Pearson Campbell Biology
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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
1. Introduction: Themes in the Study of Life				
1.1 Themes connect the concepts of biology				3-11
1.2 The Core Theme: Evolution accounts for the unity and diversity of life				12-18
1.3 Scientists use two main forms of inquiry in their study of nature				18-24
2. The Chemical Context of Life				
2.1 Matter consists of chemical elements in pure form and in combination called compounds				31-32
2.2 An element's properties depends on the structure of its atoms				32-37
2.3 The formation and function of molecules depend on chemical bonding between atoms				38-42
2.4 Chemical reaction make and break chemical bonds				42-43
3. Water and the Fitness of the Environment				
3.1 The polarity of water molecules result in hydrogen bonding	2.A.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization	46-47	Cohesion 47, 48, 775; Adhesion 47, 48, 775; High specific heat capacity 49; Heat of vaporization 49; Universal solvent supports reactions 50, 51; Root hairs 739, 740, 741; Cells of the alveoli 923, 925; Cells of the villi 889; Microvilli 100, 101, 899	
3.2 Four emergent properties of water contribute to Earth's fitness for life	2.A.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization	47-52	Cohesion 47, 48, 775; Adhesion 47, 48, 775; High specific heat capacity 49; Heat of vaporization 49; Universal solvent supports reactions 50, 51; Root hairs 739, 740, 741; Cells of the alveoli 923, 925; Cells of the villi 889; Microvilli 100, 101, 899	
3.3 Acidic and basic conditions affect living organisms	2.A.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization	52-56	Cohesion 47, 48, 775; Adhesion 47, 48, 775; High specific heat capacity 49; Heat of vaporization 49; Universal solvent supports reactions 50, 51; Root hairs 739, 740, 741; Cells of the alveoli 923, 925; Cells of the villi 889; Microvilli 100, 101, 899	
4. Carbon and the Molecular Diversity of Life				
4.1 Organic Chemistry in the study of carbon compounds	1.D.1 There are several hypotheses about the natural origin of life on Earth, each with supporting evidence	58-59		
	2.A.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization		Cohesion 47, 48, 775; Adhesion 47, 48, 775; High specific heat capacity 49; Heat of vaporization 49; Universal solvent supports reactions 50, 51; Root hairs 739, 740, 741; Cells of the alveoli 923, 925; Cells of the villi 889; Microvilli 100, 101, 899	
4.2 Carbon atoms can form diverse molecules by bonding to four other atoms	2.A.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization	60-63	Cohesion 47, 48, 775; Adhesion 47, 48, 775; High specific heat capacity 49; Heat of vaporization 49; Universal solvent supports reactions 50, 51; Root hairs 739, 740, 741; Cells of the alveoli 923, 925; Cells of the villi 889; Microvilli 100, 101, 899	
4.3 A small number of chemical groups are key to the functioning of biological molecules				63-66
5. The Structure and Function of Large Biological Molecules				
5.1 Macromolecules are polymers, built from monomers	4.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule	68-69		
	4.C.1 Variations in molecular units provides cells with a wider range of functions		Different types of phospholipids in cell membranes 65, 76, 77, 99, 125; Different types of hemoglobin 83, 84, 437, 440, 912, 913, 924; MHC proteins 938, 939; Chlorophylls 5, 101, 111, 186, 187, 196, 197; Molecular diversity of antibodies in response to an antigen 937, 938, 939	
5.2 Carbohydrates serve as fuel and building material	4.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule	69-74		
	4.C.1 Variations in molecular units provides cells with a wider range of functions		Different types of phospholipids in cell membranes 65, 76, 77, 99, 125; Different types of hemoglobin 83, 84, 437, 440, 912, 913, 924; MHC proteins 938, 939; Chlorophylls 5, 101, 111, 186, 187, 196, 197; Molecular diversity of antibodies in response to an antigen 937, 938, 939	
5.3 Lipids are a diverse group of hydrophobic molecules	4.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule	74-77		
	4.C.1 Variations in molecular units provides cells with a wider range of functions		Different types of phospholipids in cell membranes 65, 76, 77, 99, 125; Different types of hemoglobin 83, 84, 437, 440, 912, 913, 924; MHC proteins 938, 939; Chlorophylls 5, 101, 111, 186, 187, 196, 197; Molecular diversity of antibodies in response to an antigen 937, 938, 939	

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5.4 Proteins have many structures, resulting in a wide range of functions	4.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule	77-86		
	4.B.1 Interactions between molecules affect their structure and function			
	4.C.1 Variations in molecular units provides cells with a wider range of functions		Different types of phospholipids in cell membranes 65, 76, 77, 99, 125; Different types of hemoglobin 83, 84, 437, 440, 912, 913, 924; MHC proteins 938, 939; Chlorophylls 5, 101, 111, 186, 187, 196, 197; Molecular diversity of antibodies in response to an antigen 937, 938, 939	
5.5 Nucleic acid store and transmit hereditary information	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	86-89	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155, ; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
	4.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule			
	4.C.1 Variations in molecular units provides cells with a wider range of functions		Different types of phospholipids in cell membranes 65, 76, 77, 99, 125; Different types of hemoglobin 83, 84, 437, 440, 912, 913, 924; MHC proteins 938, 939; Chlorophylls 5, 101, 111, 186, 187, 196, 197; Molecular diversity of antibodies in response to an antigen 937, 938, 939	
6. A Tour of the Cell				
6.1 To study cells, biologists use microscopes and the tools of biochemistry				94-97
6.2 Eukaryotic cells have internal membranes that compartmentalize their functions	2.A.3 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization	98-102	Cohesion 47, 48, 775; Adhesion 47, 48, 775; High specific heat capacity 49; Universal solvent supports reactions 50, 51; Root hairs 739, 740, 741; Cells of the alveoli 923, 925; Cells of the villi 889; Microvilli 100, 101, 899	
	2.B.3 Eukaryotic cells maintain internal membranes that partition the cell into specialized regions		Endoplasmic reticulum 100, 101, 103, 105, 106, 109, 123; Mitochondria 100, 101, 103, 105, 107, 110, 123, 159; Chloroplasts 101, 111, 123; Golgi 100, 101, 109, 123; Nuclear envelope 100, 101, 103, 105, 109, 123	
	4.A.2 The structure and function of subcellular components, and their interactions, provide essential cellular processes			
6.3 The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes	2.B.3 Eukaryotic cells maintain internal membranes that partition the cell into specialized regions	102-104	Endoplasmic reticulum 100, 101, 103, 105, 106, 109, 123; Mitochondria 100, 101, 103, 105, 107, 110, 123, 159; Chloroplasts 101, 111, 123; Golgi 100, 101, 109, 123; Nuclear envelope 100, 101, 103, 105, 109, 123	
	4.A.2 The structure and function of subcellular components, and their interactions, provide essential cellular processes			
6.4 The endomembrane system regulates protein traffic and performs metabolic functions in the cell	2.B.3 Eukaryotic cells maintain internal membranes that partition the cell into specialized regions	104-108	Endoplasmic reticulum 100, 101, 103, 105, 106, 109, 123; Mitochondria 100, 101, 103, 105, 107, 110, 123, 159; Chloroplasts 101, 111, 123; Golgi 100, 101, 109, 123; Nuclear envelope 100, 101, 103, 105, 109, 123	
	4.A.2 The structure and function of subcellular components, and their interactions, provide essential cellular processes			
	4.B.2 Cooperative interactions within organisms promote efficiency in the use of energy and matter		Endoplasmic reticulum 100, 101, 103, 105, 106, 109, 123; Mitochondria 100, 101, 103, 105, 107, 110, 123, 159; Chloroplasts 101, 111, 123; Golgi 100, 101, 109, 123; Nuclear envelope 100, 101, 103, 105, 109, 123	
6.5 Mitochondria and chloroplasts change energy from one form to another	2.B.3 Eukaryotic cells maintain internal membranes that partition the cell into specialized regions	109-111	Endoplasmic reticulum 100, 101, 103, 105, 106, 109, 123; Mitochondria 100, 101, 103, 105, 107, 110, 123, 159; Chloroplasts 101, 111, 123; Golgi 100, 101, 109, 123; Nuclear envelope 100, 101, 103, 105, 109, 123	
	4.A.2 The structure and function of subcellular components, and their interactions, provide essential cellular processes			
6.6 The cytoskeleton is a network of fibers that organizes structures and activities in the cell				112-118
6.7 Extracellular components and connections between cells help coordinate cellular activities				118-122

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7. Membrane Structure and Function				
7.1 Cellular membranes are fluid mosaics of lipids and proteins	2.B.1 Cell membranes are selectively permeable due to their structure	125-130		
7.2 Membranes structure results in selective permeability	2.B.1 Cell membranes are selectively permeable due to their structure	131		
7.3 Passive transport is diffusion of a substance across a membrane with no energy investment	2.B.2 Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes	132-135	Glucose transport 166, 167, 168-169; Na+/K+ transport 136	
7.4 Active transport uses energy to move solutes against their gradients	2.B.2 Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes	135-138	Glucose transport 166, 167, 168-169; Na+/K+ transport 136	
7.5 Bulk transport across the plasma membrane occurs by exocytosis and endocytosis	2.B.2 Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes	138	Glucose transport 166, 167, 168-169; Na+/K+ transport 136	
8. An Introduction to Metabolism				
8.1 An organism's metabolism transform matter and energy, subject to the laws of thermodynamics	2.A.1 All living systems require constant input of free energy	142-145	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
8.2 The free-energy change of a reaction tells us whether or not the reaction occurs spontaneously	2.A.1 All living systems require constant input of free energy	146-149	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
8.3 ATP powers cellular work by coupling exergonic reactions to engergonic reactions	2.A.1 All living systems require constant input of free energy	149-151	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
8.4 Enzymes speed up metabolic reactions by lowering energy barriers	4.B.1 Interactions between molecules affect their structure and function	151-156		
8.5 Regulation of enzyme activity helps control metabolism	4.B.1 Interactions between molecules affect their structure and function	157-159		
9. Cellular Respiration Harvesting Chemical Energy				

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9.1 Catabolic pathways yield energy by oxidizing organic fuels	2.A.1 All living systems require constant input of free energy	162-167	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
9.2 Glycolysis harvests chemical energy by oxidizing glucose by pyruvate	2.A.1 All living systems require constant input of free energy	167	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
9.3 The citric acid cycle completes the energy-yielding oxidation of organic molecules	2.A.1 All living systems require constant input of free energy	170-172	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
9.4 During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis	2.A.1 All living systems require constant input of free energy	172-177	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	

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9.5 Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen	2.A.1 All living systems require constant input of free energy	177-179	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
9.6 Glycolysis and the citric acid cycle connect to many other metabolic pathways				180-182

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10. Photosynthesis				
10.1 Photosynthesis converts light energy to the chemical energy of food	2.A.1 All living systems require constant input of free energy	186-189	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
10.2 The light reactions converts solar energy to the chemical energy of ATP and NADPH	2.A.1 All living systems require constant input of free energy	190-198	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
10.3 The Calvin cycle uses ATP and NADPH to reduce CO_2 to sugar	2.A.1 All living systems require constant input of free energy	198-199	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.A.2 Organisms capture and store free energy for use in biological processes		NADP+ in photosynthesis 189, 195; Oxygen in cellular respiration 162, 164, 165	
10.4 Alternative mechanisms of carbon fixation have evolved in hot, arid climates				200-202
11. Cell Communications				
	3.D.1 Cell communication processes share common features that reflect a shared evolutionary history		Use of chemical messengers by microbes to communicate with other nearby cells and to regulate specific pathways in response to population density (quorum sensing) 207, 208, 209, 211; Use of pheromones to trigger reproduction and developmental pathways 639, 977, 1001, 1125; DNA repair mechanisms 318	
	2.E.2 timing and coordination of physiological events are regulated by multiple mechanisms		Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues 777, 838, 1073, 1123; Seasonal responses, such as hibernation, estivation, and migration 872; Visual displays in the reproductive cycle 1011; Fruiting body formation in fungi, slime molds and certain types of bacteria 594, 595, 639, 640, 642, 643, 644, 645, 646, 647; Quorum sensing in bacteria 207	

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11.1 External signals are converted to responses within the cell	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression	206-210	Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044	
	3.D.2 Cell communicate with each other through direct contact with other cells or from a distance via chemical signaling			
11.2 Reception: A signaling molecule binds to a receptor protein, causing it to change shape	3.D.2 Cell communicate with each other through direct contact with other cells or from a distance via chemical signaling	201-214	Immune cells interact by cell-cell contact, antigen-presenting cells (APCs), helper T-cells and killer T-cells. [See also 2.D.4] 939, 942, 943, 944; Plasmodesmata between plant cells that allow material to be transported from cell to cell 120, 208, 771; Neurotransmitters 976, 1048, 1059; Plant immune response 941; Quorum sensing in bacteria 207; Morphogens in embryonic development 367, 1035; Insulin 893, 894, 977, 982, 983; Human growth hormone 301, 397, 418, 989; Thyroid hormones 990, 991; Testosterone 63, 213, 993, 1007, 1010; Estrogen 63, 977, 993	
	3.D.3 Signal transduction pathways link signal reception with cellular response		G-protein linked receptors 211; Ligand-gated ion channels 213; Receptor tyrosine kinases 240; Second messengers, such as cyclic GMP, cyclic AMP, calcium ions (Ca2+), and inositol triphosphate (IP3), 216, 217, 218, 823, 979	
11.3 Transduction: Cascades of molecular interactions relay signals from receptors to target molecules in the cell	3.D.3 Signal transduction pathways link signal reception with cellular response	214-218	G-protein linked receptors 211; Ligand-gated ion channels 213; Receptor tyrosine kinases 240; Second messengers, such as cyclic GMP, cyclic AMP, calcium ions (Ca2+), and inositol triphosphate (IP3), 216, 217, 218, 823, 979	
11.4 Response: Cell signaling leads to regulation of transcription or cytoplasmic activities	3.D.4 Changes in signal transduction pathways can alter cellular response	218-223	Diabetes, heart disease, neurological disease, autoimmune disease, cancer, and cholera 243, 377, 950, 951, 971, 983; Effects of neurotoxins, poisons, pesticides 1238; Drugs (Hypertensives, Anesthetics, Antihistamines, and Birth Control Drugs) 461, 1017	
	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression		Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-831; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044	
11.5 Apoptosis (programmed cell death) integrates multiple cell-signaling pathways	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms	223-225	Morphogenesis of fingers and toes 225, 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	
12. The Cell Cycle				
12.1 Cell division results in genetically identical daughter cells	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization	229-230	Mitosis-promoting factor (MPF) 240; Action of platelet-derived growth factor (PDGF) 241; Cancer results from disruptions in cell cycle control 242, 243, 374, 375, 376	
12.2 The mitotic phase alternates with interphase in the cell cycle	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization	230-238	Mitosis-promoting factor (MPF) 240; Action of platelet-derived growth factor (PDGF) 241; Cancer results from disruptions in cell cycle control 242, 243, 374, 375, 376	

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12.3 The eukaryotic cell cycle is regulated by a molecular control system	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization	238-243	Mitosis-promoting factor (MPF) 240; Action of platelet-derived growth factor (PDGF) 241; Cancer results from disruptions in cell cycle control 242, 243, 374, 375, 376	
13. Meiosis and Sexual Life Cycle				
13.1 Offspring acquire genes from parents by inheriting chromosomes	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization	248-249	Mitosis-promoting factor (MPF) 240; Action of platelet-derived growth factor (PDGF) 241; Cancer results from disruptions in cell cycle control 242, 243, 374, 375, 376	
13.2 Fertilization and meiosis alternate in sexual life cycle	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization	250-253	Mitosis-promoting factor (MPF) 240; Action of platelet-derived growth factor (PDGF) 241; Cancer results from disruptions in cell cycle control 242, 243, 374, 375, 376	
13.3 Meiosis reduces the number of chromosomes sets from diploid to haploid	3.A.2 In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis, or meiosis plus fertilization	253-258	Mitosis-promoting factor (MPF) 240; Action of platelet-derived growth factor (PDGF) 241; Cancer results from disruptions in cell cycle control 242, 243, 374, 375, 376	
13.4 Genetic variation produced in sexual life cycles contributes to evolution	3.C.2 Biological systems have multiple processes that increase genetic variation	258-260		

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
14. Mendel and the Gene Idea				
14.1 Mendel used the scientific approach to identify two laws of inheritance	3.A.3 The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring	262-269	Sickle cell anemia 344, 406; Huntington's disease 415; X-linked color blindness 291; Trisomy 21/Down syndrome 299; Klinefelter's syndrome 298; Reproduction issues 273, 274	
14.2 The laws of probability govern Mendelian inheritance	3.A.3 The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring	269-271	Sickle cell anemia 344, 406; Huntington's disease 415; X-linked color blindness 291; Trisomy 21/Down syndrome 299; Klinefelter's syndrome 298; Reproduction issues 273, 274	
14.3 Inheritance patterns are often more complex than predicted by simple Mendelian genetics	4.C.2 Environmental factors influence the expression of the genotype in an organism	271-275	Density of plant hairs as a function of herbivory 739; Effect of adding lactose to a Lac + bacterial culture 354; Darker fur in cooler regions of the body in certain mammal species 292; Alterations in timing of flowering due to climate changes 275	
	3.A.3 The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring		Sickle cell anemia 344, 406; Huntington's disease 415; X-linked color blindness 291; Trisomy 21/Down syndrome 299; Klinefelter's syndrome 298; Reproduction issues 273, 274	
	4.C.4 The diversity of species within an ecosystem may influence the stability of the ecosystem			
14.4 Many human traits follow Mendelian patterns of inheritance	3.A.3 The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring	276-281	Sickle cell anemia 344, 406; Huntington's disease 415; X-linked color blindness 291; Trisomy 21/Down syndrome 299; Klinefelter's syndrome 298; Reproduction issues 273, 274	
			Sickle cell anemia 344, 406; Huntington's disease 415; X-linked color blindness 291; Trisomy 21/Down syndrome 299; Klinefelter's syndrome 298; Reproduction issues 273, 274	
15. The Chromosomal Basis of Inheritance				
15.1 Mendelian inheritance has its physical basis in the behavior of chromosomes	3.A.4 The inheritance pattern of many traits cannot by explained by simple Medelian genetics	286-289	Sickle cell anemia 344, 406; Huntington's disease 415; X-linked color blindness 291; Trisomy 21/Down syndrome 299; Klinefelter's syndrome 298; Reproduction issues 273, 274	
15.2 Sex-linked genes exhibit unique patterns of inheritance	3.A.4 The inheritance pattern of many traits cannot by explained by simple Medelian genetics	289-292	Sex-linked genes reside on sex chromosomes (X in humans); In mammals and flies, the Y chromosome is very small and carries few genes 289; In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males 290; Some traits are sex limited, and expression depends on the sex of the individual, such as milk production in female mammals and pattern baldness in males 276, 290, 291, 292	
15.3 Linked genes tend to be inherited together because they are located near each other on the same chromosome	3.A.4 The inheritance pattern of many traits cannot by explained by simple Medelian genetics	292-296	Sex-linked genes reside on sex chromosomes (X in humans); In mammals and flies, the Y chromosome is very small and carries few genes 289; In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males 290; Some traits are sex limited, and expression depends on the sex of the individual, such as milk production in female mammals and pattern baldness in males 276, 290, 291, 292	
15.4 Alteration of chromosome number or structure cause some genetic disorder	3.C.1 Biological systems have multiple processes that increase genetic variation	297-300	Pesticide resistance mutations 1238; Sickle cell disorder and heterozygote advantage 84, 344	
15.5 Some inheritance patterns are exceptions to the standard chromosome theory	3.A.4 The inheritance pattern of many traits cannot by explained by simple Medelian genetics	300-302	Sex-linked genes reside on sex chromosomes (X in humans); In mammals and flies, the Y chromosome is very small and carries few genes 289; In mammals and flies, females are XX and males are XY; as such, X-linked recessive traits are always expressed in males 290; Some traits are sex limited, and expression depends on the sex of the individual, such as milk production in female mammals and pattern baldness in males 276, 290, 291, 292	
16. The Molecular Basis of Inheritance				
16.1 DNA is the genetic material	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	305-310	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155, ; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 821; Cloned animals 413, 414	

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16.2 Many proteins work together in DNA replication and repair	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	311-319	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155, ; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
	3.C.1 Biological systems have multiple processes that increase genetic variation		Pesticide resistance mutations 1238; Sickle cell disorder and heterozygote advantage 84, 344	
16.3 A chromosome consists of a DNA molecule packed together with proteins				320-323
17. From Gene to Protein				
17.1 Genes specify proteins via transcription and translation	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	325-331	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
17.2 Transcription is the DNA-directed synthesis of RNA: *a closer look*	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	331-334	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
17.3 Eukaryotic cells modify RNA after transcription	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	334-336	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
17.4 Translation is the RNA-directed synthesis of a polypeptide: *a closer look*	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	337-344	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
17.5 Point mutations can affect protein structure and function	3.C.1 Biological systems have multiple processes that increase genetic variation	344-346	Pesticide resistance mutations 1238; Sickle cell disorder and heterozygote advantage 84, 344	
17.6 While gene expression differs among the domains of life, the concept of a gene is universal				346-347

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
18. Regulation of Gene Expression				
18.1 Bacteria often respond to environmental change by regulating transcription	3.B.1 Gene regulation results in differential gene expression, leading to cell specialization	351-356	Promoters 332, 333, 360, 361; Terminators 332; Enhancers 359, 361	
	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression		Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044	
18.2 Eukaryotic gene expression is regulated at any stage	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms	356-364	Morphogenesis of fingers and toes 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	
	3.B.1 Gene regulation results in differential gene expression, leading to cell specialization		Promoters 332, 333, 360, 361; Terminators 332; Enhancers 359, 361	
	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression		Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044,	
18.3 Noncoding RNAs play multiple roles in controlling gene expression	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms	364-366	Morphogenesis of fingers and toes 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	
	3.B.1 Gene regulation results in differential gene expression, leading to cell specialization		Promoters 332, 333, 360, 361; Terminators 332; Enhancers 359, 361	
	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression		Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044	
	4.A.3 Interactions between external stimuli and regulated gene expression result in specializations of cells, tissues and organs			
	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms		Morphogenesis of fingers and toes 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	

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18.4 A program of differential gene expression leads to the different cell types in a multicellular organism	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression	366-373	Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044	
18.5 Cancer results from genetic changes that affect cell cycle control				373-377
19. Viruses				
19.1 A virus consists of a nucleic acid surrounded by a protein coat	3.C.3 Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts	381-384	Transduction in bacteria 209, 215, 216, 562; Transposons present in incoming DNA 435	
19.2 Viruses reproduce only in host cells	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	384-390	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
	3.C.3 Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts		Transduction in bacteria 209, 215, 216, 562; Transposons present in incoming DNA 435	
19.3 Viruses, viroids, and prions are formidable pathogens in animals and plants				390-394
20. Biotechnology				
20.1 DNA cloning yields multiple copies of a gene or other DNA segment	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	396-405	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
20.2 DNA technology allows us to study the sequence, expression, and function of a gene	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	405-411	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
20.3 Cloning organisms may lead to production of stem cells for research and other applications				412-416
20.4 The practical applications of DNA technology affects our lives in many ways				416-423
21. Genomes and Their Evolution				
21.1 New approaches have accelerated the pace of genome sequencing				427-429
21.2 Scientists use bioinformatics to analyze genomes and their functions	3.C.1 Biological systems have multiple processes that increase genetic variation	429-432	Pesticide resistance mutations 1238; Sickle cell disorder and heterozygote advantage 84, 344	
21.3 Genomes vary in size, number of genes, and gene density				432-434
21.4 Multicellular eukaryotes have much noncoding DNA and many multigene families				434-438

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
21.5 Duplication, rearrangement, and mutation of DNA contribute to genome evolution	4.C.1 Variations in molecular units provides cells with a wider range of functions	438-442	Different types of phospholipids in cell membranes 65, 76, 77, 99, 125; Different types of hemoglobin 83, 84, 437, 440, 912, 913, 924; MHC proteins 938, 939; Chlorophylls 5, 101, 111, 186, 187, 196, 197; Molecular diversity of antibodies in response to an antigen 937, 938, 939	
21.6 Comparing genome sequences provides clues to evolution and development				442-447
22. Descent with Modification: A Darwinian View of Life				
22.1 The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species				452-455
22.2 Descent with modifications by natural selection explains the adaptation of organisms and the unity and diversity of life	1.A.1 Natural selection is a major mechanism of evolution	455-460	Graphical analysis of allele frequencies in a population 472, 473; Application of the Hardy-Weinberg equilibrium equation 472, 473	
22.3 Evolution is supported by an overwhelming amount of scientific evidence	1.A.4 Biological evolution is supported by scientific evidence from many disciplines, including mathematics	460-466		

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
23. The Evolution of Populations				
23.1 Mutation and sexual reproduction produce the genetic variation that makes evolution possible	1.A.2 Natural selection acts on phenotypic variations in populations	468-471	Flowering time in relation to global climate change 839, 840; Sickle cell Anemia 84, 344; DDT resistance in insects; Artificial selection 458; Loss of genetic diversity within a crop species 1249	
	4.C.3 The level of variation in a population affects population dynamics		Campbell Biology offers many examples for this area, such as the following: Potato blight causing the potato famine 578, 588; Corn rust affects on agricultural crops 650	
23.2 The Hardy-Weinberg equation can be used to test whether a population is evolving	1.A.1 Natural selection is a major mechanism of evolution	472-475	Graphical analysis of allele frequencies in a population 472, 473; Application of the Hardy-Weinberg equilibrium equation 472, 473	
	4.C.3 The level of variation in a population affects population dynamics		Campbell Biology offers many examples for this area, such as the following: Potato blight causing the potato famine 578, 588; Corn rust affects on agricultural crops 650	
	4.C.4 The diversity of species within an ecosystem may influence the stability of the ecosystem			
23.3 Natural selection, genetic drift, and gene flow can alter allele frequencies in a population	1.A.3 Evolutionary change is also driven by random processes	475-479	Graphical analyses of allele frequencies in a population 265-66 472, 473, 474 476, 477, 478, 479; Analysis of sequence data sets 410; Analysis of phylogenetic trees 536, 537, 538, 539, 40 542, 543, 544, 545; Construction of phylogenetic trees based on sequence data 539, 540, 546	
	4.C.3 The level of variation in a population affects population dynamics		Campbell Biology offers many examples for this area, such as the following: Potato blight causing the potato famine 578, 588; Corn rust affects on agricultural crops 650	
23.4 Natural selection is the only mechanism that consistently causes adaptive evolution	1.A.2 Natural selection acts on phenotypic variations in populations	479-485	Flowering time in relation to global climate change 839, 840; Sickle cell Anemia 84, 344; DDT resistance in insects; Artificial selection 458; Loss of genetic diversity within a crop species 1249	
	3.C.1 Biological systems have multiple processes that increase genetic variation		Pesticide resistance mutations 1238; Sickle cell disorder and heterozygote advantage 84, 344	
24. The Origin of Species				
	1.C.2 Speciation may occur when two populations become reproductively isolated			

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
24.1 The biological species concept emphasizes reproductive isolation	2.E.2 timing and coordination of physiological events are regulated by multiple mechanisms	487-492	Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues 777, 838, 1073, 1123; Seasonal responses, such as hibernation, estivation, and migration 872; Visual displays in the reproductive cycle 1011; Fruiting body formation in fungi, slime molds and certain types of bacteria 594, 595, 639, 640, 642, 643, 644, 645, 646, 647; Quorum sensing in bacteria 207	
24.2 Speciation can take place with or without geographic separation	1.C.3 Populations of organisms continue to evolve	492-498	Chemical resistance (mutations for resistance to antibiotics, pesticides, herbicides or chemotherapy drugs occur in the absence of the chemical) 344, 345; Emergent diseases 388, 399, 983; Observed directional phenotypic change in a population (Grants' observations of Darwin's finches in the Galapagos) 17; A eukaryotic example that describes evolution of a Structure or process such as heart chambers, limbs, the brain and the immune system 412, 413, 414	
	1.C.1 Speciation and extinction have occurred throughout the Earth's history		Five major extinctions 521, 522, 523, 1246, 1247, 1251; Human impact on ecosystems and species extinction rates 1247, 1249, 1250	
24.3 Hybrid zones opportunity to study factors that cause reproductive isolation	1.C.1 Speciation and extinction have occurred throughout the Earth's history	498-501	Five major extinctions 521, 522, 523, 1246, 1247, 1251; Human impact on ecosystems and species extinction rates 1247, 1249, 1250	
24.4 Speciation can occur rapidly or slowly and can result from changes in few or many genes	1.C.1 Speciation and extinction have occurred throughout the Earth's history	501-504	Five major extinctions 521, 522, 523, 1246, 1247, 1251; Human impact on ecosystems and species extinction rates 1247, 1249, 1250	
25. The History of Life on Earth				
25.1 Conditions on early Earth made the origin of life possible	1.B.1 Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today	507-510	Cytoskeleton (a network of structural proteins that facilitate cell movement, morphological integrity and organelle transport) 100, 101, 112, 113, 117; Membrane-bound organelles (mitochondria and/or chloroplasts) 100, 101, 103, 105, 107, 110, 111, 123, 159; Linear chromosomes; Endomembrane systems, including the nuclear envelope 100, 101, 103, 105, 109, 123	
	1.D.1 There are several hypotheses about the natural origin of life on Earth, each with supporting evidence			
25.2 The fossil record documents the history of life	1.A.4 Biological evolution is supported by scientific evidence from many disciplines, including mathematics	510-514	Graphical analyses of allele frequencies in a population 265-66 472, 473, 474 476, 477, 478, 479; Analysis of sequence data sets 410; Analysis of phylogenetic trees 536, 537, 538, 539, 40 542, 543, 544, 545; Construction of phylogenetic trees based on sequence data 539, 540, 546	
	1.C.1 Speciation and extinction have occurred throughout the Earth's history		Five major extinctions 521, 522, 523, 1246, 1247, 1251; Human impact on ecosystems and species extinction rates 1247, 1249, 1250	
25.3 Key events in life's history include the origins of single-celled and multicelled organisms and the colonization of land	1.B.1 Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today	514-519	Cytoskeleton (a network of structural proteins that facilitate cell movement, morphological integrity and organelle transport) 100, 101, 112, 113, 117; Membrane-bound organelles (mitochondria and/or chloroplasts) 100, 101, 103, 105, 107, 110, 111, 123, 159; Linear chromosomes; Endomembrane systems, including the nuclear envelope 100, 101, 103, 105, 109, 123	
	1.D.1 There are several hypotheses about the natural origin of life on Earth, each with supporting evidence			
25.4 The rise and fall of dominant groups of organisms reflect continental drift, mass extinction, and adaptive radiations	1.C.1 Speciation and extinction have occurred throughout the Earth's history	519-524	Five major extinctions 521, 522, 523, 1246, 1247, 1251; Human impact on ecosystems and species extinction rates 1247, 1249, 1250	
	4.B.3 Interaction between and within populations influence patterns of species distribution and abundance			

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25.5 Major changes in body form can result from changes in the sequences and regulation of developmental genes	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms	525-529	Morphogenesis of fingers and toes 225, 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	
25.6 Evolution is not goal oriented				529-531
26. Phylogeny and the Tree of Life				
26.1 Phylogenies show evolutionary relationships	1.B.2 Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested	537-540	Number of heart chambers in animals 901, 902, 903, 904, 898; Opposable thumbs 726, 727; Absence of legs in some sea mammals 462, 850	
26.2 Phylogenies are inferred from morphological and molecular data	1.B.2 Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested	540-542	Number of heart chambers in animals 901, 902, 903, 904, 898; Opposable thumbs 726, 727; Absence of legs in some sea mammals 462, 850	
26.3 Shared characters are used to construct phylogenetic trees	1.B.2 Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested	542-548	Number of heart chambers in animals 901, 902, 903, 904, 898; Opposable thumbs 726, 727; Absence of legs in some sea mammals 462, 850	
26.4 An organism's evolutionary history is documented in its genome				548-549
26.5 Molecular clocks help track evolutionary time				549-551
26.6 New information continues to revise our understanding of the tree of life	1.D.2 Scientific evidence from many different disciplines supports models of the origin of life	551-553		

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27. Bacteria and Archaea				
27.1 Structural and functional adaptations contribute to prokaryotic success	3.A.1 DNA, and in some cases RNA, is the primary source of heritable information	556-561	Addition of a poly-A tail 334, 401; Addition of a GTP cap 211, 223; Excision of introns 335, 336, 433-34; Enzymatic reactions 78, 154, 155; Transport by proteins 78, 131, 134-5767-68, 771; Synthesis 385; Degradation 957, 970; Electrophoresis 404; Plasmid-based transformation 397-403; Restriction enzyme analysis of DNA 395, 398; Polymerase Chain Reaction (PCR) 404, 420, 1205; Genetically modified foods 817; Transgenic animals 419, 421; Cloned animals 413, 414	
27.2 Rapid reproduction, mutation, and genetic recombination promote genetic diversity in prokaryotes	3.C.2 Biological systems have multiple processes that increase genetic variation	561-564		
27.3 Diverse nutritional and metabolic adaptations have evolved in prokaryotes				564-565
27.4 Molecular systematic is illuminating prokaryotic phylogeny				565-570
27.5 Prokaryotes play crucial roles in the biosphere				570-571
27.6 Prokaryotes have both beneficial and harmful impacts on humans				571-573
28. Protists				
28.1 Most eukaryotes are single-celled organisms				575-577
28.2 Excavates include protists with modified mitochondria and protists with unique flagella				580-581
28.3 Chromalveolates may have originated by secondary endosymbiosis				582-589
28.4 Rhizarians are a diverse group of protists defined by DNA similarities				589-590
28.5 Red algae and green algae are the closest relatives of land plants				590-592
28.6 Unikonts include protists that are closely related to fungi and animals				593-596
28.7 Protistis play key roles in ecological relationships				596-597
29. Plant Diversity I: How Plants Colonized Land				
29.1 Land plants evolved from green algae				600-606
29.2 Mosses and other nonvascular plants have life cycles dominated by gametophytes				606-610
29.3 Ferns and other seedless vascular plants were the first plants to grow tall				610-615
30. Plant Diversity II: The Evolution of Seed Plants				
30.1 Seeds and pollen grains are key adaptations for life on land				618-621
30.2 Gymnosperms bear "naked" seeds, typically on cones				621-625
30.3 The reproductive adaptations of angiosperms include flowers and fruits				625-632
30.4 Human welfare depends greatly on seed plants				632-634
31. Fungi				
31.1 Fungi are heterotrophs that feed by absorption				636-638
31.2 Fungi produce sores through sexual or asexual life cycles				638-640
31.3 The ancestor of fungi was an aquatic, single-celled, flagellated protist				640-641
31.4 Fungi have radiated into a diverse set of lineages				641-648
31.5 Fungi play key roles in nutrient cycling, ecological interactions, and human welfare				648-652
32. An Overview of Animal Diversity				
32.1 Animals are multicellular, heterotrophic eukaryotes with tissues that develop from embryonic layers				654-656
32.2 The history of animals spans more than half a billion years				656-658
32.3 Animals can be characterized by "body plans"				658-661
32.4 New views of animal phylogen are emerging from molecular data				661-664
33. Invertebrates				
33.1 Sponges are basal animals that lack true tissues				670-671
33.2 Cnidarians are an ancient phylum of eumetazoans				671-673
33.3 Lophotrochozoans, a clade identified by molecular data, have the widest range of animal body forms				674-682
33.4 Ecdysozoans are the most species-rich animal group				683-692
33.5 Echinoderms and chordates are deuterostomes				693-695
34. Vertebrates				
34.1 Chordates have a notochord and a dorsal, hollow nerve cord				698-702
34.2 Craniates are chordates that have a head				702-704
34.3 Vertebrates are craniates that have a backbone				704-705
34.4 Gnatostomes are vertebrates that have jaws				705-710
34.5 Tetrapods are gnathostomes that have limbs				710-713
34.6 Amniotes are tetrapods that have a terrestrially adapted egg				713-720

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
34.7 Mammals are amniotes that have hair and produce milk				720-728
34.8 Humans are mammals that have a large brain and bipedal locomotion				728-733
35. Plant Structure, Growth, and Development				
35.1 The plant body has a hierarchy of organs, tissues, and cells				738-743
35.2 Meristems generate cells for new organs				746-747
35.3 Primary growth lengthens roots and shoots				747-751
35.4 Secondary growth ad grith to stems and roots in woody plants				751-754
35.5 Growth, morphogenesis, and cell differentiation produce the plant body				755-761
36. Resource Acquisition and Transport in Vascular Plants				
36.1 Land plants acquire resources both above and below ground				764-767
36.2 Transport occurs by short-distance diffusion or active transport and by long-distace bulk flow				767-772
36.3 Water and minerals are transported from roots to shoots				772-776
36.4 Stomata help regulate the rate of transpiration				776-779
36.5 Sugars are transported from leaves and other sources to sites of use or stoarge				779-781
36.6 The symplast is highly dynamic				781-782
37. Soil and Plant Nutrition				
37.1 Soil is a living, finite resource				785-789
37.2 Plants require essential elements to complete their life cycle				789-792
37.3 Plant nutrition often involves relationships with other organisms				792-797

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
38. Angiosperm Reproduction and Biotechnology				
38.1 Flowers, double fertilization, and fruits are unique features of the angiosperm life cycle	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms	801-811	Morphogenesis of fingers and toes 225, 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	
	2.E.2 timing and coordination of physiological events are regulated by multiple mechanisms		Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues 777, 838, 1073, 1123; Diurnal/nocturnal and sleep/awake cycles 838, 1072; Seasonal responses, such as hibernation, estivation, and migration 872; Visual displays in the reproductive cycle 1011; Fruiting body formation in fungi, slime molds and certain types of bacteria 594, 595, 639, 640, 642, 643, 644, 645, 646, 647; Quorum sensing in bacteria 207	
38.2 Flowering plants reproduce sexually, asexually, or both				812-815
38.3 Humans modify crops by breeding and genetic engineering				815-819
39. Plant Responses to Internal and External Signals				
39.1 Signals transduction pathways link signal reception to response	2.E.2 timing and coordination of physiological events are regulated by multiple mechanisms	821-824	Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues 777, 838, 1073, 1123; Diurnal/nocturnal and sleep/awake cycles 838, 1072; Seasonal responses, such as hibernation, estivation, and migration 872; Visual displays in the reproductive cycle 1011; Fruiting body formation in fungi, slime molds and certain types of bacteria 594, 595, 639, 640, 642, 643, 644, 645, 646, 647; Quorum sensing in bacteria 207	
39.2 Plant hormones help coordinate growth, development, and responses to stimuli	2.E.2 timing and coordination of physiological events are regulated by multiple mechanisms	824-835	Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues 777, 838, 1073, 1123; Diurnal/nocturnal and sleep/awake cycles 838, 1072; Seasonal responses, such as hibernation, estivation, and migration 872; Visual displays in the reproductive cycle 1011; Fruiting body formation in fungi, slime molds and certain types of bacteria 594, 595, 639, 640, 642, 643, 644, 645, 646, 647; Quorum sensing in bacteria 207	
	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection		Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
39.3 Responses to light are critical for plant success	2.E.2 timing and coordination of physiological events are regulated by multiple mechanisms	835-841	Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues 777, 838, 1073, 1123; Diurnal/nocturnal and sleep/awake cycles 838, 1072; Seasonal responses, such as hibernation, estivation, and migration 872; Visual displays in the reproductive cycle 1011; Fruiting body formation in fungi, slime molds and certain types of bacteria 594, 595, 639, 640, 642, 643, 644, 645, 646, 647; Quorum sensing in bacteria 207	
	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection		Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
39.4 Plants respond to a wide variety of stimuli other than light				841-845

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
39.5 Plants respond to attacks by herbivores and pathogens	2.D.4 Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis	845-847	Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses 931, 932, 933; Plant defenses against pathogens include molecular recognition systems with systemic responses 846; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects 935; Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens 935, 937, 938, 939, 940, 941	
40. Basic Principles of Animal Form and Function				
40.1 Animals form and function are correlated at all levels of organization	2.A.1 All living systems require constant input of free energy	852-860	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	4.B.2 Cooperative interactions within organisms promote efficiency in the use of energy and matter		Exchange of gases 854, 898, 899, 901, 916, 917, 918, 919, 921, 922, 923, 924, 925; Circulation of fluids 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910; Digestion of food; Excretion of wastes 954, 955, 956, 957, 958, 959, 961, 962, 963, 965, 967; Bacterial community in the rumen of animals 892; Bacterial community in and around deep sea vents 1165	
40.2 Feedback control loops maintains the internal environment in many animals	2.A.1 All living systems require constant input of free energy	860-862	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.C.1 Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes		Operons in gene regulation 353, 354; Temperature regulation in animals 863, 864, 865, 866, 867; Plant responses to water limitations 777; Lactation in mammals 1016; Onset of labor in childbirth 1015; Ripening of fruit 626; Diabetes mellitus in response to decreased insulin 983; Dehydration in response to decreased antidiuretic hormone (ADH) 68-69; Graves' disease (hyperthyroidism) 990; Blood clotting 397, 913	
	2.D.2 Homeostatic mechanism reflect both common ancestry and divergence due to adaptation in different environments		Gas exchange in aquatic and terrestrial plants 765, 768, 770, 776, 777; Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892; Respiratory systems of aquatic and terrestrial animals 916, 917, 918, 919, 921, 922, 923, 924, 925, 926; Nitrogenous waste production and elimination in aquatic and terrestrial animals 793, 794; Excretory systems in flatworms, earthworms and vertebrates 961, 962, 963, 965, 967; Osmoregulation in bacteria, fish and protests 956, 973; Osmoregulation in aquatic and terrestrial plants 844; Circulatory systems in fish, amphibians and mammals 900, 901902, 903, 904, 905, 906, 907, 908, 909, 910;	

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
	2.D.3 Biological systems are affected by disruptions to their dynamic homeostatis		Physiological responses to toxic substances; Dehydration 68-69; Immunological responses to pathogens, toxins, and allergens 937, 938, 939, 940, 941; Invasive and/or eruptive species 1249; Human impact 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1246, 1250, 1256, 1257; Hurricanes, floods, earthquakes, volcanoes, and fires 1212, 1213; Water limitation 1167, 1263; Salination 788	
40.3 Homeostatic processes for thermoregulation involve form, function, and behavior	2.C.2 Organisms respond to changes in their external environment	862-868	Physiological responses to toxic substances; Dehydration 68-69; Immunological responses to pathogens, toxins, and allergens 937, 938, 939, 940, 941; Invasive and/or eruptive species 1249; Human impact 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1246, 1250, 1256, 1257; Hurricanes, floods, earthquakes, volcanoes, and fires 1212, 1213; Water limitation 1167, 1263; Salination 788	
	2.A.1 All living systems require constant input of free energy		Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.C.1 Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes		Operons in gene regulation 353, 354; Temperature regulation in animals 863, 864, 865, 866, 867; Plant responses to water limitations 777; Lactation in mammals 1016; Onset of labor in childbirth 1015; Ripening of fruit 626; Diabetes mellitus in response to decreased insulin 983; Dehydration in response to decreased antidiuretic hormone (ADH) 68-69; Graves' disease (hyperthyroidism) 990; Blood clotting 397, 913	
	2.D.2 Homeostatic mechanism reflect both common ancestry and divergence due to adaptation in different environments		Gas exchange in aquatic and terrestrial plants 765, 768, 770, 776, 777; Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892; Respiratory systems of aquatic and terrestrial animals 916, 917, 918, 919, 921, 922, 923, 924, 925, 926; Nitrogenous waste production and elimination in aquatic and terrestrial animals 793, 794; Excretory systems in flatworms, earthworms and vertebrates 961, 962, 963, 965, 967; Osmoregulation in bacteria, fish and protests 956, 973; Osmoregulation in aquatic and terrestrial plants 844; Circulatory systems in fish, amphibians and mammals 900, 901902, 903, 904, 905, 906, 907, 908, 909, 910;	
	2.D.3 Biological systems are affected by disruptions to their dynamic homeostatis		Physiological responses to toxic substances; Dehydration 68-69; Immunological responses to pathogens, toxins, and allergens 937, 938, 939, 940, 941; Invasive and/or eruptive species 1249; Human impact 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1246, 1250, 1256, 1257; Hurricanes, floods, earthquakes, volcanoes, and fires 1212, 1213; Water limitation 1167, 1263; Salination 788	

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
40.4 Energy requirements are related to animal size, activity, and environment	2.A.1 All living systems require constant input of free energy	868-872	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
41. Animal Nutrition				
41.1 An animal's diet must supply chemical energy, organic molecules, and essential nutrients				875-880
41.2 The main stages of food processing are ingestion, digestion, absorption, and elimination				880-883
41.3 Organs specialized for sequential stages of food processing form the mammalian digestive system				884-890
41.4 Evolutionary adaptations of vertebrate digestive systems correlate with diet				891-893
41.5 Homeostatic mechanisms contribute to an animal's energy balance				893-896
42. Circulation and Gas Exchange				
42.1 Circulatory systems link exchange surfaces with cells throughout the body				898-903
42.2 Coordinated cycles of heart contraction drive double circulation in mammals				903-905
42.3 Patterns of blood pressure and flow reflect the structure and arrangement of blood vessels				906-911
42.4 Blood components function in exchange, transport, and defense				911-915
42.5 Gas exchange occurs across specialized respiratory surfaces				915-920
42.6 Breathing ventilates the lungs				920-922
42.7 Adaptations for gas exchange include pigments that bind and transport gases				923-927
43. The Immune System				
43.1 In innate immunity, recognition and response rely on shared traits of pathogens	2.D.4 Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis	931-936	Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses 931, 932, 933; Plant defenses against pathogens include molecular recognition systems with systemic responses 846; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects 935; Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens 935, 937, 938, 939, 940, 941	
43.2 In acquired immunity, lymphocyte receptors provide pathogen-specific recognition	2.D.4 Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis	936-942	Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses 931, 932, 933; Plant defenses against pathogens include molecular recognition systems with systemic responses 846; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects 935; Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens 935, 937, 938, 939, 940, 941	
43.3 Acquired immunity defends against infection of body cells and fluids	2.D.4 Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis	942-948	Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses 931, 932, 933; Plant defenses against pathogens include molecular recognition systems with systemic responses 846; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects 935; Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens 935, 937, 938, 939, 940, 941	

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43.4 Disruptions in immune system function can elicit or exacerbate disease	2.D.4 Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis	948-951	Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses 931, 932, 933; Plant defenses against pathogens include molecular recognition systems with systemic responses 846; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects 935; Vertebrate immune systems have nonspecific and nonheritable defense mechanisms against pathogens 935, 937, 938, 939, 940, 941	
44. Osmoregulation and Excretion				
44.1 Osmoregulation balances the uptake and loss of water and solutes				954-959
44.2 An animal's nitrogenous wastes reflect its phylogeny and habitat				959-960
44.3 Diverse excretory systems are variations on a tubular theme				960-964
44.4 The nephron is organized for stepwise processing of blood filtrate				964-969
44.5 Hormonal circuits link kidney function, water balance, and blood pressure				969-972
45. Hormones and the Endocrine System				
45.1 Hormones and other signaling molecules bind to target receptors, triggering specific response pathways	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression	975-981	Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044,	
	3.D.2 Cell communicate with each other through direct contact with other cells or from a distance via chemical signaling		Immune cells interact by cell-cell contact, antigen-presenting cells (APCs), helper T-cells and killer T-cells. [See also 2.D.4] 939, 942, 943, 944; Plasmodesmata between plant cells that allow material to be transported from cell to cell 120, 208, 771; Neurotransmitters 976, 1048, 1059; Plant immune response 941; Quorum sensing in bacteria; Morphogens in embryonic development 367, 1035; Insulin 893, 894, 977, 982, 983; Human growth hormone 301, 397, 418, 989; Thyroid hormones 990, 991; Testosterone 63, 213, 993, 1007, 1010; Estrogen 63, 977, 993	
45.2 Negative feedback and antagonistic hormone pairs are common in endocrine systems	3.D.1 Cell communication processes share common features that reflect a shared evolutionary history	981-984	Use of chemical messengers by microbes to communicate with other nearby cells and to regulate specific pathways in response to population density (quorum sensing) 207, 208, 209, 211; Use of pheromones to trigger reproduction and developmental pathways 639, 977, 1001, 1125; DNA repair mechanisms 318	
	3.B.2 A variety of intercellular and intracellular signal transmissions mediate gene expression		Cytokines regulate gene expression to allow for cell replication and division 254-255; Mating pheromones in yeast trigger mating gene expression 207; Levels of cAMP regulate metabolic gene expression in bacteria 220, 221, 355; Expression of the SRY gene triggers the male sexual development pathway in animals 290; Ethylene levels cause changes in the production of different enzymes, allowing fruits to ripen 834; Seed germination and gibberellin 827, 830-31; Mating pheromones in yeast trigger mating genes expression and sexual reproduction 207; Morphogens stimulate cell differentiation and development 372; Changes in p53 activity can result in cancer 375, 376; HOX genes and their role in development 446, 526, 527, 657, 684, 702, 1044	

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
	3.D.2 Cell communicate with each other through direct contact with other cells or from a distance via chemical signaling		Immune cells interact by cell-cell contact, antigen-presenting cells (APCs), helper T-cells and killer T-cells. [See also 2.D.4] 939, 942, 943, 944; Plasmodesmata between plant cells that allow material to be transported from cell to cell 120, 208, 771; Neurotransmitters 976, 1048, 1059; Plant immune response 941; Quorum sensing in bacteria; Morphogens in embryonic development 367, 1035; Insulin 893, 894, 977, 982, 983; Human growth hormone 301, 397, 418, 989; Thyroid hormones 990, 991; Testosterone 63, 213, 993, 1007, 1010; Estrogen 63, 977, 993	
	2.C.1 Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes		Operons in gene regulation 353, 354; Temperature regulation in animals 863, 864, 865, 866, 867; Plant responses to water limitations 777; Lactation in mammals 1016; Onset of labor in childbirth 1015; Ripening of fruit 626; Diabetes mellitus in response to decreased insulin 983; Dehydration in response to decreased antidiuretic hormone (ADH) 68-69; Graves' disease (hyperthyroidism) 990; Blood clotting 397, 913	
45.3 The endocrine and nervous systems act individually and together in regulating animal physiology				984-990
45.4 Endocrine glands respond to diverse stimuli in regulating metabolism, homeostasis, development, and behavior				990-994

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
46. Animal Reproduction				
46.1 Both asexual and sexual reproduction occurs in the animal kingdom				997-1000
46.2 Fertilization depends on mechanisms that bring together sperm and eggs of the same species				1000-1003
46.3 Reproductive organs produce and transport gametes				1003-1007
46.4 The timing and pattern of meiosis in mammals differ for males and females				1007
46.5 The interplay of tropic and sex hormones regulates mammalian reproduction				1007-1012
46.6 In placental mammals, an embryo develops fully within the mother's uterus				1012-1018
47. Animal Development				
47.1 After fertilization, embryonic development proceeds through cleavage, gastrulation, and organogenesis				1022-1035
47.2 Morphogenesis in animals involves specific changes in cell shape, position, and survival				1035-1038
47.3 The developmental fate of cells depends on their history and on inductive signals	2.E.1 Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms	1038-1044	Morphogenesis of fingers and toes 225, 366, 1021, 1035 1040, 1041, 1042, 1043, 1044; Immune function 941; *C. elegans* development 224, 1039; Flower Development 624, 625, 627, 629, 632, 802, 803	
48. Neurons, Synapses, and Signaling				
48.1 Neurons organization and structure reflect function in information transfer	3.E.2 Animals have nervous systems that detest external and internal signals, transmit and integrate information, and produce responses	1047-1049	Acetylcholine 1059; Epinephrine 209, 219, 221, 977, 979, 991, 992; Norepinephrine 991, 992, 1059,; Dopamine 1059, 1083; Serotonin 1059, 1061, 1071; GABA 1059; Vision Hearing 1093, 1094, 1095, 1100, 1101, 1102, 1103, 1104, 1105; Muscle movement 1066, 1071, 1106, 1107, 1108, 1109, 1110; Abstract thought and emotions; Neuro-hormone production 986; Forebrain (cerebrum), midbrain (brainstem), and hindbrain (cerebellum) 1070; Right and left cerebral hemispheres in humans 1076	
48.2 Ion pumps and ion channels establish the resting potential of a neuron	3.E.2 Animals have nervous systems that detest external and internal signals, transmit and integrate information, and produce responses	1050-1052	Acetylcholine 1059; Epinephrine 209, 219, 221, 977, 979, 991, 992; Norepinephrine 991, 992, 1059,; Dopamine 1059, 1083; Serotonin 1059, 1061, 1071; GABA 1059; Vision Hearing 1093, 1094, 1095, 1100, 1101, 1102, 1103, 1104, 1105; Muscle movement 1066, 1071, 1106, 1107, 1108, 1109, 1110; Abstract thought and emotions; Neuro-hormone production 986; Forebrain (cerebrum), midbrain (brainstem), and hindbrain (cerebellum) 1070; Right and left cerebral hemispheres in humans 1076	
48.3 Action potentials are the signals conducted by axons	3.E.2 Animals have nervous systems that detest external and internal signals, transmit and integrate information, and produce responses	1052-1056	Acetylcholine 1059; Epinephrine 209, 219, 221, 977, 979, 991, 992; Norepinephrine 991, 992, 1059,; Dopamine 1059, 1083; Serotonin 1059, 1061, 1071; GABA 1059; Vision Hearing 1093, 1094, 1095, 1100, 1101, 1102, 1103, 1104, 1105; Muscle movement 1066, 1071, 1106, 1107, 1108, 1109, 1110; Abstract thought and emotions; Neuro-hormone production 986; Forebrain (cerebrum), midbrain (brainstem), and hindbrain (cerebellum) 1070; Right and left cerebral hemispheres in humans 1076	
48.4 Neurons communicate with other cells at synapses	4.A.4 Organisms exhibit complex properties due to interactions between their constituent parts	1056-1061	Stomach and small intestines 884, 885, 886, 887, 888; Kidney and bladder 963, 965, 967; Root, stem and leaf 603, 613, 614, 739, 740, 762; Respiratory and circulatory 916, 917, 918, 919, 921, 923; Nervous and muscular1066, 1071, 1106, 1107, 1108, 1109, 1110; Plant vascular and leaf 742, 743, 745	
	3.E.2 Animals have nervous systems that detest external and internal signals, transmit and integrate information, and produce responses		Acetylcholine 1059; Epinephrine 209, 219, 221, 977, 979, 991, 992; Norepinephrine 991, 992, 1059,; Dopamine 1059, 1083; Serotonin 1059, 1061, 1071; GABA 1059; Vision Hearing 1093, 1094, 1095, 1100, 1101, 1102, 1103, 1104, 1105; Muscle movement 1066, 1071, 1106, 1107, 1108, 1109, 1110; Abstract thought and emotions; Neuro-hormone production 986; Forebrain (cerebrum), midbrain (brainstem), and hindbrain (cerebellum) 1070; Right and left cerebral hemispheres in humans 1076	
49. Nervous System				

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
49.1 Nervous system consists of curcuits of neurons and supporting cells				1064-1069
49.2 The vertebrates brain is regionally specialized	3.E.2 Animals have nervous systems that detest external and internal signals, transmit and integrate information, and produce responses	1070-1074	Acetylcholine 1059; Epinephrine 209, 219, 221, 977, 979, 991, 992; Norepinephrine 991, 992, 1059,; Dopamine 1059, 1083; Serotonin 1059, 1061, 1071; GABA 1059; Vision Hearing 1093, 1094, 1095, 1100, 1101, 1102, 1103, 1104, 1105; Muscle movement 1066, 1071, 1106, 1107, 1108, 1109, 1110; Abstract thought and emotions; Neuro-hormone production 986; Forebrain (cerebrum), midbrain (brainstem), and hindbrain (cerebellum) 1070; Right and left cerebral hemispheres in humans 1076	
49.3 The cerebral cortex controls voluntary movement and cognitive functions				1075-1078
49.4 Changes in synaptic connections underlie memory and learning				1078-1080
49.5 Nervous system disorder can be explained in molecular terms				1080-1084
50. Sensory and Motor Mechanisms				
50.1 Sensory receptors transduce stimulus energy and transmit signals to the central nervous system				1087-1091
50.2 The mechanoreceptors responsible for hearing and equilibrium detest moving fluid or settling particles				1091-1096
50.3 The senses of taste and smell rely on similar sets of sensory receptors				1096-1099
50.4 Similar mechanisms underlie vision throughout the animal kingdom				1099-1105
50.5 The physical interaction of protein filaments is required for muscle function				1105-1112
50.6 Skeletal systems transform muscle contraction into locomotion				1112-1117
51. Animal Behavior				
51.1 Discrete sensory inputs can stimulate both simple and complex behaviors	3.E.1 Individuals can act on information and communicate it to others	1120-1125	Fight or flight response 980; Predator warning 1141, 1187; Protection of young 1135, 1140; Herbivory responses 1202; Bee dances 1124; Birds songs 1130; Territorial marking in mammals 1187; Herd, flock, and schooling behavior in animals 1128; Predator warning 1141; Coloration; Parent and offspring interactions 1128, 1140; Migration patterns 1123, 1131; Courtship and mating behaviors 1120, 1123, 1134, 1141; Foraging in bees and other animals 1127; Avoidance behavior to electric fences, poisons, or traps 1132	
	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection		Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
51.2 Learning establishes specific links between experience and behavior	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection	1125-1129	Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
51.3 Both genetic makeup and environment contribute to the development of behaviors	2.A.1 All living systems require constant input of free energy	1129-1133	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
51.4 Selection for individual survival and reproductive success can explain most behaviors	1.A.1 Natural selection is a major mechanism of evolution	1133-1138	Graphical analysis of allele frequencies in a population 472, 473; Application of the Hardy-Weinberg equilibrium equation 472, 473	
	1.A.2 Natural selection acts on phenotypic variations in populations		Flowering time in relation to global climate change 839, 840; Sickle cell Anemia 84, 344; DDT resistance in insects; Artificial selection 458; Loss of genetic diversity within a crop species 1249	
	1.A.3 Evolutionary change is also driven by random processes		Graphical analyses of allele frequencies in a population 472, 473; Analysis of sequence data sets 541; Analysis of phylogenetic trees 536, 537, 538, 539, 540, 542, 543, 544, 545; Construction of phylogenetic trees based on sequence data 540, 546	
	1.A.4 Biological evolution is supported by scientific evidence from many disciplines, including mathematics		Graphical analyses of allele frequencies in a population 472, 473; Analysis of sequence data sets 541; Analysis of phylogenetic trees 536, 537, 538, 539, 540, 542, 543, 544, 545; Construction of phylogenetic trees based on sequence data 540, 546	
	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection		Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
51.5 Inclusive fitness can account for evolution of altruistic social behavior	1.A.1 Natural selection is a major mechanism of evolution	1138-1142	Graphical analysis of allele frequencies in a population 472, 473; Application of the Hardy-Weinberg equilibrium equation 472, 473	
	1.A.2 Natural selection acts on phenotypic variations in populations		Flowering time in relation to global climate change 839, 840; Sickle cell Anemia 84, 344; DDT resistance in insects; Artificial selection 458; Loss of genetic diversity within a crop species 1249	
	1.A.3 Evolutionary change is also driven by random processes		Graphical analyses of allele frequencies in a population 472, 473; Analysis of sequence data sets 541; Analysis of phylogenetic trees 536, 537, 538, 539, 540, 542, 543, 544, 545; Construction of phylogenetic trees based on sequence data 540, 546	
	1.A.4 Biological evolution is supported by scientific evidence from many disciplines, including mathematics		Graphical analyses of allele frequencies in a population 472, 473; Analysis of sequence data sets 541; Analysis of phylogenetic trees 536, 537, 538, 539, 540, 542, 543, 544, 545; Construction of phylogenetic trees based on sequence data 540, 546	
	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection		Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
52. An Introduction to Ecology and the Biosphere				
52.1 Ecology integrates all areas of biological research and informs environmental decision making				1148-1151
52.2 Interactions between organisms and the environment limit the distribution of species	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1151-1159	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
52.3 Aquatic biomes are diverse and dynamic systems that cover most of Earth				1159-1166
52.4 The structure and distribution of terrestrial biomes are controlled by climate and disturbance				1166-1167
53. Population Ecology				

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
53.1 Dynamic biological processes influence population density, dispersion, and demographics	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1174-1179	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.5 Communities are composed of populations of organisms that interact in complex ways		Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
53.2 Life history traits are products of natural selection	2.A.1 All living systems require constant input of free energy	1179-1181	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy		Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
53.3 The exponential model describes population growth in an idealized, unlimited environment	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1181-1183	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.5 Communities are composed of populations of organisms that interact in complex ways		Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
53.4 The logistic model describes how a population grows	2.A.1 All living systems require constant input of free energy	1183-1186	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 1179, 1180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
more slowly as it nears its carrying capacity	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1183-1186	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.5 Communities are composed of populations of organisms that interact in complex ways		Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
53.5 Many factors that regulate population growth are density dependent	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1186-1190	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.5 Communities are composed of populations of organisms that interact in complex ways		Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
53.6 The human population is no longer growing exponentially but is still increasing rapidly	4.A.5 Communities are composed of populations of organisms that interact in complex ways	1190-1195	Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
54. Community Ecology				
54.1 Community interactions are classified by whether they help, harm, or have no effect on the species involved	4.B.3 Interactions between and within populations influence patterns of species distribution and abundance	1198-1204	Loss of keystone species 1208; Kudzu 1249; Dutch elm disease 650	
	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy		Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	2.E.3 Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection		Availability of resources leading to fruiting body formation in fungi and certain types of bacteria 642, 643, 644, 645, 646, 647; Niche and resource partitioning 1199, 1200; Mutualistic relationships (lichens; bacteria in digestive tracts of animals; and mycorrhizae) 767, 892; Biology of pollination 504, 602, 632, 804, 805; Hibernation 872; Estivation 872; Migration 1122; Courtship 1123	
	4.A.5 Communities are composed of populations of organisms that interact in complex ways		Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
54.2 Dominant and keystone species exert strong controls on community structure	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1204-1210	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	

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	4.A.5 Communities are composed of populations of organisms that interact in complex ways		Symbiotic relationship 570, 571, 572, 646, 649, 804, 805, 1203; Introduction of species 1249; Global climate change models 520, 1159, 1239, 1240, 1241	
	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy			
	4.C.4 The diversity of species within an ecosystem may influence the stability of the ecosystem			
54.3 Disturbance influences species diversity and composition	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1211-1214	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
54.4 Biogeographic factors affect community biodiversity	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1214-1217	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
54.5 Community ecology is useful for understanding pathogen life cycles and controlling human disease	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1217-1219	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
55. Ecosystems				
55.1 Physical laws govern energy flow and chemical cycling in ecosystems	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1223-1224	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy			
55.2 Energy and other limiting factors control primary production in ecosystems	2.A.1 All living systems require constant input of free energy	1224-1228	Krebs cycle 166, 167, 168-169, 170, 171, 175, 176, 180, 181; Glycolysis 166, 167, 168-169, 170, 171, 175, 176, 180, 181, 189; Calvin cycle 189, 199, 201, 202, 203; Fermentation 178; Endothermy (the use of thermal energy generated by metabolism to maintain homeostatic body temperatures) 860, 863, 865; Ectothermy (the use of external thermal energy to help regulate and maintain body temperature) 860, 863, 866, 867; Life-history strategy (biennial plants, reproductive diapause) 11791180, 1181, 1185; Change in the producer level can affect the number and size of other trophic levels 1224, 1228, 1229, 1230; Change in energy resources levels such as sunlight can affect the number and size of the trophic levels 1224, 1226	
	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy		Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
55.3 Energy transfer between trophic levels is typically only 10% efficient	2.A.1 All living systems require constant input of free energy	1228-1230	Gas exchange in aquatic and terrestrial plants 765, 768, 770, 776, 777; Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892; Respiratory systems of aquatic and terrestrial animals 916, 917, 918, 919, 921, 922, 923, 924, 925, 926; Nitrogenous waste production and elimination in aquatic and terrestrial animals 793, 794; Excretory systems in flatworms, earthworms and vertebrates 961, 962, 963, 965, 967; Osmoregulation in bacteria, fish and protests 956, 973; Osmoregulation in aquatic and terrestrial plants 844; Circulatory systems in fish, amphibians and mammals 900, 901902, 903, 904, 905, 906, 907, 908, 909, 910; Thermoregulation in aquatic and terrestrial animals (countercurrent exchange mechanisms) 860, 863, 864, 865	
	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy		Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy			

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Chapters/Sections	Essential Knowledge	Required content for the AP Course	Illustrative examples covered in this textbook - teach at least one	Content not required for the AP Course
55.4 Biological and geochemical processes cycle nutrients between organic and inorganic parts of an ecosystem	2.D.1 All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy	1231-1236	Cell density 206, 208, 209, 210, 211; Biofilms 207, 565; Temperature; Water availability 778 1215; Sunlight; Symbiosis (mutualism, commensalism, parasitism) 570, 571, 572, 646, 649, 804, 805, 1203; Predator–prey relationships 1132, 1208; Water and nutrient availability, temperature, salinity, pH 1232-1233; Water and nutrient availability 1232-1233; Availability of nesting materials and sites 1127; Food chains and food webs 1205, 1206, 1207, 1208; Species diversity 1204, 1205 1211; Population density 1174, 1175, 1176; Algal blooms 582, 1227	
	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy			
55.5 Human activities now dominate most chemical cycles on Earth	4.A.6 Interactions among living systems and with their environment result in the movement of matter and energy	1236-1242		
56. Conservation Biology and Global Change				
56.1 Human activities threaten Earth's biodiversity	2.D.2 Homeostatic mechanism reflect both common ancestry and divergence due to adaptation in different environments	1246-1250	Gas exchange in aquatic and terrestrial plants 765, 768, 770, 776, 777; Digestive mechanisms in animals such as food vacuoles, gastrovascular cavities, one-way digestive systems, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892; Respiratory systems of aquatic and terrestrial animals 916, 917, 918, 919, 921, 922, 923, 924, 925, 926; Nitrogenous waste production and elimination in aquatic and terrestrial animals 793, 794; Excretory systems in flatworms, earthworms and vertebrates 961, 962, 963, 965, 967; Osmoregulation in bacteria, fish and protests 956, 973; Osmoregulation in aquatic and terrestrial plants 844; Circulatory systems in fish, amphibians and mammals 900, 901902, 903, 904, 905, 906, 907, 908, 909, 910; Thermoregulation in aquatic and terrestrial animals (countercurrent exchange mechanisms) 860, 863, 864, 865	
	2.D.3 Biological systems are affected by disruptions to their dynamic homeostatis		Physiological responses to toxic substances; Dehydration 68-69; Immunological responses to pathogens, toxins, and allergens 937, 938, 939, 940, 941; Invasive and/or eruptive species 1249; Human impact 1236, 1237, 1238, 1239, 1240, 1241, 1242, 1246, 1250, 1256, 1257; Hurricanes, floods, earthquakes, volcanoes, and fires 1212, 1213; Water limitation 1167, 1263; Salination 788	
	4.B.4 Distribution of local and global ecosystems change over time		Dutch elm diseas 650; Potato blight 588; Small pox [historic example for Native Americans] 947; Continental drift 519, 520; Meteor impact on dinosaurs 519, 520	
	4.C.4 The diversity of species within an ecosystem may influence the stability of the ecosystem			
56.2 Population conservation focuses on population size, genetic diversity, and critical habitat				1250-1255
56.3 Landscape and regional conservation help sustain entire biotas				1255-1260
56.4 Restoration ecology attempts to restore degraded ecosystems to a more natural state	4.B.4 Distribution of local and global ecosystems change over time	1260-1264	Dutch elm diseas 650; Potato blight 588; Small pox [historic example for Native Americans] 947; Continental drift 519, 520; Meteor impact on dinosaurs 519, 520	
56.5 Sustainable development can improve human lives while conserving biodiversity				1264-1265