

# visual anatomy & physiology

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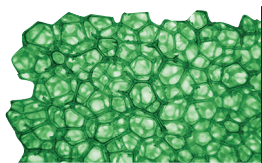
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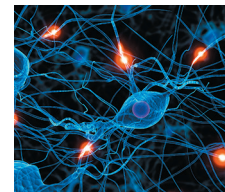
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- 17.1 Blood is the fluid portion of the cardiovascular system 673
- 17.2 Blood is a fluid connective tissue containing plasma and formed elements 674
- 17.3 Formed elements are produced by stem cells in red bone marrow 676

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## SECTION 2 Structure and Function of Formed Elements 679

- 17.4 Hematology is the study of blood and blood-forming tissues 679
- 17.5 Red blood cells, the most common formed elements, contain hemoglobin that transports respiratory gases 680
- 17.6 Red blood cells are continually produced and their components recycled or eliminated 682
- 17.7 Blood type is determined by the presence or absence of specific surface antigens on RBCs 684
- 17.8 **CLINICAL MODULE:** Hemolytic disease of the newborn is an RBC-related disorder caused by a cross-reaction between fetal and maternal blood types 686
- 17.9 The various types of white blood cells contribute to the body's defenses 688
- 17.10 The clotting response is a complex cascade of events that reduces blood loss 690
- 17.11 **CLINICAL MODULE:** Blood disorders can be classified by their origins and the changes in blood characteristics 692

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### Chapter 17 Review 695

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# 18 The Heart and Cardiovascular Function 700



## SECTION 1 Structure of the Heart 701

- 18.1 The heart has four chambers that pump and circulate blood through the pulmonary and systemic circuits 701
- 18.2 The heart is located in the mediastinum and is enclosed by the pericardial cavity 702
- 18.3 The heart wall contains concentric layers of cardiac muscle tissue 704
- 18.4 The boundaries between the four chambers of the heart can be identified on its external surface 706
- 18.5 The heart has an extensive blood supply 708
- 18.6 Internal valves control the direction of blood flow between the heart chambers and great vessels 710
- 18.7 When the heart beats, the AV valves close before the semilunar valves open, and the semilunar valves close before the AV valves open 712
- 18.8 **CLINICAL MODULE:** Arteriosclerosis can lead to coronary artery disease 714

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## SECTION 2 Cardiac Cycle 717

- 18.9 The cardiac cycle is a complete round of systole and diastole 717
  - 18.10 The cardiac cycle creates pressure gradients that maintain blood flow 718
- SmartArt Video:** The cardiac cycle 719
- 18.11 Cardiac muscle cell contractions last longer than skeletal muscle fiber contractions primarily because of differences in calcium ion membrane permeability 720

**SmartArt Video:** The conducting system of the heart 721

- 18.12 Electrical events of pacemaker cells and conducting cells establish the heart rate 722
- 18.13 **CLINICAL MODULE:** Normal and abnormal cardiac activity can be detected in an electrocardiogram 724
- 18.14 The intrinsic heart rate can be altered by autonomic activity 726
- 18.15 Stroke volume depends on the relationship between end-diastolic volume and end-systolic volume 728
- 18.16 Cardiac output is regulated by adjustments in heart rate and stroke volume 730

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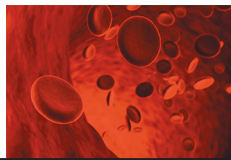
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## 19 Blood Vessels and Circulation 738



### SECTION 1 Functional Anatomy of Blood Vessels 739

- 19.1 The heart pumps blood, in sequence, through the arteries, capillaries, and veins of the pulmonary and systemic circuits 739
- 19.2 Arteries and veins differ in the structure and thickness of their walls 740
- 19.3 Capillary structure and capillary blood flow affect the rates of exchange between the blood and interstitial fluid 742
- 19.4 The venous system has low pressures and contains almost two-thirds of the body's blood volume 744

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### SECTION 2 Coordination of Cardiac Output and Blood Flow 747

- 19.5 Pressure, resistance, and venous return affect cardiac output 747
- 19.6 Vessel luminal diameter is the main source of resistance within the cardiovascular system 748
- 19.7 Blood flow is determined by the interplay between arterial pressure and peripheral resistance 750
- 19.8 Capillary exchange is a dynamic process that includes diffusion, filtration, and reabsorption 752
- 19.9 Cardiovascular regulatory mechanisms respond to changes in blood pressure or blood chemistry 754
- 19.10 Endocrine responses to low blood pressure and low blood volume are very different from those to high blood pressure and high blood volume 756
- 19.11 Chemoreceptors monitor the chemical composition of the blood and cerebrospinal fluid 758
- 19.12 The cardiovascular center makes extensive adjustments to cardiac output and blood distribution during exercise 759
- 19.13 **CLINICAL MODULE:** Short-term and long-term mechanisms compensate for a reduction in blood volume 760

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### SECTION 3 Patterns of Blood Flow 763

- 19.14 New blood vessels form through vasculogenesis and angiogenesis 763
- 19.15 The pulmonary circuit carries deoxygenated blood from the right ventricle to the lungs and returns oxygenated blood to the left atrium 764
- 19.16 The arteries and veins of the systemic circuit operate in parallel, and the major vessels often have similar names 766
- 19.17 The branches of the aortic arch supply structures that are drained by the superior vena cava 768
- 19.18 The external carotid arteries supply the neck, lower jaw, and face, and the internal carotid and vertebral arteries supply the brain while the external jugular veins drain the regions supplied by the external carotid arteries, and the internal jugular veins drain the brain 770
- 19.19 The internal carotid arteries and the vertebral arteries supply the brain which is drained by the dural sinuses and the internal jugular veins 772
- 19.20 The regions supplied by the descending aorta are drained by the superior and inferior venae cavae 774
- 19.21 The viscera supplied by the celiac trunk and mesenteric arteries are drained by the branches of the hepatic portal vein 776
- 19.22 The pelvis and lower limbs are supplied by branches of the common iliac arteries and drained by branches of the common iliac veins 778
- 19.23 The arteries of the systemic circuit deliver oxygenated blood throughout the body and the veins of the systemic circuit return deoxygenated blood back to the heart 780
- 19.24 **CLINICAL MODULE:** The pattern of blood flow through the fetal heart and the systemic circuit must change at birth 782

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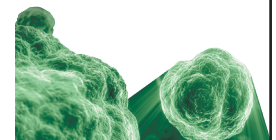
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## 20 The Lymphatic System and Immunity 792



### SECTION 1 Anatomy of the Lymphatic System 793

- 20.1 The lymphatic system consists of lymphatic vessels, nodes, and lymphoid tissue 793
- 20.2 Interstitial fluid flows continuously into lymphatic capillaries and exits tissues as lymph in lymphatic vessels 794
- 20.3 Small lymphatic vessels converge to form lymphatic ducts that empty into the subclavian veins 796
- 20.4 Lymphocytes are responsible for the immune functions of the lymphatic system 798
- 20.5 Lymphocytes aggregate within lymphoid tissues and lymphoid organs 800
- 20.6 The thymus is a lymphoid organ that produces functional T cells 802
- 20.7 The spleen, the largest lymphoid organ, responds to antigens in the bloodstream 804

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## SECTION 2 Innate Immunity 807

- 20.8 Innate immunity is nonspecific and is not stimulated by specific antigens 807
  - 20.9 Physical barriers prevent pathogens and toxins from entering body tissues 808
  - 20.10 Phagocytes respond to pathogen invasion 809
  - 20.11 NK cells perform immune surveillance, detecting and destroying abnormal cells 810
  - 20.12 Interferons and the complement system are distributed widely in body fluids 812
  - 20.13 Inflammation is a localized tissue response to injury; fever is a generalized response to tissue damage and infection 814
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## SECTION 3 Adaptive Immunity 817

- 20.14 Adaptive immunity provides the body's specific defenses 817
  - 20.15 Adaptive immunity is triggered by exposure of T cells and B cells to specific antigens 818
- SmartArt Video:** The immune response 819
- 20.16 Infected cells stimulate the formation and division of cytotoxic T cells, memory T<sub>c</sub> cells, and regulatory T cells 820
  - 20.17 Antigen-presenting cells can stimulate activation of CD4 T cells, producing helper T cells that promote B cell activation and antibody production 822
  - 20.18 Antibodies are small soluble proteins that bind to specific antigens and whose abundance increases upon later antigen exposure 824
  - 20.19 Antibodies use many different mechanisms to destroy target antigens 826
  - 20.20 **CLINICAL MODULE:** Hypersensitivities are abnormal reactions to antigens 827
  - 20.21 Innate immunity and adaptive immunity work together to defeat pathogens 828
  - 20.22 **CLINICAL MODULE:** Immune disorders involving either overactivity or underactivity can be harmful 830
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# 21 The Respiratory System 838



## SECTION 1 Anatomy of the Respiratory System 839

- 21.1 The respiratory system has an upper and lower respiratory tract with different functions 839
- 21.2 The respiratory defense system protects the respiratory mucosa 840
- 21.3 The upper respiratory system includes the nose, nasal cavity, paranasal sinuses, and pharynx 842
- 21.4 The larynx protects the glottis that produces sounds 844
- 21.5 The trachea, bronchi, and bronchial branches convey air to and from lung gas exchange surfaces 846

- 21.6 The lungs have lobes that are subdivided into bronchopulmonary segments 848
  - 21.7 Pulmonary lobules contain alveoli, where gas exchange occurs 850
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- 21.8 Respiratory physiology involves external and internal respiration 853
  - 21.9 Pulmonary ventilation is driven by pressure changes within the pleural cavities 854
  - 21.10 Respiratory muscles are involved with breathing, and pulmonary function tests determine lung performance 856
  - 21.11 Pulmonary ventilation must be closely regulated to meet tissue oxygen demands 858
  - 21.12 Gas diffusion depends on the partial pressures and solubilities of gases 860
- SmartArt Video:** Partial pressures and gas diffusion 861
- 21.13 Almost all the oxygen in blood is transported bound to hemoglobin within red blood cells 862
  - 21.14 Carbon dioxide is transported three ways in the bloodstream 864
  - 21.15 **CLINICAL MODULE:** Pulmonary disease can affect both lung elasticity and airflow 866
  - 21.16 Respiratory control mechanisms involve interacting centers in the brainstem 868
  - 21.17 Respiratory reflexes provide rapid automatic adjustments in pulmonary ventilation 870
  - 21.18 **CLINICAL MODULE:** Respiratory function decreases with age; smoking makes matters worse 872
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# 22 The Digestive System 880



## SECTION 1 Organization of the Digestive System 881

- 22.1 The digestive system consists of the digestive tract and accessory organs 881
  - 22.2 The digestive tract is a muscular tube lined by a mucous epithelium 882
  - 22.3 Smooth muscle tissue is found throughout the body, but it plays a particularly prominent role in the digestive tract 884
  - 22.4 Smooth muscle contractions produce motility of the digestive tract and local factors interact with neural and hormonal mechanisms to regulate digestive activities 886
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## SECTION 2 Digestive Tract 889

- 22.5 The digestive tract begins with the mouth and ends with the anus 889
- 22.6 The oral cavity is a space that contains the tongue, teeth, and gums 890

- 22.7 Teeth in different regions of the jaws vary in size, shape, and function 892
  - 22.8 The muscular walls of the pharynx and esophagus play a key role in swallowing 894
  - 22.9 The stomach and most of the intestinal tract are suspended by mesenteries and covered by the peritoneum 896
  - 22.10 The stomach is a muscular, expandable, J-shaped organ with three layers in the muscular layer 898
  - 22.11 The stomach receives food and liquids from the esophagus and aids in mechanical and chemical digestion 900
  - 22.12 The intestinal tract is specialized to absorb nutrients 902
  - 22.13 The small intestine is divided into the duodenum, jejunum, and ileum 904
  - 22.14 Several hormones regulate digestion 906
  - 22.15 Central and local mechanisms coordinate gastric and intestinal activities 908
  - 22.16 The large intestine stores and concentrates fecal material 910
  - 22.17 The large intestine compacts fecal material; the defecation reflex coordinates the elimination of feces 912
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### SECTION 3 Accessory Digestive Organs 915

- 22.18 Some accessory digestive organs have secretory functions 915
  - 22.19 Saliva lubricates, moistens, and protects the mouth and begins carbohydrate digestion 916
  - 22.20 The liver, the largest visceral organ, is divided into left, right, caudate, and quadrate lobes 918
  - 22.21 The liver tissues have an extensive and complex blood supply 920
- SmartArt Video:** Structure and function of the liver lobule 921
- 22.22 The gallbladder stores and concentrates bile 922
  - 22.23 The pancreas has vital endocrine and exocrine functions 923
  - 22.24 **CLINICAL MODULE:** Disorders of the digestive system are diverse and relatively common 924
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## 23 Metabolism, Nutrition, and Energetics 934



### SECTION 1 Introduction to Cellular Metabolism 935

- 23.1 Metabolism is the sum of catabolic and anabolic reactions 935
- 23.2 Cells use nutrients from the nutrient pool for metabolism 936
- 23.3 Glycolysis is the first step in glucose catabolism 937
- 23.4 The citric acid cycle transfers hydrogen atoms to coenzymes 938
- 23.5 The electron transport chain establishes a proton gradient used to make ATP 940
- 23.6 Glucose catabolism yields 30–32 ATP 942
- 23.7 Nutrient metabolism follows several pathways 943

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### SECTION 2 Digestion and Metabolism of Organic Nutrients 945

- 23.8 Digestion involves a series of steps to make nutrients available to the body 945
  - 23.9 Carbohydrates are usually the preferred substrates for catabolism and ATP production under resting conditions 946
  - 23.10 Lipids reach the bloodstream in chylomicrons; the cholesterol is then extracted and released as lipoproteins 948
  - 23.11 Fatty acids can be broken down to provide energy or converted to other lipids 950
  - 23.12 An amino acid not needed for protein synthesis may be broken down or converted to a different amino acid 952
  - 23.13 There are two general patterns of metabolic activity: the absorptive and postabsorptive states 954
  - 23.14 Vitamins are essential to the function of many metabolic pathways 956
  - 23.15 Proper nutrition depends on eating a balanced diet 958
  - 23.16 **CLINICAL MODULE:** Metabolic disorders may result from nutritional or biochemical problems 960
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### SECTION 3 Energetics and Thermoregulation 963

- 23.17 Energetics is the study of energy changes, and thermoregulation involves heat balance 963
- 23.18 The control of appetite is complex and involves both short-term and long-term mechanisms 964
- 23.19 To maintain a constant body temperature, heat gain and heat loss must be in balance 965
- 23.20 Thermoregulatory centers in the hypothalamus adjust heat loss and heat gain 966

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## 24 The Urinary System 974



### SECTION 1 Anatomy of the Urinary System 975

- 24.1 The urinary system organs are the kidneys, ureters, urinary bladder, and urethra 975
  - 24.2 The kidneys are paired retroperitoneal organs 976
  - 24.3 The kidneys are complex at the gross and microscopic levels 978
  - 24.4 A nephron is divided into segments; each segment has specific functions 980
- SmartArt Video:** Structure of the nephron 981
- 24.5 The kidneys are highly vascular, and the circulation patterns are complex 982

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## SECTION 2 Overview of Renal Physiology 985

- 24.6 The kidneys maintain homeostasis by removing wastes and producing urine 985
- 24.7 Filtration, reabsorption, and secretion occur in specific segments of the nephron and collecting system 986
- 24.8 Filtration occurs at the renal corpuscle 988
- 24.9 The glomerular filtration rate is the amount of filtrate produced each minute 990
- 24.10 Reabsorption predominates along the proximal convoluted tubule, whereas reabsorption and secretion are often linked along the distal convoluted tubule 992
- 24.11 Exchange between the limbs of the nephron loop creates an osmotic concentration gradient in the renal medulla 994
- 24.12 Urine volume and concentration are hormonally regulated 996
- 24.13 Renal function is an integrative process involving filtration, reabsorption, and secretion 998
- 24.14 **CLINICAL MODULE:** Renal failure is a life-threatening condition 1000  
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## SECTION 3 Urine Storage and Elimination 1003

- 24.15 The urinary tract transports, stores, and eliminates urine 1003
- 24.16 The ureters, urinary bladder, and urethra are specialized to conduct urine 1004
- 24.17 Urinary reflexes coordinate urine storage and voiding 1006
- 24.18 **CLINICAL MODULE:** Urinary disorders can often be detected by physical examinations and laboratory tests 1007  
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## 25 Fluid, Electrolyte, and Acid-Base Balance 1014



## SECTION 1 Fluid and Electrolyte Balance 1015

- 25.1 Body composition may be viewed in terms of solids and two fluid compartments 1015
- 25.2 Fluid balance exists when water gain equals water loss 1016
- 25.3 Mineral balance involves balancing electrolyte gain and loss 1018
- 25.4 Water balance depends on sodium balance, and the two are regulated simultaneously 1020
- 25.5 **CLINICAL MODULE:** Disturbances of potassium balance are uncommon but extremely dangerous 1022  
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## SECTION 2 Acid-Base Balance 1025

- 25.6 There are three categories of acids in the body 1025
- 25.7 Potentially dangerous disturbances in acid-base balance are opposed by buffer systems 1026
- 25.8 Buffer systems can delay, but not prevent, pH shifts in the ICF and ECF 1028

- 25.9 The homeostatic responses to metabolic acidosis and alkalosis involve respiratory and renal mechanisms as well as buffer systems 1030
- 25.10 **CLINICAL MODULE:** Respiratory acid-base disorders are the most common challenges to acid-base balance 1032  
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## 26 The Reproductive System 1040



## SECTION 1 Male Reproductive System 1041

- 26.1 Male reproductive structures include the external genitalia and internal genitalia 1041
- 26.2 Sperm transport relies on ducts, glands, and related structures of the scrotum and testes 1042
- 26.3 Spermatogenesis occurs in the testes and produces mature sperm 1044
- 26.4 Meiosis and early spermiogenesis occur within the seminiferous tubules 1046
- 26.5 The male reproductive tract receives secretions from the seminal, prostate, and bulbo-urethral glands 1048
- 26.6 The penis conducts urine and semen to the exterior 1050
- 26.7 Testosterone plays a key role in establishing and maintaining male sexual function 1052  
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## SECTION 2 Female Reproductive System 1055

- 26.8 Female reproductive structures include the external genitalia and internal genitalia 1055
- 26.9 Major female reproductive organs are the ovaries, uterus, and their associated structures 1056
- 26.10 Oogenesis occurs in the ovaries, and ovulation occurs during the 28-day ovarian cycle 1058
- 26.11 The uterine tubes are connected to the uterus, a hollow organ with thick muscular walls 1060
- 26.12 The uterine (menstrual) cycle involves changes in the functional layer of the endometrium 1062
- 26.13 The vagina opens into the vestibule 1064
- 26.14 Each breast contains a mammary gland that secretes milk 1065
- 26.15 The ovarian and uterine cycles are regulated by hormones of the hypothalamus, pituitary gland, and ovaries 1066
- 26.16 **CLINICAL MODULE:** Birth control strategies vary in effectiveness and associated risks 1068
- 26.17 **CLINICAL MODULE:** Reproductive system disorders are relatively common and often deadly 1070  
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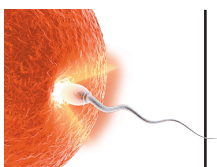
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# 27 Development and Inheritance 1078



## SECTION 1 Overview of Development 1079

- 27.1 Gestation and development are marked by various stages 1079
- 27.2 At fertilization, an ovum and a sperm form a zygote that prepares for cell division 1080
- 27.3 Cleavage continues until the blastocyst implants in the uterine wall 1082
- 27.4 Gastrulation produces three germ layers: ectoderm, endoderm, and mesoderm 1084
- 27.5 The extra-embryonic membranes form the placenta that supports fetal growth and development 1086
- 27.6 The formation of extra-embryonic membranes is associated with major changes in the shape and complexity of the embryo 1088
- 27.7 The placenta performs many vital functions during prenatal development 1090
- 27.8 Organ systems form in the first trimester and become functional in the second and third trimesters 1092
- 27.9 Pregnancy places anatomical and physiological stresses on maternal systems 1094
- 27.10 Multiple factors initiate and accelerate labor and delivery 1096

- 27.11 After delivery, development initially requires nourishment by maternal systems 1098
- 27.12 Postnatal development includes five life stages 1099
- 27.13 At puberty, male and female sex hormones have differing effects on most body systems 1100

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## SECTION 2 Genetics and Inheritance 1103

- 27.14 A person may be described in terms of genotype and phenotype 1103
- 27.15 Genes and chromosomes determine patterns of inheritance 1104
- 27.16 There are several different patterns of inheritance 1106
- 27.17 **CLINICAL MODULE:** Many clinical disorders are linked to individual chromosomes or their genes 1108

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