
- Vasoconstriction, 650
arteriolar resistance, 604
bleeding restriction, 494
kidneys, 704
perfusion regulation, 589–590
- Vasodilation
arteriolar resistance, 604
inflammation, 511
perfusion regulation, 591–592, 593, 594–595
- Vasomotion phenomena, 583–584
- Vasopressin. *See* Antidiuretic hormone (ADH)
- VC. *See* Vital capacity (VC)
- Veins
arcuate veins, 700f, 701
circulatory system overview, 489
interlobar veins, 701
- Velocity centrifugation, 116
- Venoconstriction, 602
- Venous compliances, 602–603
- Venous return, 599
- Ventilation control, 623, 672
- Ventilation/perfusion ratios, 649–650
- Ventilatory acclimatization, 679
- Ventilatory drive
carbon dioxide pressure, 678
hypercapnia, 678, 678
hypoxia, 679
metabolic acidosis, 678–679
- Ventilatory response: chemoreceptor firing rates, 677
- Ventral corticospinal tract, 405
- Ventral respiratory group (VRG), 672, 673–674
- Ventricles, 518, 519
action potentials, 528, 530–534
cerebral spinal fluid, 369–370
electrocardiograms, 540
filling, 520–522
function curves, 558
- Ventromedial hypothalamus (VMH), 839
- Venules, 489, 578
- Very-low density lipoproteins (VLDL), 499
- Vesicles
cytoskeleton, 103
fusion, 379–380
pre-synaptic terminals, 381
transcytosis, 584
- Vessels. *See* Blood—vessels
- Vestibular apparatuses
afferent sensory neurons, 419
balance, 415–419
head rotation, 419
- Vestibular nuclei, 419
- Vestibulospinal tract, 405–406
- Video esophagography, 783
- Villi, 105, 797
- Villin, 105
- Vinculin, 314–315
- VIP. *See* Vasoactive intestinal peptide (VIP)
- Visceral pleura, 625f
- Viscosity, 19–20
- Vision, 456
bipolar cells, 462–463
central pathway crossover, 463–464
eye shape, 458
eye structure, 456–458
far-sightedness, 459–460
ganglion cells, 462–463, 464
near-sightedness, 459–460
system overview, 456
visual cortex, 464–465
vitreous body, 458
- Vital capacity (VC), 633–634
- Vitalism, 5–6
- Vitamin B₁₂, 506
- Vitamin D
activation, 929
bone mineralization, 931, 941–942
definition, 929
forms, 930
goals, 941–942
- inactivation, 929
- kidneys, 703
- metabolism, 929–930
- 25(OH)2-D, 930–931
- synthesis, 928–929
- Vitreous body: eye shape, 458
- VLDL. *See* Very-low density lipoproteins (VLDL)
- VMH. *See* Ventromedial hypothalamus (VMH)
- Volatile acids, 752
- Voltage-dependent changes: action potentials, 268–269
- Voltage-gated ion channels, 167, 206
- Volume
blood
antidiuretic hormone, 873
integrated response, 749
long-term blood pressure regulation, 613–615
vascular function curves, 605
body fluid compartments, 689, 690
concentration, 60
diastolic volume, 556–557
end-diastolic volume, 520–522, 556–557
end-systolic volume, 556, 561
expiratory reserve volume, 633
Fick dilution principle, 62
fluid problem sets, 715
integrated response, 749–750
lungs, 633
air movement, 625
airway resistance, 638–639
anatomic dead space, 647
body size, 634
capacity, 633–634
spirometry, 633
partial volumes, 652
plasma volume estimations, 62b
pressure-driven flow, 18
pressure–volume loops, 556–557
regulatory volumes, 193
residual volume, 633, 634t
spirometry, 633
stressed volumes, 601–602, 608–609
stroke
afterload, 556, 558–559
cardiac output, 556
contractility, 556
Frank–Starling law, 558
preload, 556, 558–559
pulse pressure, 570–571
systolic volume, 556, 561
tidal volume, 633, 635, 647
unstressed volumes, 601–602, 608–609
vascular function, 569–570
- Volume contraction, 762
- Voluntary ventilation control, 672
- Vomiting, 668, 804
- Von Willebrand factor (vWF), 496
- VRG. *See* Ventral respiratory group (VRG)
- V-type ATPases, 174
- vWF. *See* von Willebrand factor (vWF)
- VX nerve gas, 484
- W**
- Warm receptors, 393
- Warming of air: breathing, 623–624
- Water
antidiuretic hormone, 744
aquaporins, 168, 727, 731, 751
biological membranes
amphiphatic molecules, 149
phospholipids, 146–147
surface tension, 147
body fluid compartments, 692, 694–695

bonding of atoms, 48, 54
 collecting duct, 733
 degrees of freedom, 56*f*
 distal nephron permeability, 745
 filtered load, 719
 free diffusion coefficients, 79–80
 gas dissolution, 644–645
 hydrogen bonds, 54
 inulin, 725
 late distal tubule, 733
 late proximal tubule, 728
 loop of Henle, 730, 732
 nephron adjustment, 743–744
 osmotic pressure, 182, 584, 584, 727–728
 passive transport, 168
 plasma blood cells, 498–500
 polar bonds, 53–54
 protein structure, 134
 reabsorption mechanisms, 725, 727–728,
 743–744

secondary protein structure, 134–136
 structure, 54*f*
 urine concentration, 730–731
 vapor pressure, 643, 644
 Wave equations: propagation of sound,
 454–455
 Wave summation: repetitive stimulation,
 327
 Weber–Fechner law of psychology, 391–392
 Weight regulation, 838
 White blood cells, 494, 507
 White ramus communicans,
 475
 Whole-cell current–voltage relationship,
 275*f*
 Why? questions, 5
 Withdrawal reflexes, 400–401
 Womb. *See* Uterus
 Work
 conservative forces, 33–34

electrical potential, 31–32
 fatigue, 341–343
 Wound closure, 495
 Woven bone, 934

X

Xenobiotics, 816
 Xenochemicals, 814

Y

Y⁺L system, 825

Z

Zero electrodes, 542–543
 Z-lines/disks: muscle, 306, 310
 Zona glomerulosa, 911
 Zonula adherens, 111
 Zonula occludens, 110–111
 Zwitterions, 130