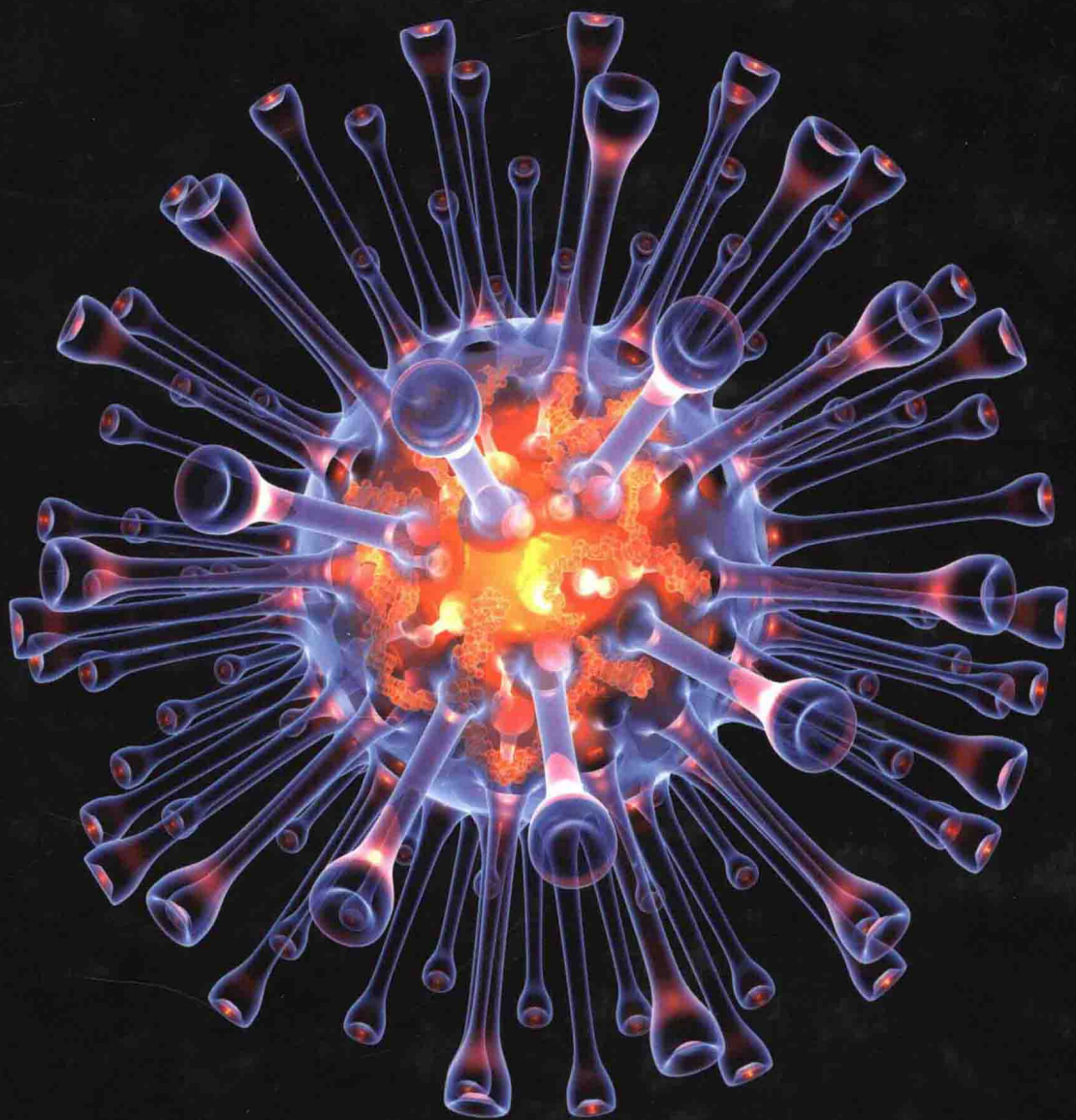
MICROBIOLOGY

PRINCIPLES AND EXPLORATIONS

9th EDITION



JACQUELYN G. BLACK | LAURA J. BLACK

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Swine flu virus particle. Computer artwork of a swine influenza (flu) virus particle. At the core of the virus is RNA (ribonucleic acid, orange) genetic material. This is surrounded by a nucleocapsid and a lipid envelope. In the envelope are two types of protein spike, hemagglutinin (H) and neuraminidase (N), which determine the strain of virus. These are used for recognizing and binding to the host cell.

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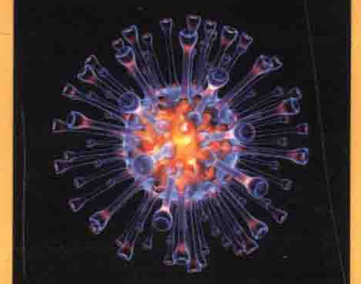

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9 TH EDITION

JACQUELYN G. BLACK

Marymount University, Arlington, Virginia

LAURA J. BLACK

Laura Black has been working on this book since she was ten years old. She has been a contributing author for the past two editions and is now a coauthor of this ninth edition.

JACQUELYN and LAURA BLACK

WILEY

TO ROBERT . . .
for sharing his mother and grandmother with that greedy sibling "the book."

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Diseases and the Organisms that Cause Them

BACTERIAL DISEASES—ALSO SEE APPENDIX B

Disease	Organism	Type*	Page
acne	*Propionibacterium acnes*	R, +	591
actinomycosis	*Actinomyces israelii*	I, +	603
anthrax	*Bacillus anthracis*	R, +	95, 740–744
bacterial meningitis	*Haemophilus influenzae*	R, –	775
	Neisseria meningitidis	C, –	451, 774
	Streptococcus pneumoniae	C, +	775
	Listeria monocytogenes	R, –	775
bacterial vaginitis	*Gardnerella vaginalis*	R, –	624
botulism	*Clostridium botulinum*	R, +	420, 699, 785–787
brucellosis (undulant fever, Malta fever)	*Brucella* sp.†	CB, –	747–748
cat scratch fever	*Afipia felis*, *Bartonella henselae*	R, – CB, NA	609
chancroid	*Haemophilus ducreyi*	R, –	634
cholera (Asiatic cholera)	*Vibrio cholerae*	vibrio, –	420, 703–705
conjunctivitis	*Haemophilus aegyptius*	CB, –	603
dental caries	*Streptococcus mutans*	C, +	693–695
diptheria	*Corynebacterium diptheriae*	R, +	656–658
ehrlichiosis	*Ehrlichia* sp.	R, NA	754
endocarditis	*Enterococcus faecalis*	C, +	737–738
food poisoning	*Staphylococcus aureus*	C, +	420, 698–699
	Streptococcus pyogenes	C, +	734
	Clostridium perfringens	R, +	420, 699
	Clostridium botulinum	R, +	699
	Bacillus cereus	R, +	699
	Listeria monocytogenes	R, +	775
	Campylobacter sp.	R, –	399, 699–705
	Shigella sp.	R, –	420, 701–703
	Salmonella sp.	R, –	398, 700–701
	Vibrio parahaemolyticus	R, –	705–706
gas gangrene	*Clostridium perfringens* and others	R, –	608–609
gonorrhea	*Neisseria gonorrhoeae*	C, –	627–630
granuloma inguinale (donovanosis)	*Calymmatobacterium granulomatis*	R, –	638
Hansen's disease (leprosy)	*Mycobacterium leprae*	R, A-F	414, 782–784
Legionnaires' disease (legionellosis)	*Legionella pneumophilia*	R, –	665–666
leptospirosis	*Leptospira interrogans*	S, –	624
listeriosis	*Listeria monocytogenes*	R, +	775
Lyme disease	*Borrelia burgdorferi*	S, –	339, 748–751
lymphogranuloma venereum	*Chlamydia trachomatis*	coccoid, NA	637–638
Madura foot (maduromycosis)	*Actinomadura*, *Streptomyces*, *Nocardia*	I, +, some A-F	603
nongonococcal urethritis (NGU)	*Chlamydia trachomatis*	R, VAR	636
	Ureaplasma urealyticum	I, NA	636–637
ornithosis (psittacosis)	*Chlamydia psittaci*	coccoid, NA	670
Oroyo fever (Carrion's disease, bartonellosis)	*Bartonella bacilliformis*	coccoid, –	754
peptic ulcer	*Helicobacter pylori*	R, –	707–708
periodontal disease	*Porphyromonas gingivalis* and others	R, –	696–697
pharyngitis (strep throat)	*Streptococcus pyogenes*	C, +	655–656
plague (black death)	*Yersinia pestis*	R, –	339,
bubonic plague			744–746
pneumonic plague			745
pneumonia	*Streptococcus pneumoniae*	C, +	663–664
	Klebsiella pneumoniae	R, –	127, 170, 664, 684
pneumonia, atypical (walking pneumonia)	*Mycoplasma pneumoniae*	I, NA	664
pseudomembranous colitis	*Clostridium difficile*	R, +	708
puerperal fever (childbed fever)	*Streptococcus pyogenes*	C, +	736
Q fever	*Coxiella burnetti*	CB, NA	339, 671–672
rat bite fever	*Spirillum minor*	S, –	609–610
	Streptobacillus moniliformis	R, –	609–610
relapsing fever	*Borrelia* sp.	S, –	748
rheumatic fever	*Streptococcus pyogenes*	C, +	736–737
rickettsialpox	*Rickettsia akari*	CB, NA	754
Rocky Mountain spotted fever	*Rickettsia rickettsii*	CB, NA	753–754
salmonellosis	*Salmonella* sp.	R, –	700–701
shigellosis (bacillary dysentery)	*Shigella* sp.	R, –	701–703
skin and wound infections (scalded skin syndrome, scarlet fever, erysipelas, impetigo, etc.)	*Staphylococcus aureus*	C, +	589
	Staphylococcus epidermidis	C, +	589
	Streptococcus sp.	C, +	590
	Providencia stuartii	R, –	591
	Pseudomonas aeruginosa	R, –	591
	Serratia marcescens	R, –	199, 591
syphilis	*Treponema pallidum*	S, –	631–634
tetanus	*Clostridium tetani*	R, +	784–785
toxic shock syndrome	*Staphylococcus aureus*	C, +	625–626
trachoma	*Chlamydia trachomatis*	coccoid, NA	603
trench fever	*Rochalimaea quintana*	CB, NA	339, 754
tuberculosis	*Mycobacterium tuberculosis*	R, A-F	666–667
tuberculosis, avian	*Mycobacterium avium*	R, A-F	666
tularemia	*Francisella tularensis*	R, –	339, 746–747
typhoid fever	*Salmonella typhi*	R, –	701
typhus, endemic (murine typhus)	*Rickettsia typhi*	CB, NA	751–752
typhus, epidemic	*Rickettsia prowazekii*	CB, NA	752
typhus, recrudescent (Brill-Zinsser disease)	*Rickettsia prowazekii*	CB, NA	752
typhus, scrub (tsutsugamushi disease)	*Rickettsia tsutsugamushi*	CB, NA	752

Diseases and the Organisms that Cause Them (*Continued*)

BACTERIAL DISEASES—ALSO SEE APPENDIX B

Disease	Organism	Type*	Page
verruga peruana (bartonellosis)	*Bartonella bacilliformis*	coccoid, –	754
vibriosis	*Vibrio parahaemolyticus*	R, –	705
whooping cough (pertussis)	*Bordetella pertussis*	CB, –	660–663
yersiniosis	*Yersinia enterocolitica*	R, –	707

*Key to types:
C = coccus
CB = coccobacillus
R = rod
S = spiral
I = irregular
– = Gram-negative
+ = Gram-positive
VAR = Gram-variable
A-F = acid-fast
NA = not applicable
†Species

VIRAL DISEASES

Disease	Virus	Reservoir	Page
aplastic crisis in sickle cell anemia	erythrovirus (B19)	humans	760
avian (bird) flu	influenza	birds	672–676
bronchitis, rhinitis	parainfluenza	humans, some other mammals	659–660
Burkitt's lymphoma	Epstein-Barr	humans	757–759
cervical cancer	human papillomavirus	humans	279, 598, 644
chickenpox	varicella-zoster	humans	284–287, 595–596
coryza (common cold)	rhinovirus	humans	278, 659
	coronavirus	humans	658–659
cytomegalic inclusion disease	cytomegalovirus	humans	644
Dengue fever encephalitis	Dengue	humans	240, 755–756
	Colorado tick fever	mammals	240, 760–761
	Eastern equine encephalitis	birds	278, 436, 779
	St. Louis encephalitis	birds	779
	Venezuelan equine encephalitis	rodents	278, 779
	Western equine encephalitis	birds	278, 339, 437, 779
epidemic keratoconjunctivitis	adenovirus	humans	605–606
fifth disease (erythema infectiosum)	erythrovirus (B19)	humans	279, 760
hantavirus pulmonary syndrome	bunyavirus	rodents	279, 681
hemorrhagic fever	Ebola virus (filovirus)	humans (?)	279, 759
	Marburg virus (filovirus)	humans (?)	279, 759
hemorrhagic fever, Bolivian	arenavirus	rodents and humans	760
hemorrhagic fever, Korean	bunyavirus (Hantaan)	rodents	279, 759–760
hepatitis A (infectious hepatitis)	hepatitis A	humans	278, 711–713
hepatitis B (serum hepatitis)	hepatitis B	humans	279, 713–715
hepatitis C (non-A, non-B)	hepatitis C	humans	715
hepatitis D (delta hepatitis)	hepatitis D	humans	715
hepatitis E (enterically transmitted non-A, non-B, non-C)	hepatitis E	humans	715
herpes, genital	usually herpes simplex type 2, sometimes type 1	humans	279, 640–642
herpes, oral	usually herpes simplex type 1, sometimes type 2	humans	279, 639
HIV disease, AIDS	human immunodeficiency virus (HIV)	humans	278, 564–571
infectious mononucleosis	Epstein-Barr	humans	757
influenza	influenza	swine, humans (type A)	278, 282, 523, 673–677
		humans (type B)	278, 282, 523, 673–677
		humans (type C)	774, 673–677
Lassa fever	arenavirus	rodents	760
measles (rubeola)	measles	humans	278, 641, 781
meningoencephalitis	herpes	humans	641, 781
molluscum contagiosum	poxvirus group	humans	598
monkeypox	orthopoxvirus	humans, monkeys	597
mumps	paramyxovirus	humans	697–698
pneumonia	adenoviruses, respiratory syncytial virus	humans	663–664
poliomyelitis	poliovirus	humans	278, 787–789
rabies	rabies	all warm-blooded animals	776–779
respiratory infections	adenovirus	humans	684
	polyomavirus	none	781
Rift Valley fever	bunyavirus (phlebovirus)	humans, sheep, cattle	759–760
roseola	human herpes virus-6	humans	595
rubella (German measles)	rubella	humans	278, 593–594
SARS (sudden acute respiratory syndrome)	coronavirus	animal	679–680
shingles	varicella-zoster	humans	279, 595–596
smallpox	variola (major and minor)	humans	279, 596–597
viral enteritis	rotavirus	humans	679–681
warts, common (papillomas)	human papillomavirus	humans	279, 598–599
warts, genital (condylomas)	human papillomavirus	humans	279, 598–599, 642–643
West Nile	West Nile	birds	779–780
yellow fever	yellow fever	monkeys, humans, mosquitoes	278, 281, 340, 756–757

The tables of fungal and parasitic diseases appear on the following page.

Diseases and the Organisms that Cause Them (*Concluded*)

UNCONVENTIONAL AGENTS

Disease	Agent	Resevior	Page	Disease	Agent	Resevior	Page
chronic wasting disease	prion	elk, deer	791	mad cow disease (bovine spongiform encephalopathy)	prion	cattle	791
Creutzfeldt-Jacob disease	prion	humans	789–791				
kuru	prion	humans	790				
				scrapie	prion	sheep	790–791

FUNGAL DISEASES

Disease	Organism	Page	Disease	Organism	Page
aspergillosis	*Aspergillus* sp	601, 683	histoplasmosis	*Histoplasma capsulatum*	682
blastomycosis	*Blastomyces dermatitidis*	601–602	*Pneumocystis* pneumonia	*Pneumocystis carinii*	683
candidiasis	*Candida albicans*	602	ringworm (tinea)	various species of *Epidermophyton, Trichophyton, Microsporum*	600–601
coccidioidomycosis (San Joaquin valley fever)	*Coccidioides immitis*	681–682			
cryptococcosis	*Filobasidiella neoformans*	682–683	sporotrichosis	*Sporothrix schenckii*	601
ergot poisoning	*Claviceps purpurea*	836	zygomycosis	*Rhizopus* sp., *Mucor* sp	602

PARASITIC DISEASES

Disease	Organism	Type	Page	Disease	Organism	Type	Page
Acanthamoeba keratitis	*Acanthamoeba culbertsoni*	protozoan	445	malaria	*Plasmodium* sp.	protozoan	318, 450, 762–765
African sleeping sickness (trypanosomiasis)	*Trypanosoma brucei gambiense* and *T. brucei rhodesiense*	protozoan	339–340, 792–793	pediculosis (lice infestation)	*Pediculus humanus*	louse	611
amoebic dysentery	*Entamoeba histolytica*	protozoan	715–717	pinworm	*Enterobius vermicularis*	roundworm	725
ascariasis	*Ascaris lumbricoides*	roundworm	724–725	river blindness (onchocerciasis)	*Onchocerca volvulus*	roundworm	606–607
babesiosis	*Babesia microti*	protozoan	765–766	scabies (sarcoptic mange)	*Sarcoptes scabiei*	mite	610–611
balantidiasis	*Balantidium coli*	protozoan	715–717	schistosomiasis	*Schistosoma* sp.	flatworm	331, 738–740
Chagas' disease	*Trypanosoma cruzi*	protozoan	339, 793–796	sheep liver fluke (fascioliasis)	*Fasciola hepatica*	flatworm	719–720
chigger dermatitis	*Trombicula* sp.	mite	610	strongyloidiasis	*Strongyloides stercoralis*	roundworm	724–725
chigger infestation	*Tunga penetrans*	sandflea	610	swimmer's itch	*Schistosoma* sp.	flatworm	603
Chinese liver fluke	*Clonorchis sinensis*	flatworm	720	tapeworm infestation (taeniasis)	*Hymenolepsis nana* (dwarf tapeworm)	flatworm	720–722
crab louse	*Phthirus pubis*	louse	611		*Taenia saginata* (beef tapeworm)	flatworm	330, 332, 720–722
cryptosporidiosis	*Cryptosporidium* sp.	protozoan	716		*Taenia solium* (pork tapeworm)	flatworm	720–722
dracunculiasis (Guinea worm)	*Dracunculus medinensis*	roundworm	333, 603		*Diphyllobothrium latum* (fish tapeworm)	flatworm	720–722
elephantiasis (filariasis)	*Wuchereria bancrofti*	roundworm	333, 740		*Echinococcus granulosus* (dog tapeworm)	flatworm	720–722
fasciiolopsiasis	*Fasciolopsis buski*	flatworm	719	toxoplasmosis	*Toxoplasma gondii*	protozoan	765
giardiasis	*Giardia intestinalis*	protozoan	715–717	trichinosis	*Trichinella spiralis*	roundworm	332, 722–723
heartworm disease	*Dirofilaria immitis*	roundworm	313, 735	trichomoniasis	*Trichomonas vaginalis*	protozoan	626–627
hookworm	*Ancylostoma duodenale* (Old World hookworm)	roundworm	724–725	trichuriasis (whipworm)	*Trichuris trichiura*	roundworm	725–726
	Necator americanus (New World hookworm)	roundworm	725	visceral larva migrans	*Toxocara* sp.	roundworm	725–726
leishmaniasis kala azar oriental sore	*Leishmania braziliensis, L. donovani, L. tropica*	protozoan	339, 761				
liver/lung fluke (paragonimiasis)	*Paragonimus westermani*	flatworm	329, 683				
loaiasis	*Loa loa*	roundworm	333, 607				

Preface

The development of microbiology—from Leeuwenhoek's astonished observations of "animalcules," to Pasteur's first use of rabies vaccine on a human, to Fleming's discovery of penicillin, to today's race to develop an AIDS vaccine is one of the most dramatic stories in the history of science. To understand the roles microbes play in our lives, including the interplay between microorganisms and humans, we must examine, learn about, and study their world—the world of microbiology.

Microorganisms are everywhere. They exist in a range of environments from mountains and volcanoes to deep-seas vents and hot springs. Microorganisms can be found in the air we breathe, in the food we eat, and even within our own body. In fact, we come in contact with countless numbers of microorganisms every day. Although some microbes can cause disease, most are not disease producers; rather they play a critical role in the processes that provide energy and make life possible. Some even prevent disease, and others are used in attempts to cure disease. Because microorganisms play diverse roles in the world, microbiology continues to be an exciting and critical discipline of study. And because microbes affect our everyday lives, microbiology provides many challenges and offers many rewards. Look at your local newspaper, and you will find items concerning microbiology: to mention a few, reports on diseases such as AIDS, tuberculosis, and cancer; the resurgence of malaria and dengue fever, or "new" diseases.

Did you know that the microbes in your gut (the gut microbiome) affect you even before you are born? If your mother was obese during pregnancy, she had a low diversity of microbes in her gut, which she will pass on to you setting the stage for development of obesity and diabetes later in you. As a woman approaches her delivery date, beneficial microbes migrate down to the birth canal where they will hopefully be passed on to her baby. But if it is premature or born by Caesarian section, it won't get them. Even the milk of C-sectioned mothers lacks proper diversity of microbes–and it won't catch up to normal for 6 months. But if the mother has been in labor for some hours before the C-section is done, the milk will be normal from day one. Hard labor causes a leaky gut which allows microbes to get into the circulation and reach the breast milk. So when you plan to have a baby, think of the microbial implications: lose weight before you get pregnant, don't have unnecessary C-sections, and breast feed. Those microbes are important.

One of the most exciting and controversial new developments occurred 5 years ago, when J. Craig Venter (of Human Genome fame) made a synthetic bacterium (*Synthia laboratorium*). Was he usurping the role of God? Did we have to fear a whole new horde of man-made bacteria which would ruin the environment, create new diseases, or set off huge epidemics? Or, would they be the answer to problems such as providing biofuels that would take care of energy needs? Read about Dr. Venter's work in Chapter 10. Incidentally, he already created the first synthetic virus a few years ago, from parts that he ordered from biological supply houses.

NAVIGATING MICROBIOLOGY

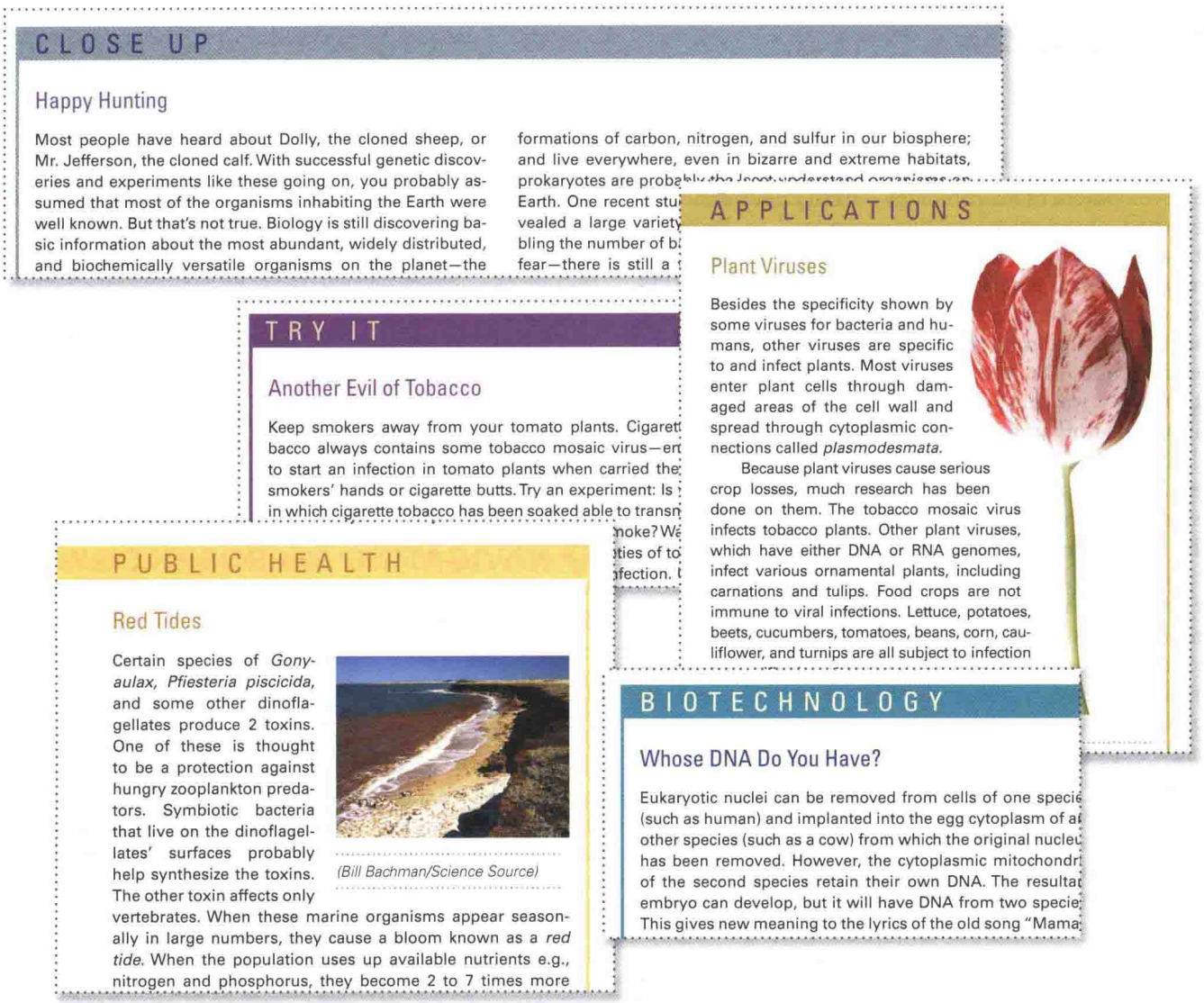
The theme that permeates this book is that microbiology is a current, relevant, exciting central science that affects all of us. I would like to share this excitement with you. Come with me as I take you, and your students, on a journey through the relevancy of microbiology. In countless areas—from agriculture to evolution, from ecology to dentistry—microbiology is contributing to scientific knowledge as well as solving human problems. Accordingly, a goal of this text is to offer a sense of the history of this science, its methodology, its many contributions to humanity, and the many ways in which it continues to be on the cutting edge of scientific advancement.

AUDIENCE AND ORGANIZATION

This book meets the needs of students in the health sciences as well as biology majors and students enrolled in other science programs who need a solid foundation in microbiology. It is designed to serve both audiences—in part by using an abundance of clinically important information to illustrate the general principles of microbiology and in part by offering a wide variety of additional applications.

In this edition, boxed essay titles appear in a different color to help students easily identify the type of application.

The organization of the ninth edition continues to combine logic with flexibility. The chapters are grouped in units from the fundamentals of chemistry, cells, and microscopy; to metabolism, growth, and genetics; to taxonomy of microbes and multicellular parasites; to control of microorganisms; to host-microbe interactions; to infectious diseases of humans; and finally to environmental



CLOSE UP

Happy Hunting

Most people have heard about Dolly, the cloned sheep, or Mr. Jefferson, the cloned calf. With successful genetic discoveries and experiments like these going on, you probably assumed that most of the organisms inhabiting the Earth were well known. But that's not true. Biology is still discovering basic information about the most abundant, widely distributed, and biochemically versatile organisms on the planet—the formations of carbon, nitrogen, and sulfur in our biosphere; and live everywhere, even in bizarre and extreme habitats, prokaryotes are probably the least understood organisms on Earth. One recent stu vealed a large variety bling the number of b fear—there is still a

TRY IT

Another Evil of Tobacco

Keep smokers away from your tomato plants. Cigaret bacco always contains some tobacco mosaic virus—en to start an infection in tomato plants when carried the smokers' hands or cigarette butts. Try an experiment: Is in which cigarette tobacco has been soaked able to transn noke? W ties of to fection.

APPLICATIONS

Plant Viruses

Besides the specificity shown by some viruses for bacteria and humans, other viruses are specific to and infect plants. Most viruses enter plant cells through damaged areas of the cell wall and spread through cytoplasmic connections called *plasmodesmata*.

Because plant viruses cause serious crop losses, much research has been done on them. The tobacco mosaic virus infects tobacco plants. Other plant viruses, which have either DNA or RNA genomes, infect various ornamental plants, including carnations and tulips. Food crops are not immune to viral infections. Lettuce, potatoes, beets, cucumbers, tomatoes, beans, corn, cauliflower, and turnips are all subject to infection

PUBLIC HEALTH

Red Tides

Certain species of *Gonyaulax, Pfiesteria piscicida,* and some other dinoflagellates produce 2 toxins. One of these is thought to be a protection against hungry zooplankton predators. Symbiotic bacteria that live on the dinoflagellates' surfaces probably help synthesize the toxins. The other toxin affects only vertebrates. When these marine organisms appear seasonally in large numbers, they cause a bloom known as a *red tide*. When the population uses up available nutrients e.g., nitrogen and phosphorus, they become 2 to 7 times more

(Bill Bachman/Science Source)

BIOTECHNOLOGY

Whose DNA Do You Have?

Eukaryotic nuclei can be removed from cells of one specie (such as human) and implanted into the egg cytoplasm of a other species (such as a cow) from which the original nucle has been removed. However, the cytoplasmic mitochondr of the second species retain their own DNA. The resulta embryo can develop, but it will have DNA from two specie This gives new meaning to the lyrics of the old song "Mama

and applied microbiology. The chapter sequence will be useful in most microbiology courses as they are usually taught. However, it is not essential that chapters be assigned in their present order; it is possible to use this book in courses organized along different lines.

STYLE AND CURRENCY

In a field that changes so quickly—with new research, new drugs, and even new diseases—it is essential that a text be as up-to-date as possible. This book incorporates the latest information on all aspects of microbiology, including geomicrobiology, phage therapy, deep hot biosphere vents, and clinical practice. Special attention has been paid to such important, rapidly evolving topics as genetic engineering, gut microbiome, fecal transplants, prions, virophages, giant Mimi viruses, cervical cancer, and immunology.

One of the most interesting ideas new to immunology is found in the opener to Chapter 18: are worms our friends? Many autoimmune diseases such as Crohn's disease and irritable bowel disease are being treated by giving the patient 2,500 whipworm eggs every 2 or 3 weeks. They hatch, but can't develop as they are in the wrong host. But they induce a win—win symbiosis: They induce a dampening of the host's inflammatory immune response, meaning that they don't get killed (their win). The human host wins by not having a huge inflammatory immune response which would lead to an autoimmune disease. Our ancestors must have all had many kinds of worms with which they could have evolved symbioses. Maybe it's time to go back to "our old friends, the worms."

The rapid advances being made in microbiology make teaching about—and learning about—microorganisms challenging. Therefore, every effort has been made in the ninth edition of Microbiology: Principles and Explorations to ensure that the writing is simple, straightforward, and functional; that microbiological concepts and methodologies are clearly and thoroughly described;

and that the information presented is as accessible as possible to students. Students who enjoy a course are likely to retain far more of its content for a longer period of time than those who take the course like a dose of medicine. There is no reason for a text to be any less interesting than the subject it describes. So, in addition to a narrative that is direct and authoritative, students will find injections of humor, engaging stories, and personal reflections that I hope impart a sense of discovery and wonder and a bit of my passion for microbial life.

Because students find courses most interesting when they can relate topics to their everyday life or to career goals, I have emphasized the connection between microbiological knowledge and student experiences. One way that this connection is made is through the many boxed essays described previously. Another is through the use of factoids, post-it type notes that are tidbits of information relating to the running text and that add an extra dimension of flavor to the discussion at hand.

Over 20 milion deaths each year are due to infectious disease.

Post-it type notes give additional information in the margin.

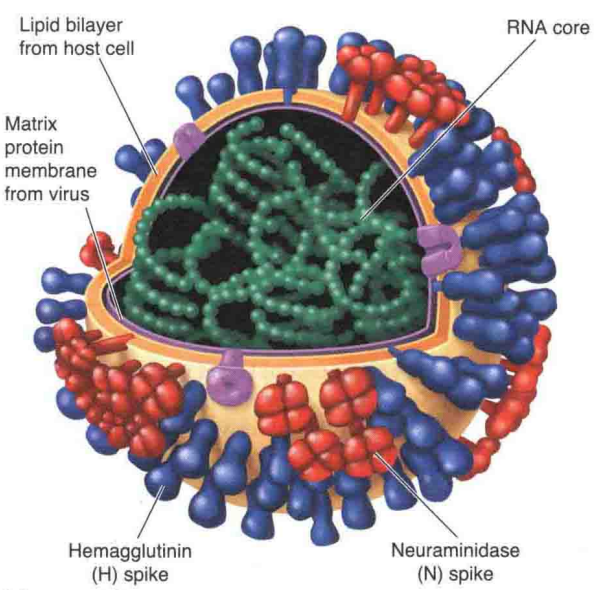
DESIGN AND ILLUSTRATIONS

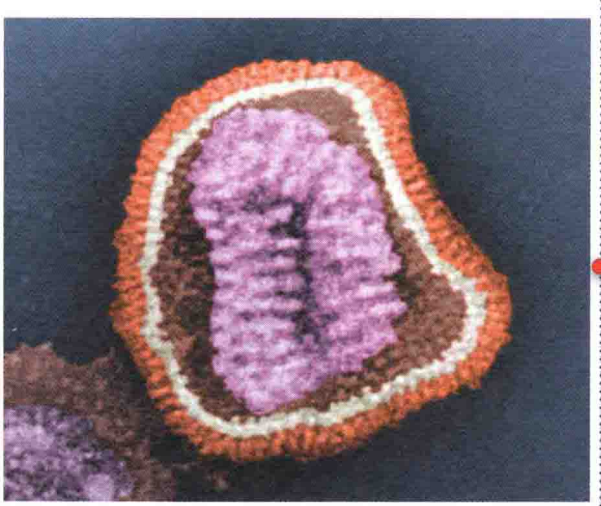
The ninth edition of Microbiology: Principles and Explorations has been completely redesigned with an eye toward increasing the readability, enhancing the presentation of illustrations and photographs, and making the pedagogical features more effective for use. The use of clear, attractive drawings and carefully chosen photographs can significantly contribute to the student's understanding of a scientific subject. Throughout, color has been used not just decoratively but for its pedagogic value. For example, every effort has been made to color similar molecules and structures the same way each time they appear, making them easier to recognize.

Illustrations have been carefully developed to amplify and enhance the narrative. The line art in this text is sometimes as simple as a flow diagram or just as often a

Should boys be vaccinated with Gardasil against HPV?

FIGURE 20.24 **Genital warts of the penis.** *(Biophoto Associates/Science Source)*

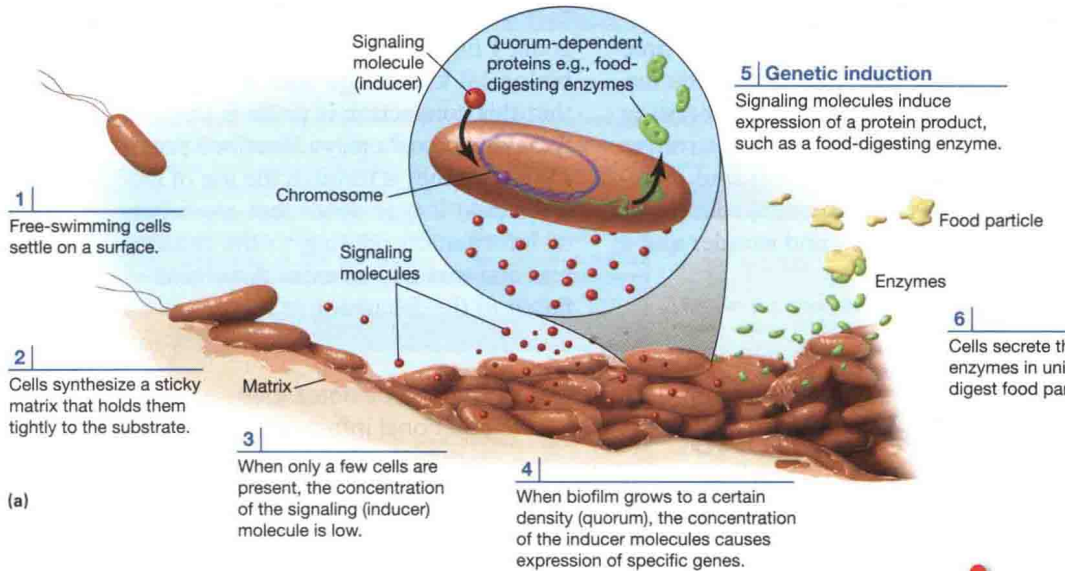




(b)

FIGURE 21.20 **The influenza virus. (a)** The virus shows hemagglutinin and neuraminidase spikes on its outer surface and an RNA core. **(b)** A colorized TEM of an influenza virion (magnification unknown). *(Science Source/Photo Researchers).*

Line drawings and photos complement each other.



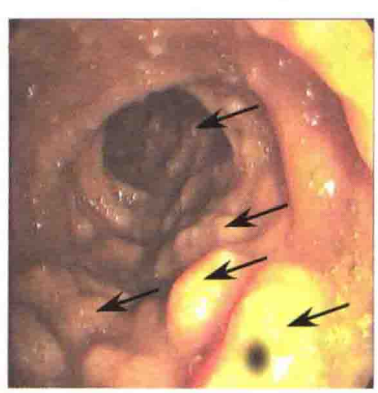
New illustrations combine art and photos.

FIGURE 6.17 (a) Quorum sensing. (b) Sibling warfare. Bacteria in streaks from the same original colony will only grow away from each other, another example of microbial communication. *(Eshel Ben-Jacob)*

complex illustration of a structure drawn by some of the best medical illustrators working today.

Photographs also richly enhance the text. The diversity of the photo program encompasses numerous micrographs, photographs of clinical conditions, microbiologists at work, and some laboratory techniques and results. Often, you will find a photograph accompanied by a line drawing aiding in the understanding of an unfamiliar subject.

Paired photos illustrate the text discussion.



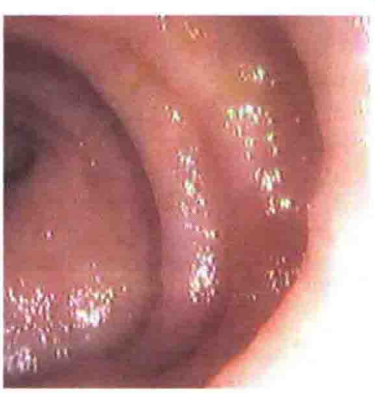


Figure 18.24 Gastrointestinal tract endoscopy: before and a few weeks after HIV infection. **(a)** The interior lining of the gut of an uninfected person showing numerous lymph node patches (GALT). **(b)** The gut lining stripped of lymph node Peyer's patches in an HIV-infected person. *(Photographs from Brenchley et al., Journal of Experimental Medicine, 2004, Vol. 200, pp. 749–759 by copyright permission of The Rockefeller University Press.)*

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ORION includes a number of reports and ongoing recommendations for students to help them maintain their proficiency over time for each topic. Students can easily access ORION from multiple places within WileyPLUS. It does not require any additional registration, and there will not be any additional charge for students using this adaptive learning system.

3D Animations

To help explain "the most difficult topics in Microbiology to teach," a new set of animations by renowned 3D Visualization artist, Janet Iwasa, University of Utah, are included in this edition. An icon accompanying key illustrations and sections of the text directs students to these animations in *WileyPLUS*. A complete set of animations is listed here:

CHAPTER 2

Acids and Bases
Chemical Bonding
Polarity and Solubility
Types of Reactions and Equilibrium

CHAPTER 3

Staining Bacteria: The Gram Stain
Wavelength Analogy

CHAPTER 4

Endocytosis and Exocytosis
Endosymbiosis
Eukaryotic Cell Structure
Mitosis and Meiosis Compared
Molecular Movement
Osmosis
Peptidoglycan
Prokaryotic Cell Structure
3D Animation: What do bacteria look like?
3D Animation: What structures are found inside of bacteria?
3D Animation: What types of cell envelopes are found in bacteria?
3D Animation: What features are found on the surface of bacteria?

CHAPTER 5

Catabolism of Fats and Proteins
Cell Respiration
Competitive and Noncompetitive Inhibition of Enzymes
Functions of Enzymes and uses of ATP
Metabolism: The Sum of Catabolism and Anabolism
3D Animation: What becomes of electrons generated by glycolysis and the TCA cycle?

CHAPTER 6

Binary Fission
Budding
Endospore Formation
Enterotube
Streak Plate Method
3D Animation: How can we grow microorganisms in the laboratory?
3D Animation: What other roles do bacteriological media perform?
3D Animation: How can a pure culture of a microorganism be obtained?
3D Animation: Besides spread and pour plate counts, how else can we measure microbial populations?
3D Animation: How do bacteria communicate with their neighbors?

CHAPTER 7

End Product Inhibition
Enzyme Induction: the Lac Operon
Eukaryotic Genes Contain Introns
Mutations
Polymerase Chain Reaction
Protein Synthesis
Thymine Dimer Repair
3D Animation: How are genome sequences determined?
3D Animation: How is gene expression measured using genomics tools?
3D Animation: How do regulatory proteins control transcription?
3D Animation: How can mRNA be controlled?

CHAPTER 8

Gene Transfer: Transformation
Recombinant DNA
Transduction
3D Animation: How do bacteria acquire free DNA from their environment?
3D Animation: How do bacteria share their DNA directly with other bacteria?
3D Animation: How do viruses help transfer DNA into bacteria?
3D Animation: How do transposable elements influence DNA variation in bacteria?
3D Animation: How can molecular biology tools be used to improve microbial strains?
3D Animation: What roles do microbes play in agricultural biotechnology?

CHAPTER 9

DNA Hybridization
Five Kingdom System of Classification
Lateral Gene Transfer
Shrub of Life

CHAPTER 10

Replication of An Enveloped dsDNA Animal Virus
Replication of (+) sense RNA viruses: HIV
Replication of (+) sense RNA viruses: poliovirus
Replication of a Virulent Bacteriophage
Replication of Temperate Bacteriophage
3D Animation: How do viruses recognize and attach to host cells?
3D Animation: How do viruses enter host cells?
3D Animation: How do viruses replicate their genome?
3D Animation: How do replicated viruses exit their host cells?
3D Animation: How do viruses interact with host cells?
3D Animation: How do some viruses become highly virulent?

CHAPTER 13

Antivirals
Effects of Premature Termination of Antibiotic Treatment

CHAPTER 16

Inflammation
Non-Specific Disease Resistance

CHAPTER 17

Antibody Mediated Immunity
Cell Mediated Immunity
Introduction to Disease Resistance
Production of Monoclonal Antibodies
3D Animation: What is the Cell-Mediated Immune Response?
3D Animation: How does humoral immunity fight infection?

CHAPTER 18

Four Types of Hypersensitivity
Myasthenia Gravis

For Instructors

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ALSO AVAILABLE

Laboratory Exercises in Microbiology, 4e (ISBN 9781118135259) Robert A. Pollack, Lorraine Findlay, Walter Mondschein, and R. Ronald Modesto is a publication that carefully corresponds to *Microbiology* 9e. This hands-on laboratory manual contains a variety of interactive activities and experiments that teach students the basic concepts of microbiology. It also covers methods that allow the safe movement or transfer of microbial cells from one type of growth environment to another, classification and identification of microbes, and microbial biochemistry.

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