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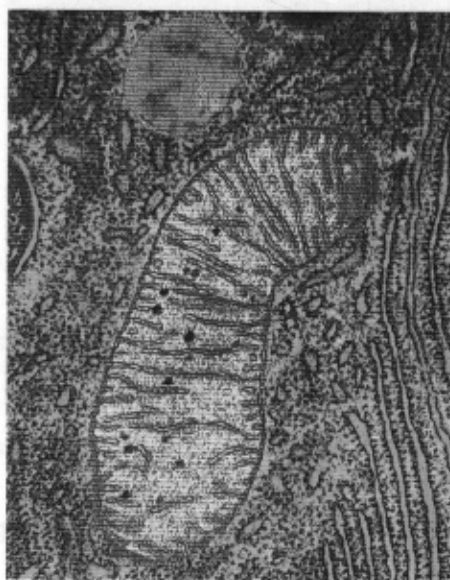
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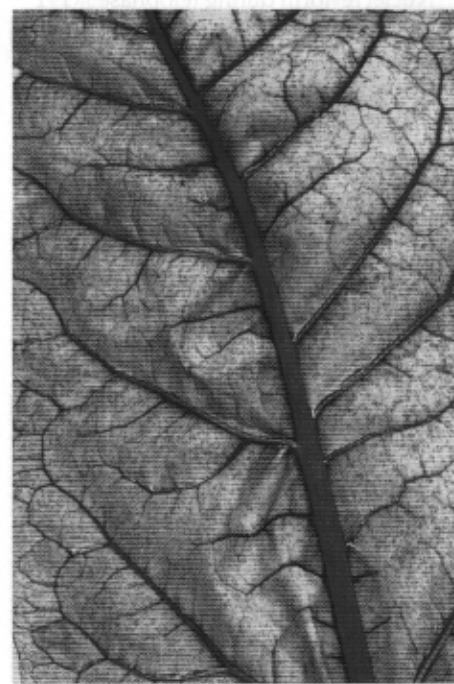
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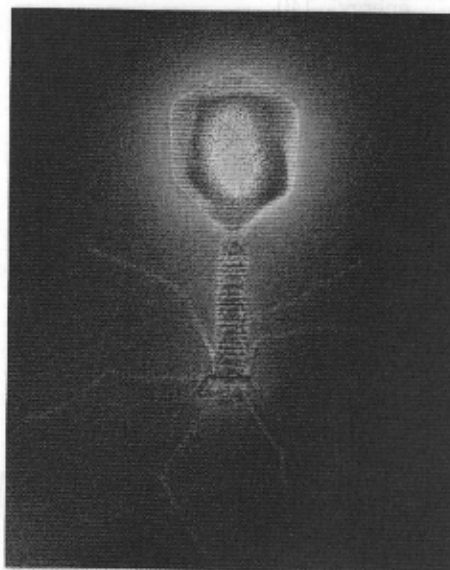
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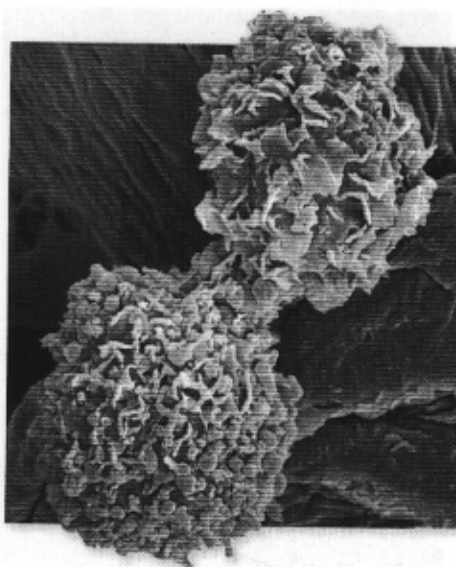
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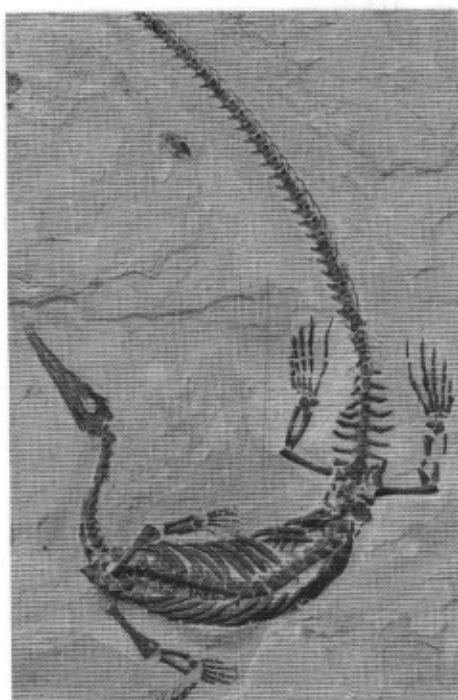
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Sexual selection influences reproductive success 498

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Species form over time 510

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Sympatric speciation occurs without physical barriers 513

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Models of sequence evolution are used to calculate evolutionary divergence 527

Experimental studies examine molecular evolution directly 527

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- New functions can arise by gene duplication 534
- Some gene families evolve through concerted evolution 535

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- Comparisons among species require an evolutionary perspective 544

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- Phylogenies are reconstructed from many sources of data 547
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- The accuracy of phylogenetic methods can be tested 549

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- Phylogenies help us reconstruct the past 551
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- Chlamydias are extremely small parasites 572
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- The Proteobacteria are a large and diverse group 574
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Red algae have a distinctive accessory photosynthetic pigment 601

Chlorophytes, charophytes, and land plants contain chlorophylls *a* and *b* 602

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Life cycles of land plants feature alternation of generations 614

The sporophytes of nonvascular plants are dependent on gametophytes 616

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Vascular plants have been evolving for almost half a billion years 618

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The vascular plants branched out 619

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Fungi are in intimate contact with their environment 652

Fungi exploit many nutrient sources 653

Fungi balance nutrition and reproduction 654

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- Mutualistic relationships are beneficial to both partners 655
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- Mycorrhizae are essential to most plants 657
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- "Imperfect fungi" lack a sexual stage 663

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- The structure of the body cavity influences movement 674
- Segmentation improves control of movement 675
- Appendages enhance locomotion 676

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- Herbivores eat plants 677
- Predators capture and subdue large prey 678
- Parasites live in or on other organisms 679

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- All life cycles have at least one dispersal stage 680
- No life cycle can maximize all benefits 680
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- Cnidarians are specialized carnivores 685

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- Ecdysozoans must shed their exoskeletons 693
- Arrow worms retain some ancestral developmental features 694

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- Flatworms, rotifers, and ribbon worms are structurally diverse relatives 695
- Phoronids and brachiopods use lophophores to extract food from the water 697
- The annelids and the mollusks are sister groups 698
- Annelids have segmented bodies 698
- Mollusks have undergone a dramatic evolutionary radiation 700

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- Several marine groups have relatively few species 702
- Nematodes and their relatives are abundant and diverse 703

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- Arthropod relatives have fleshy, unjointed appendages 705

Jointed legs first appeared in the trilobites 706

Crustaceans are diverse and abundant 706

Insects are the dominant terrestrial arthropods 708

Myriapods have many legs 712

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- Hemichordates have a three-part body plan 721

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- A new dorsal supporting structure replaces the notochord in vertebrates 723
- The vertebrate body plan can support large animals 724
- Fins and swim bladders improved stability and control over locomotion 725

33.4 How Did Vertebrates Colonize the Land? 728

- Jointed fins enhanced support for fishes 728
- Amphibians adapted to life on land 728
- Amniotes colonized dry environments 730
- Reptiles adapted to life in many habitats 731
- Crocodylians and birds share their ancestry with the dinosaurs 731
- The evolution of feathers allowed birds to fly 733
- Mammals radiated after the extinction of dinosaurs 734
- Most mammals are therians 735

33.5 What Traits Characterize the Primates? 737

- Human ancestors evolved bipedal locomotion 738
- Human brains became larger as jaws became smaller 740
- Humans developed complex language and culture 741

Signal transduction pathways are involved in all stages of plant development 798

The seed germinates and forms a growing seedling 798

The plant flowers and sets fruit 798

The plant senesces and dies 798

Not all seeds germinate without cues 799

Seed dormancy affords adaptive advantages 799

Seed germination begins with the uptake of water 800

The embryo must mobilize its reserves 800

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"Foolish seedling" disease led to the discovery of the gibberellins 801

The gibberellins have many effects on plant growth and development 802

37.3 What Does Auxin Do? 803

Phototropism led to the discovery of auxin 803

Auxin transport is polar and requires carrier proteins 803

Light and gravity affect the direction of plant growth 805

Auxin affects plant growth in several ways 805

Auxin analogs as herbicides 807

Auxin promotes growth by acting on cell walls 807

Auxin and gibberellins are recognized by similar mechanisms 808

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Cytokinins are active from seed to senescence 809

Ethylene is a gaseous hormone that hastens leaf senescence and fruit ripening 810

Absciscic acid is the "stress hormone" 811

Brassinosteroids are hormones that mediate effects of light 811

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Phytochromes mediate the effects of red and far-red light 812

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Cryptochromes, phototropins, and zeaxanthin are blue-light receptors 814

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The flower is an angiosperm's structure for sexual reproduction 820

Flowering plants have microscopic gametophytes 821

Pollination enables fertilization in the absence of water 821

Some flowering plants practice "mate selection" 822

A pollen tube delivers sperm cells to the embryo sac 822

Angiosperms perform double fertilization 822

Embryos develop within seeds 823

Some fruits assist in seed dispersal 824

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Apical meristems can become inflorescence meristems 825

A cascade of gene expression leads to flowering 825

Photoperiodic cues can initiate flowering 826

Plants vary in their responses to different photoperiodic cues 826

The length of the night is the key photoperiodic cue determining flowering 827

Circadian rhythms are maintained by a biological clock 828

Photoreceptors set the biological clock 829

The flowering stimulus originates in a leaf 829

In some plants flowering requires a period of low temperature 831

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Vegetative reproduction has a disadvantage 833

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Plants seal off infected parts to limit damage 837

Some plants have potent chemical defenses against pathogens 838

The hypersensitive response is a localized containment strategy 838

Systemic acquired resistance is a form of long-term "immunity" 839

Some plant genes match up with pathogen genes 839

Plants develop specific immunity to RNA viruses 840

39.2 How Do Plants Deal with Herbivores? 840

Grazing increases the productivity of some plants 840

Some plants produce chemical defenses against herbivores 841

Some secondary metabolites play multiple roles 841

Some plants call for help 842

Many defenses depend on extensive signaling 842

Recombinant DNA technology may confer resistance to insects 842

Why don't plants poison themselves? 844

The plant doesn't always win 844

39.3 How Do Plants Deal with Climate Extremes? 845

Some leaves have special adaptations to dry environments 845

Plants have other adaptations to a limited water supply 846

In water-saturated soils, oxygen is scarce 846

Plants have ways of coping with temperature extremes 847

39.4 How Do Plants Deal with Salt and Heavy Metals? 848

Most halophytes accumulate salt 848

Halophytes and xerophytes have some similar adaptations 848

Some habitats are laden with heavy metals 849



Part Eight ■ Animals: Form and Function

40 Physiology, Homeostasis, and Temperature Regulation 854

40.1 Why Must Animals Regulate Their Internal Environments? 855

- An internal environment makes complex multicellular animals possible 855
- Homeostasis requires physiological regulation 856
- Physiological systems are made up of cells, tissues, and organs 857
- Organs consist of multiple tissues 859

40.2 How Does Temperature Affect Living Systems? 860

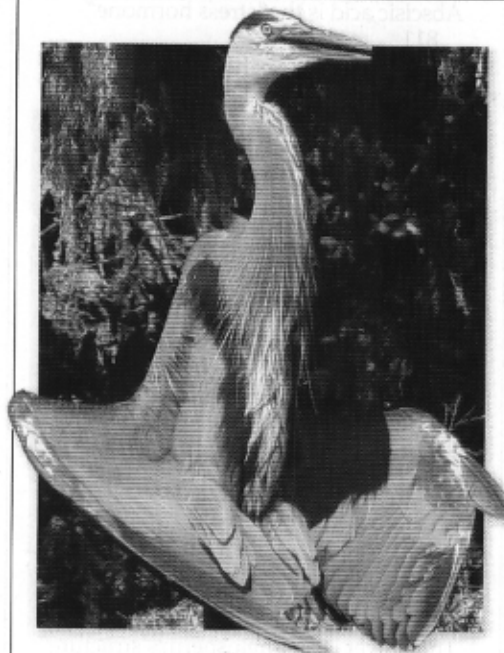
- Q_{10} is a measure of temperature sensitivity 860
- Animals can acclimatize to a seasonal temperature change 861

40.3 How Do Animals Alter Their Heat Exchange with the Environment? 861

- How do endotherms produce so much heat? 861
- Ectotherms and endotherms respond differently to changes in temperature 862
- Energy budgets reflect adaptations for regulating body temperature 863
- Both ectotherms and endotherms control blood flow to the skin 864
- Some fish elevate body temperature by conserving metabolic heat 864
- Some ectotherms regulate heat production 865

40.4 How Do Mammals Regulate Their Body Temperatures? 866

- Basal metabolic rates are correlated with body size and environmental temperature 866
- Endotherms respond to cold by producing heat and reducing heat loss 867
- Evaporation of water can dissipate heat, but at a cost 868
- The vertebrate thermostat uses feedback information 868
- Fever helps the body fight infections 869
- Turning down the thermostat 870



41 Animal hormones 874

41.1 What Are Hormones and How Do They Work? 875

- Hormones can act locally or at a distance 875
- Hormonal communication arose early in evolution 876
- Hormones from the head control molting in insects 876
- Juvenile hormone controls development in insects 877
- Hormones can be divided into three chemical groups 878
- Hormone receptors are found on the cell surface or in the cell interior 878
- Hormone action depends on the nature of the target cell and its receptors 879

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- The pituitary connects nervous and endocrine functions 880
- The anterior pituitary is controlled by hypothalamic hormones 882
- Negative feedback loops control hormone secretion 883

41.3 What Are the Major Mammalian Endocrine Glands and Hormones? 883

- Thyroxine controls cell metabolism 883
- Thyroid dysfunction causes goiter 885
- Calcitonin reduces blood calcium 885

- Parathyroid hormone elevates blood calcium 885
- Vitamin D is really a hormone 886
- PTH lowers blood phosphate levels 887
- Insulin and glucagon regulate blood glucose levels 887
- Somatostatin is a hormone of the brain and the gut 887
- The adrenal gland is two glands in one 887
- The sex steroids are produced by the gonads 889
- Changes in control of sex steroid production initiate puberty 889
- Melatonin is involved in biological rhythms and photoperiodicity 890
- The list of hormones is long 890

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- A hormone can act through many receptors 892
- A hormone can act through different signal transduction pathways 893

42 Animal Reproduction 896

42.1 How Do Animals Reproduce Without Sex? 897

- Budding and regeneration produce new individuals by mitosis 897
- Parthenogenesis is the development of unfertilized eggs 898

42.2 How Do Animals Reproduce Sexually? 899

- Gametogenesis produces eggs and sperm 899
- Fertilization is the union of sperm and egg 901
- Mating brings eggs and sperm together 903
- A single body can function as both male and female 904
- The evolution of vertebrate reproductive systems parallels the move to land 904
- Reproductive systems are distinguished by where the embryo develops 905

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- Male sex organs produce and deliver semen 906
- Male sexual function is controlled by hormones 909

Female sex organs produce eggs, receive sperm, and nurture the embryo 909
 The ovarian cycle produces a mature egg 910
 The uterine cycle prepares an environment for the fertilized egg 911
 Hormones control and coordinate the ovarian and uterine cycles 911
 In pregnancy, hormones from the extra-embryonic membranes take over 912
 Childbirth is triggered by hormonal and mechanical stimuli 912

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Human sexual responses have four phases 913
 Humans use a variety of methods to control fertility 914
 Reproductive technologies help solve problems of infertility 916
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The sperm and the egg make different contributions to the zygote 921
 Rearrangements of egg cytoplasm set the stage for determination 922
 Cleavage repackages the cytoplasm 922
 Cleavage in mammals is unique 923
 Specific blastomeres generate specific tissues and organs 925

43.2 How Does Gastrulation Generate Multiple Tissue Layers? 926

Invagination of the vegetal pole characterizes gastrulation in the sea urchin 927
 Gastrulation in the frog begins at the gray crescent 928
 The dorsal lip of the blastopore organizes embryo formation 928
 The molecular mechanisms of the organizer involve multiple transcription factors 929
 The organizer changes its activity as it migrates from the dorsal lip 931
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 Body segmentation develops during neurulation 933
 Hox genes control development along the anterior-posterior axis 933

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 Extraembryonic membranes in mammals form the placenta 935
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 The fetus grows and matures during the second and third trimesters 937
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 Neurons are the functional units of nervous systems 944
 Glial cells are also important components of nervous systems 946

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Simple electrical concepts underlie neuronal function 947
 Membrane potentials can be measured with electrodes 947
 Ion pumps and channels generate membrane potentials 947
 Ion channels and their properties can now be studied directly 950
 Gated ion channels alter membrane potential 950
 Sudden changes in Na^+ and K^+ channels generate action potentials 951
 Action potentials are conducted along axons without loss of signal 953
 Action potentials can jump along axons 954

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 The arrival of an action potential causes the release of neurotransmitter 955

The postsynaptic membrane responds to neurotransmitter 956
 Synapses between neurons can be excitatory or inhibitory 957
 The postsynaptic cell sums excitatory and inhibitory input 957
 Synapses can be fast or slow 958
 Electrical synapses are fast but do not integrate information well 958
 The action of a neurotransmitter depends on the receptor to which it binds 958
 Glutamate receptors may be involved in learning and memory 959
 To turn off responses, synapses must be cleared of neurotransmitter 960

45 Sensory Systems 964

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 Sensory transduction involves changes in membrane potentials 966
 Sensation depends on which neurons receive action potentials from sensory cells 967
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 The vomeronasal organ senses pheromones 969
 Gustation is the sense of taste 969

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 Hair cells provide information about displacement 974

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The spinal cord transmits and processes information 987

The reticular system alerts the forebrain 988

The core of the forebrain controls physiological drives, instincts, and emotions 988

Regions of the telencephalon interact to produce consciousness and control behavior 989

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Language abilities are localized in the left cerebral hemisphere 1000

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Sliding filaments cause skeletal muscle to contract 1005

Actin-myosin interactions cause filaments to slide 1007

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Single skeletal muscle twitches are summed into graded contractions 1012

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A muscle has an optimal length for generating maximum tension 1014

Exercise increases muscle strength and endurance 1014

Muscle ATP supply limits performance 1014

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Exoskeletons are rigid outer structures 1016

Vertebrate endoskeletons provide supports for muscles 1017

Bones develop from connective tissues 1018

Bones that have a common joint can work as a lever 1019

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Chromatophores allow an animal to change its color or pattern 1020

Glands secrete chemicals for defense, communication, or predation 1021

Electric organs generate electricity used for sensing, communication, defense, or attack 1021

Light-emitting organs use enzymes to produce light 1021

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Diffusion is driven by concentration differences 1025

Fick's law applies to all systems of gas exchange 1026

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High temperatures create respiratory problems for aquatic animals 1026

O₂ availability decreases with altitude 1026

CO₂ is lost by diffusion 1027

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Transporting gases to and from the exchange surfaces optimizes partial pressure gradients 1028

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Fish gills use countercurrent flow to maximize gas exchange 1029

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Breathing is controlled in the brain stem 1039

Regulating breathing requires feedback information 1039

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Some animals do not have circulatory systems 1045

Open circulatory systems move extracellular fluid 1046

Closed circulatory systems circulate blood through a system of blood vessels 1046

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Fish have two-chambered hearts 1047

Amphibians have three-chambered hearts 1048

Reptiles have exquisite control of pulmonary and systemic circulation 1048

Birds and mammals have fully separated pulmonary and systemic circuits 1049

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Blood flows from right heart to lungs to left heart to body 1050

The heartbeat originates in the cardiac muscle 1052

A conduction system coordinates the contraction of heart muscle 1053

Electrical properties of ventricular muscles sustain heart contraction 1054

The ECG records the electrical activity of the heart 1055

49.4 What Are the Properties of Blood and Blood Vessels? 1055

Red blood cells transport respiratory gases 1055

Platelets are essential for blood clotting 1056

Plasma is a complex solution 1056

Blood circulates throughout the body in a system of blood vessels 1057

Materials are exchanged in capillary beds by filtration, osmosis, and diffusion 1057

Blood flows back to the heart through veins 1059

Lymphatic vessels return interstitial fluid to the blood 1060

Vascular disease is a killer 1060

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Autoregulation matches local blood flow to local need 1061

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Cardiovascular control in diving mammals conserves oxygen 1063

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Energy can be measured in calories 1069

Energy budgets reveal how animals use their resources 1070

Sources of energy can be stored in the body 1071

Food provides carbon skeletons for biosynthesis 1072

Animals need mineral elements for a variety of functions 1073

Animals must obtain vitamins from food 1073

Nutrient deficiencies result in diseases 1074

50.2 How Do Animals Ingest and Digest Food? 1075

The food of herbivores is often low in energy and hard to digest 1075

Carnivores must detect, capture, and kill prey 1075

Vertebrate species have distinctive teeth 1076

Animals digest their food extracellularly 1076

Tubular guts have an opening at each end 1077

Digestive enzymes break down complex food molecules 1077

50.3 How Does the Vertebrate Gastrointestinal System Function? 1078

The vertebrate gut consists of concentric tissue layers 1078

Mechanical activity moves food through the gut and aids digestion 1079

Chemical digestion begins in the mouth and the stomach 1080

What causes stomach ulcers? 1081

The stomach gradually releases its contents to the small intestine 1082

Most chemical digestion occurs in the small intestine 1082

Nutrients are absorbed in the small intestine 1083

Absorbed nutrients go to the liver 1084

Water and ions are absorbed in the large intestine 1084

The problem with cellulose 1084

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Some toxins are retained and concentrated 1089

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Water enters or leaves cells by osmosis 1093

Excretory organs control extracellular fluid osmolarity by filtration, secretion, and reabsorption 1094

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Animals can be ionic conformers or ionic regulators 1095

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Animals excrete nitrogen in a number of forms 1095

Most species produce more than one nitrogenous waste 1096

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The protonephridia of flatworms excrete water and conserve salts 1097

The metanephridia of annelids process coelomic fluid 1097

The Malpighian tubules of insects depend on active transport 1098

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Marine fishes must conserve water 1099

Terrestrial amphibians and reptiles must avoid desiccation 1099

Birds and mammals can produce highly concentrated urine 1099

The nephron is the functional unit of the vertebrate kidney 1099

Blood is filtered in the glomerulus 1100

The renal tubules convert glomerular filtrate to urine 1101

51.5 How Does the Mammalian Kidney Produce Concentrated Urine? 1101

Kidneys produce urine and the bladder stores it 1101

Nephrons have a regular arrangement in the kidney 1101

Most of the glomerular filtrate is reabsorbed by the proximal convoluted tubule 1103

The loop of Henle creates a concentration gradient in the surrounding tissue 1103

Water permeability of kidney tubules depends on water channels 1104

Water reabsorption begins in the distal convoluted tubule 1104

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The kidneys help regulate acid-base balance 1105

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The heart produces a hormone that influences kidney function 1108

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Global oceanic circulation is driven by wind patterns 1115

Organisms must adapt to changes in their environment 1115

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Tundra is found at high latitudes and in high mountains 1118

Evergreen trees dominate most boreal forests 1119

Temperate deciduous forests change with the seasons 1120

Temperate grasslands are widespread 1121

Cold deserts are high and dry 1122

Hot deserts form around 30° latitude 1123

The chaparral climate is dry and pleasant 1124

Thorn forests and tropical savannas have similar climates 1125

Tropical deciduous forests occur in hot lowlands 1126

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Biotic interchange follows fusion of land masses 1134

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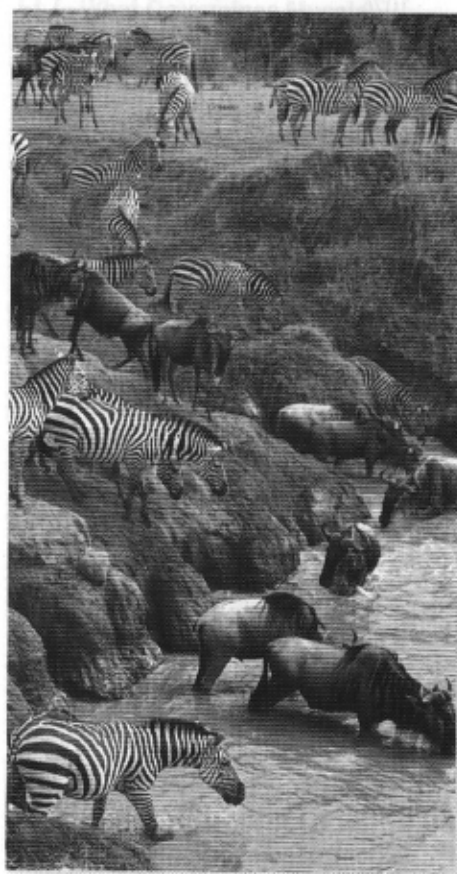
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Defending a territory has benefits and costs 1148

Animals choose what foods to eat 1149

An animal's choice of associates influences its fitness 1152

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Animals must find their way around their environment 1154

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Chemical signals are durable 1157

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Altruism can evolve by contributing to an animal's inclusive fitness 1159

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Territoriality influences community structure 1161

Social animals may achieve great population densities 1161

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Ecologists use a variety of devices to track individuals 1167

Population densities can be estimated from samples 1168

Birth and death rates can be estimated from population density data 1169

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All populations have the potential for exponential growth 1173

Population growth is limited by resources and biotic interactions 1173

Population densities influence birth and death rates 1174

Several factors explain why some species are more common than others 1175

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Communities are loose assemblages of species 1185

The organisms in a community use diverse sources of energy 1186

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Predation and parasitism are universal 1189

Competition is widespread because all species share resources 1192

Commensal and amensal interactions are widespread 1193

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Water moves rapidly through lakes and rivers 1206

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Solar energy drives ecosystem processes 1209

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Conservation biology aims to prevent species extinctions 1228

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Species are endangered by habitat loss, degradation, and fragmentation 1231

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