ALICE LORRAINE SMITH

Principles of microbiology

Ninth edition

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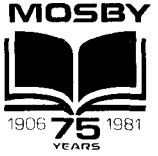

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To
the memory of my father

Preface

The quick harvest of applied science is the usable process, the medicine, the machine.
The shy fruit of pure science is Understanding.

Lincoln Barnett

The quick harvest is indeed apparent, for scientific advances come thick and fast, as it were, plowing the furrows of knowledge and sowing the seeds of discovery. Microbiology, never a static science, is rapidly caught up. Again it is time for a revision, time to take stock, time to rework, "time to plant and . . . time to pluck up that which is planted."

Here then is the text reworked to cover the contemporary scene and designed to be assimilated readily by students in health science training programs. The basic pattern of prior editions continues, comprising six units in orbit around microorganisms. It begins with basic concepts in the first unit, includes laboratory methods for the study of microbes in the second, and, in subsequent units, develops the events of microbial injury, indicts culprits, and emphasizes restraints; it also includes benefits that microbes confer.

What follows from the contact of microbes with living cells of the human body is a theme permeating this book. One full unit (Unit Three) is devoted to it, concentrating on defenses inherent in the body. It discusses macrophages, the immune system, kinds of immunity, the dual nature of the immune response, allergy, and key laboratory reactions in immunology.

A small and fairly compact unit (Unit Four) categorizes various agents destroying or impeding microbes. The action of antimicrobial agents is noted, and unfavorable side effects with antimicrobial drugs are stressed. Admittedly, with the increasing use and availability of commercial, prepackaged, sterile disposable units of all kinds, drastic changes are occurring in our concepts of sterilization. However, certain standard, long-reliable measures for practical sterilization in the health field still merit consideration. For instance, hands are not as yet disposable.

The largest unit of the book (Unit Five) makes up the roster of significant pathogens and parasites, stressing their identity and injury. Infections are matched to agents.

An unusual unit and the last one, Unit Six relates the student to the microbial life of our environment. A survey, yet a practical unit, it accommodates such items as measures to safeguard food and fluoridation of water. Two chapters herein are paired to focus on the best available information on immunization from the United States Public Health Service, the American Academy of Pediatrics, the United States Armed Forces, the World Health Organization (WHO), and the Center for Disease Control (CDC). The companion chapters sort out modern biologic products, outline technics in passive immunization, tabulate latest schedules for active immunization, give crucial guidelines for administration of biologic products, and provide health information for the traveler.

In addition to thought-provoking questions for review at the end of each chapter, a cluster of exercises arranged at the end of each unit allows for evaluation of the student's progress. Also at the end

of each unit is the laboratory survey. Projects selected are adaptable to the needs of students and suitable for use with varied, and sometimes limited, facilities. *For maximum laboratory safety at all times, please heed the warnings!*

"What is the use of a book," thought Alice, "without pictures or conversations?" (Lewis Carroll, *Alice's Adventures in Wonderland*). *That* Alice is partly right on both counts, but *this* Alice can only comply with the first and hope that the "pictures" are good and forceful. Every teacher knows that tables dramatize and give quick access to information. Immunization schedules, sterilization maneuvers, incubation periods, differential characteristics, and biologic properties can thus be arranged effectively.

Current references are gathered at the end of every unit (except Unit One). Sources for the glossary are found in the text, standard medical dictionaries, and Webster's unabridged dictionary.

This revision would not have been possible without the counsel, technical know-how, and cooperation of certain talents at The University of Texas Health Science Center at Dallas. In the Department of Pathology, I gratefully acknowledge the kindness of Dr. V. A. Stembridge, Chairman; Drs. R. C. Reynolds, Mary Lipscomb, R. G. Freeman, P. M. Southern, Jr., and C. S. Petty, professors; Mr. Gale Spring, Mr. Stacey Bartus, and Mrs. Linda Bolding, medical photographers; Mr. Donald Calhoun, photographer for the Medical Examiner's office; and my secretary, Mrs. Phyllis Kitterman; in Medical Illustration Services, Mr. William Winn, Associate Professor and Director, and Ms. Jean Gionas, medical photographer; and in the Library, Mrs. Elinor Reinmiller, Faculty Associate, and other able members of Ms. Jean Miller's staff. I am indebted to Mrs. Earline Kutscher, Chief Technologist, and her staff at the Microbiology Laboratory of Parkland Memorial Hospital, Dallas, for invaluable assistance.

Now a special word of appreciation to teachers and students whose ever-welcome criticisms and comments have guided me: may I voice a heartfelt thanks to the many of you who have used this text and who carefully consider this new edition.

Alice Lorraine Smith

Contents

unit one

MICROBIOLOGY
PRELUDE AND PRIMER

chapter 1

Definition and dimension

Take interest, I implore you, in those sacred dwellings which one designates by the expressive term: laboratories. Demand that they be multiplied, that they be adorned. These are the temples of the future—temples of well-being and of happiness. There it is that humanity grows greater, stronger, better.

Louis Pasteur

DEFINITION

Microbiology is the branch of biology dealing with *microbes*—living, minute-sized organisms, usually structured as one cell and studied with the microscope. Within the province of microbiology lies the study of certain kinds of microbes classified as bacteria (bacteriology), viruses (virology), fungi (mycology), and protozoa (protozoology). Microbiology considers the occurrence in nature of the microscopic forms of life, their reproduction and physiology, their participation in the processes of nature, their helpful or harmful relationships with other living things, and their significance in science and industry.

Although human beings have lived with microorganisms from time immemorial and have used certain of their activities such as fermentation to their advantage, the science of microbiology is a product of only the last 100 years or so. The studies of Antonj van Leeuwenhoek in the seventeenth century had shown the existence of microscopic forms of life, but it was not until the work of Louis Pasteur toward the end of the nineteenth century (some 200 years later) that the science of microbiology really took shape. The new science stated the germ theory of disease, demonstrated patterns of communicable disease, and gave human beings a measure of protection they had not known in their struggle against the injurious forces in the biologic environment. In its time this very young science has influenced practically every phase of human endeavor.

For scientific knowledge to bring results, as in the organization of public health programs, it must be disseminated. Such is the aim of *health education.* To the individual it explains the mechanisms by which he can protect himself against microbial hazards. To the social group it designates the available community resources.

DIMENSION

Biologic classification

All living things are classified in a scheme wherein categories represent successively dependent and related groups. The highest possible levels are designated *kingdoms.* For years, the traditional two were the plant and animal kingdoms. Today this approach is changed.

The lower forms of life incorporate features of both plants and animals and do not show the dramatic differences of the higher forms. It is difficult to define many microbes as either plant or animal, and as bacteria and other microbes long classified as plants have been more closely studied, the inconsistencies appear even greater. Because of this fact, a third biologic compartment with equivalent rank to the plant and animal kingdoms has been

advocated to sift out the simpler units, designating them as *protists*. Basically most protists are one-cell units and remain so throughout their life history. Even if they pile cells up in large plantlike masses, their component cells remain the same and do not differentiate.

An alternate scheme of classification of living things, also based on complexity of structure, focuses directly on the nucleus. Since "higher" organisms possess a true nucleus and "lower" ones do not, two distinct taxonomic categories emerge. The obvious nucleus in the higher forms is complete, with the expected number of chromosomes and mitotic apparatus, and these organisms are termed *eucaryotic* (from the Greek word that means true nucleus). This category (or kingdom), Eucaryotae, contains plants, animals, and some protists.

In the lower forms of life, nuclear function is carried out by only a single chromosome devoid of any membrane. Lower forms are small and less complex in other ways. For instance, they do not contain such membrane-bound organelles as mitochondria. They are designated *procaryotic*. Procaryotae, the second category or kingdom, encompasses all bacteria and a small group of blue-green algae (algae demonstrate plantlike photosynthesis).

Procaryotes are distinctive. They possess certain unique components in their cell walls, and they display remarkable capabilities with regard to carbon storage, nitrogen fixation, obligate anaerobiosis, and derivation of energy from oxidation of inorganic compounds.

Microorganisms usually surveyed in a treatise of microbiology include not only unicellular procaryotes but also fungi (best known as plants) and lower forms of animal life, such as the unicellular protozoa and a restricted number of the more complex multicellular, or metazoan, animals.

Fungi were formerly classified in Thallophyta, one of the four divisions of the plant kingdom. (For current concepts, see p. 481.) Thallophytes, or thallus plants (Greek *thallos*, young shoot or branch), are defined as simple forms of plant life that do not differentiate into true roots, stems, or leaves. Thallus plants would be the algae, which contain chlorophyl, and the fungi, which do not. Algae, many of which are microscopic, are shaped like bacteria and form pond scums and seaweeds. The term *fungi*, as ordinarily used, refers to molds, yeasts, and certain related microorganisms.

Classification of bacteria*

The classification of bacteria is difficult with regard to both the separation of bacteria into groups and the placing of certain organisms into the proper group. Biologic classification is based largely on morphology, but the morphology of bacteria as a whole is so uniform that it is useful only in dividing bacteria into comparatively large groups. Shape has been an important factor in general classification, but for more exact identification, such criteria as staining reactions, cultural characteristics, biochemical and physiologic behavior patterns, genetic analyses, animal inoculations, and immunologic differences must be used.

In this book we adhere to the scientific classification embodied in *Bergey's Manual of Determinative Bacteriology*, with certain important exceptions to be noted in the text. This is the one most generally accepted in the United States. Table 1-1 presents in abbreviated form an overall survey of Bergey's classification of the microorganisms designated as bacteria.

Naming of microbes

The scientific name of a living organism is usually made up of two words that are Latin or Greek in form. The first name begins with a capital letter and denotes the genus. The second name begins with a small letter and denotes the species. Either

Text continued on p. 17.

*Please note the basic terms in classification listed in ascending rank:

1. Species—organisms sharing a set of biologic traits and reproducing only their exact kind
   a. Strain—organisms within the species varying in a given quality
   b. Type—organisms within the species varying immunologically
2. Genus (*plural*, genera)—closely related species
3. Family—closely related genera
4. Order—closely related families
5. Class—closely related orders
6. Phylum (*plural*, phyla)—related classes (In botany, the term *division* is used instead of phylum. In Table 1-1, note the use of the term *division* for either of the two major classifications in the kingdom including the procaryotes.)

Table 1-1. Abbreviated classification of microbes from *Bergey's Manual of Determinative Bacteriology* (1974)*

Kingdom *Procaryotae*† (highest level taxon encompassing microbes wherein nucleoplasm lacks basic protein and is not bounded by nuclear membrane)

Division I. The Cyanobacteria (blue-green algae with gliding motility, producing oxygen in light; photosynthetic procaryotes as single cells or simple or branched chains of cells; photopigments include chlorophyll *a*)

Division II. The Bacteria (unicellular procaryotes multiplying by growth and division, usually binary; if cells remain together, arrangement classical; true branching may be seen; motility from flagella or by gliding, twitching, snapping, or darting motions; majority encased in rigid cell wall [constancy of form], most of which contain peptidoglycans; photosynthesis, if carried out, is anaerobic and bacteriochlorophylls used; chemosynthesis requires aerobic or anaerobic conditions, with some microbes facultative; endospores formed in some species, arthrospores and cysts in others, but no heterocysts)

Part 1 Phototrophic bacteria‡

Order I. *Rhodospirillales*§ (mostly water bacteria; gram negative, variably shaped, all with bacteriochlorophylls and carotenoid pigments; purple-violet, purple, red, or orange-brown, brown, or green colors from photopigments in cell suspensions; some can fix nitrogen; purple [sulfur or nonsulfur] and green sulfur groups of bacteria here)

Part 2 Gliding bacteria

Order I. *Myxobacterales* (slime bacteria; gram negative, strict aerobes with slow gliding movements found on soil and decomposing plant and animal matter; no photosynthetic pigments; chemo-organotrophs; energy-yielding mechanism respiratory, never fermentative; fruiting bodies formed from cell aggregates often brightly colored and macroscopic; bacteriolytic and cellulolytic [attacking cellulose] groups here)

Order II. *Cytophagales* (rods or filaments, gram negative, with slow or rapid gliding; no fruiting bodies; chemolithotrophs, chemo-organotrophs, or mixotrophs)

Part 3 Sheathed bacteria

(sheath present, may be encrusted with iron or manganese oxides; single cells; flagella may be found)

Genus *Leptothrix* (gram-negative, strictly aerobic straight rods in chains within a sheath; also free-swimming as single cells, in pairs, or in motile short chains; sheaths often impregnated with hydrated ferric or manganic oxides; prevalent in iron-containing, uncontaminated, slow-running fresh waters)

Genus *Streptothrix* (thin, gram-negative rods in chains; strictly aerobic; widely distributed in fresh water and in activated sludge; barely visible sheaths not encrusted)

Part 4 Budding and/or appendaged bacteria

(soil and water bacteria reproducing by budding; may have excreted appendages and holdfasts; in some a semirigid appendage, the prostheca, proceeds out from the cell [stalk of *Caulobacter* genus] extending the length of the rod and holding a small bit of glue at its tip)

Part 5 Spirochetes

Order I. *Spirochaetales*

Family I. *Spirochaetaceae*

Genus I. *Spirochaeta* (helical cells, motile, free living in H_2S-containing mud and sewage)

Genus II. *Cristispira* (helical cells with two to ten complete turns; commensal in mollusks)

Genus III. *Treponema*

Treponema pallidum (type species; syphilis)

Treponema pertenue (yaws)

Treponema carateum (pinta, a chronic skin disease of children endemic in South and Central America)

Treponema macrodentium (oral microflora)

Treponema denticola [*microdentium*] (oral microflora)

*Based on data from Buchanan, R. E., and Gibbons, N. E., co-editors: Bergey's manual of determinative bacteriology, ed. 8, Baltimore, 1974, The Williams & Wilkins Co.

†*Eucaryotae*, the corresponding taxon at the same level, includes other protists and plants and animals.

‡Photosynthetic.

§Names indicating bacterial orders end consistently in *ales*; those indicating families, in *aceae*.

Continued.

Table 1-1. Abbreviated classification of microbes from *Bergey's Manual of Determinative Bacteriology* (1974)—cont'd

Part 5 Spirochetes
- Order I. *Spirochaetales*
  - Family I. *Spirochaetaceae*
    - Genus III. *Treponema*—cont'd
      - *Treponema* [*Borrelia*] *vincentii* (oral microflora)
      - Species *incertae sedis*: *Treponema buccale* [*Borrelia buccalis*] (large oral treponemes)
    - Genus IV. *Borrelia*
      - *Borrelia recurrentis* (louse-borne epidemic relapsing fever)
      - *Borrelia* species (tick-borne endemic relapsing fever)
    - Genus V. *Leptospira*
      - *Leptospira interrogans* [*icterohaemorrhagiae*] (type species; leptospirosis)

Part 6 Spiral and curved bacteria
- Family I. *Spirillaceae*
  - Genus I. *Spirillum*
    - *Spirillum minor* (one type of human rat-bite fever)
  - Genus II. *Campylobacter* (slender spiral rods found in reproductive and alimentary tracts of humans and animals; some species pathogenic)
    - *Campylobacter* [*Vibrio*] *fetus* (type species; abortion in sheep and cattle; human infections)

Part 7 Gram-negative aerobic rods and cocci
- Family I. *Pseudomonadaceae*
  - Genus I. *Pseudomonas*
    - *Pseudomonas aeruginosa* (type species; wound, burn, and urinary tract infections)
    - *Pseudomonas* [*Actinobacillus*] *mallei* (glanders and farcy in horses and donkeys; infection transmissible to humans)
    - *Pseudomonas pseudomallei* (human and animal melioidosis)
  - Genus II. *Xanthomonas* (plant pathogens)
  - Genus III. *Zoogloea* (motile gram-negative rods in natural waters and sewage)
  - Genus IV. *Gluconobacter* (ellipsoids or rods in flowers, souring fruits, vegetables, cider, wine, baker's yeast, garden soil; ropiness in beer and wort)
- Family II. *Azotobacteraceae* (large, motile, aerobic gram-negative rods fixing atmospheric nitrogen; found in soil and water and on leaf surfaces)
  - Genus I. *Azotobacter* (nitrogen fixation)
  - Genus II. *Azomonas* (nitrogen fixation)
  - Genus III. *Beijerinckia* (nitrogen fixation)
  - Genus IV. *Derxia* (found in tropical soils of Asia, Africa, South America; fixation of atmospheric nitrogen)
- Family III. *Rhizobiaceae* (nitrogen fixation; symbionts in root nodules of legumes; cortical overgrowths in plants)
  - Genus I. *Rhizobium* (nitrogen fixation)
  - Genus II. *Agrobacterium* (plant pathogens—tumorigenic phytopathogens; hypertrophies [galls] on stems of more than 40 plants; free nitrogen not fixed; found in soil)
- Family IV. *Methylomonadaceae* (gram-negative bacteria using only one-carbon organic compounds such as methane and methanol as carbon source)
- Family V. *Halobacteriaceae* (high concentration of sodium chloride for growth; found in salterns, salt lakes, Dead Sea, proteinaceous material preserved with solar salt [fish, sausage casings, and hides])
  - Genus I. *Halobacterium* (salt-loving rods)
  - Genus II. *Halococcus* (halophilic cocci; red colonies)
- Genera of uncertain affiliation
  - Genus *Alcaligenes* [*Achromobacter*] (motile aerobic rods or cocci, common saprophytes in intestines of vertebrates, in dairy products, rotting eggs, fresh water, soil; important in decomposition and mineralization processes)
    - *Alcaligenes faecalis* (type species; some strains denitrify)

Genus *Acetobacter* (motile aerobic vinegar rods; oxidize ethanol to acetic acid; found on fruits and vegetables, in souring fruit juices, vinegar, alcoholic beverages)
Acetobacter aceti (acetic acid bacteria)
Genus *Brucella* (brucellosis)
Brucella melitensis (type species; Malta fever; infection in goats, sheep, and cattle)
Brucella abortus (abortion in cattle; disease in humans)
Brucella suis (infection in pigs, other animals, and humans)
Genus *Bordetella*
Bordetella pertussis (type species; whooping cough)
Bordetella parapertussis (whooping cough)
Bordetella bronchiseptica (found in respiratory tract of animals, sometimes human beings; rodent bronchopneumonia)
Genus *Francisella*
Francisella [*Pasteurella*] *tularensis* (type species; tularemia)
Genus *Thermus* (gram-negative nonmotile rods and filaments; often pigmented; common in hot springs, hot water tanks, and thermally polluted rivers; unusually thermostable enzymes, ribosomes, plasma membrane found here)

Part 8 Gram-negative facultatively anaerobic rods

Family I. *Enterobacteriaceae*
Genus I. *Escherichia*
Escherichia coli (type species [the colon bacillus]; important opportunist pathogens)
Genus II. *Edwardsiella*
Edwardsiella tarda (type species; found in intestine of snakes, sometimes in humans)
Genus III. *Citrobacter*
Citrobacter freundii (type species; found in water, food, and human excreta)
Genus IV. *Salmonella* (salmonellosis)
Subgenus I
Salmonella cholerae-suis (type species; salmonellosis)
Salmonella hirschfeldii (paratyphoid C bacilli; enteritis)
Salmonella typhi (typhoid fever)
Salmonella paratyphi-A (paratyphoid [enteric] fever)
Salmonella schottmuelleri (enteritis)
Salmonella typhimurium (food poisoning in humans)
Salmonella enteritidis (enteritis)
Salmonella gallinarum (fowl typhoid)
Subgenus II
Salmonella salamae (type species of subgenus)
Subgenus III
Salmonella arizonae (type species of subgenus; isolated from reptiles)
Subgenus IV
Salmonella houtenae (type species of subgenus)
Genus V. *Shigella* (shigellosis)
Shigella dysenteriae (type species; bacillary dysentery plus effects of diffusible neurotoxin)
Shigella flexneri (bacillary dysentery)
Shigella boydii (bacillary dysentery)
Shigella sonnei (one cause of summer diarrhea in young children; milder form of bacillary dysentery in adults)
Genus VI. *Klebsiella*
Klebsiella pneumoniae (type species; pneumonia, infections of respiratory and urinary tracts)
Klebsiella ozaenae (found in ozena and chronic respiratory disease)
Klebsiella rhinoscleromatis (found in rhinoscleroma, a granulomatous disorder of nose and pharynx associated with nodular induration of tissues)

Continued.

Table 1-1. Abbreviated classification of microbes from *Bergey's Manual of Determinative Bacteriology* (1974)—cont'd

Part 8 Gram-negative facultatively anaerobic rods

Family I. *Enterobacteriaceae*—cont'd

Genus VII. *Enterobacter*

Enterobacter cloacae (type species; opportunist pathogens)

Enterobacter [*Aerobacter*] *aerogenes* (opportunist pathogens)

Genus VIII. *Hafnia* (Hafnia, the old name for Copenhagen; opportunist pathogens)

Genus IX. *Serratia*

Serratia marcescens (type species; opportunist pathogens)

Genus X. *Proteus* (urinary tract infections, community and hospital acquired)

Proteus vulgaris (type species; urinary tract and wound infections, rarely peritonitis, meningitis)

Proteus mirabilis (most frequent species in medical specimens)

Proteus morganii (one cause of summer diarrhea in infants)

Proteus rettgeri (gastroenteritis)

Proteus [*Providencia*] *inconstans* (urinary tract infections)

Genus XI. *Yersinia*

Yersinia [*Pasteurella*] *pestis* (type species; plague)

Yersinia [*Pasteurella*] *pseudotuberculosis* (pseudotuberculosis in animals, usually mesenteric lymphadenitis; human septicemia)

Yersinia enterocolitica (widespread; has been found in sick and healthy animals and in material likely contaminated by their feces; enterocolitis in young children, mesenteric lymphadenitis, variety of other infections)

Genus XII. *Erwinia* (plant pathogens)

Family II. *Vibrionaceae*

Genus I. *Vibrio*

Vibrio cholerae [*comma*] (type species; cholera)

Vibrio cholerae biotype *eltor* (El Tor vibrio; cholera)

Vibrio parahaemolyticus (acute gastroenteritis)

Vibrio [*Photobacterium*] *fischeri* (luminescent saltwater bacteria)

Genus II. *Aeromonas* (motile gas-forming rods)

Aeromonas hydrophilia (type species; nonluminescent freshwater bacteria; infections of cold-blooded animals—red leg [bacteremia] in frogs and septicemia in snakes; rarely infections in compromised host)

Genus III. *Plesiomonas* (motile rods growing mostly on mineral media containing ammonia as sole source of nitrogen and glucose as sole source of carbon; found in feces; infectious gastroenteritis reported in humans)

Genus IV. *Photobacterium* (luminescent saltwater bacteria)

Genus V. *Lucibacterium* (light-emitting bacteria; luminescent saltwater bacilli; found on surfaces of dead fish)

Genera of uncertain affiliation

Genus *Chromobacterium* (soil and water bacteria producing violet pigment violacein; infections in animals; food spoilage)

Genus *Flavobacterium* (proteolytic soil and water bacteria producing yellow, orange, or red pigments; found on vegetables and in dairy products; rare human infection by unpigmented organism)

Genus *Haemophilus*

Haemophilus influenzae (type species; purulent meningitis in young children; acute respiratory infection; acute conjunctivitis)

Haemophilus suis (with virus, causes swine influenza)

Haemophilus haemolyticus (commensal in upper respiratory tract of humans)

Haemophilus parainfluenzae (found in upper respiratory tract of humans and cats)

Haemophilus parahaemolyticus (found in human upper respiratory tract; associated with acute pharyngitis; pleuropneumonia and septicemia in swine)

Haemophilus aphrophilus (endocarditis and other human infections)

Haemophilus ducreyi (chancroid)

Species incertae sedis, A: Haemophilus aegyptius (Koch-Weeks bacillus; acute infectious conjunctivitis)

Species incertae sedis, B: Haemophilus vaginalis (gram-variable bacilli and coccobacilli showing metachromatic granules and arranged like *Corynebacterium,* found in human genital tract; nonspecific vaginitis and urethritis)

Genus *Pasteurella*
Pasteurella multocida (type species; chicken cholera; shipping fever of cattle; hemorrhagic septicemia in warm-blooded animals; cat- and dog-bite wound infections in human beings)
Pasteurella pneumotropica (infections in animals; dog-bite wounds in humans)
Pasteurella haemolytica (enzootic pneumonia of sheep and cattle; septicemia of lambs)
Genus *Actinobacillus* (actinobacillosis)
Actinobacillus lignieresii (type species; actinobacillosis of cattle [wooden tongue] and of sheep)
Actinobacillus equuli (actinobacillosis in horses and pigs)
Genus *Cardiobacterium*
Cardiobacterium hominis (type species; found in human nose and throat; endocarditis)
Genus *Streptobacillus* [*Haverhillia*] (rods and filaments in chains with filaments showing bulbous swellings, like a string of beads; parasites and pathogens of rats and other mammals)
Streptobacillus moniliformis [*Actinomyces muris ratti*] (type species; necklace-shaped bacteria found in nasopharynx of rats; streptobacillary rat-bite fever)
Genus *Calymmatobacterium* (pleomorphic encapsulated rods like safety pins)
Calymmatobacterium [*Donovania*] *granulomatis* (type species; granuloma inguinale)

Part 9 Gram-negative anaerobic bacteria
Family I. *Bacteroidaceae*
Genus I. *Bacteroides* (bacteroidosis)
Bacteroides fragilis (type species; opportunists in visceral and wound infections; most common anaerobe in soft-tissue infections)
Bacteroides oralis (gingival crevice of humans; oral, upper respiratory, and genital infections)
Bacteroides [*Eikenella*] *corrodens* (part of normal flora of humans and animals; opportunists in infections of respiratory and alimentary tracts)
Bacteroides melaninogenicus (brown to black pigment on blood agar; opportunists in infections of mouth, soft tissue, and respiratory, alimentary, and urogenital tracts)
Genus II. *Fusobacterium* (purulent or gangrenous infections)
Fusobacterium nucleatum (type species; wound and respiratory tract infections)
Fusobacterium varium (wound and serous cavity infections; intestinal contents of roaches, termites)
Fusobacterium necrophorum [*Sphaerophorus necrophorus*] (abscesses of humans and animals)
Fusobacterium mortiferum (visceral abscesses and septicemia in humans)
Genus III. *Leptotrichia* (human oral cavity; not known as pathogens but found in clinical material)
Leptotrichia buccalis (type species)
Genera of uncertain affiliation
Genus *Butyrivibrio* (many members, biochemically versatile in rumen of most ruminants and in intestinal tract of other mammals)
Genus *Selenomonas* (gastrointestinal tract of mammals; dirty river water)

Part 10 Gram-negative cocci and coccobacilli (aerobes)
Family I. *Neisseriaceae*
Genus I. *Neisseria* (parasites of mucous membranes of mammals)
Neisseria gonorrhoeae (type species; gonorrhea)
Neisseria meningitidis (epidemic cerebrospinal fever)
Neisseria sicca (human nasopharynx)
Neisseria subflava [*flava*] [*perflava*] (yellowish green pigment; human nasopharynx)
Neisseria flavescens (xanthophil pigment)
Neisseria mucosa (human rhinopharynx)
Genus II. *Branhamella* (parasites of mammalian mucous membranes)
Branhamella [*Neisseria*] *catarrhalis* (type species; venereal discharges; catarrhal inflammations)
Genus III. *Moraxella* (parasites of mucous membranes of humans and warm-blooded animals)
Moraxella lacunata (type species; pink-eye—conjunctivitis)

Continued.