Preface

Welcome to 1830—a time when Europe was recovering from the Napoleonic conflict and Napoleon left a legacy that included canning meats to control spoilage by the application of heat. Nicholas Appert was credited with this discovery of microbiologically influenced spoilage of meats. The ability to control spoilage helped the French-led troops to reach the outskirts of Moscow before the Russian winter played its hand. Canning was the first major advance in the application of heat to control microorganisms.

Another battle in progress then continues today. In 1830, four science factions were fighting for dominance over the emerging field of microbiology. The botanists and zoologists were two major contestants who already controlled the plant and animal kingdoms; microbes were considered members of one of the two kingdoms. Major progress in chemistry led to the understanding of the natures of chemical elements and the complexities of life processes. Chemists, in conjunction with the then-primitive medical and pharmaceutical sciences believed that all diseases were caused by chemicals called miasmas. The fourth major contestants were the western religious movements that considered microbes the work of the devil based on the belief that the human eye was capable of seeing every living thing. Microbes were too small to be seen except with a compound microscope and thus the "invisible" microbes were the devil's creations. Any scientist who investigated microbes sinned by investigating the work of the devil.

From 1830 to 1870, microbiology did not develop significantly because of the negative forces exerted by religion (unseen entities were the works of the devil) and chemists (all significant events are chemical in form). Positive reinforcement for the development of microbiology came from the botanical and zoological scientists, but there were caveats. First was the dogmatic application of the Linnaean reductionist concepts: all life forms were independent species that were not dependent on other species. These concepts remain in effect today and microbial species are judged only when they can be cultured independently. No consideration was given to the possibility that communities of microorganisms participated in environmental activities involving soils, waters, sediments, crustal elements, and clouds.

The years from 1850 to 1880 saw development of intensive monocropping followed by the major fungal infestations, primarily in the form of cereal rusts that decimated crop yields. Plant breeders rapidly developed rust-resistant strains of cereal plants and the fungi were recognized as major plant pathogens and thus embraced as plants by the botanists.

Louis Pasteur undertook a sequence of scientific investigations that primarily demonstrated that microorganisms resulted from reproduction by living cells and not from activities of the devil. Pasteur's proof finally put to rest the debate that spontaneous generation of microorganisms was the work of the devil. Religious objections faded, leading to private and government sponsorship of research that gave birth to the golden age of bacteriology from 1880 to 1890.

Zoologists and botanists eventually allowed bacteriology to be recognized as a science, but identification of bacteria continued to follow the reductionist Linnaean form of classification. Breakthroughs occurred almost weekly as typhoid, dysentery, and cholera were attributed to the work of specific bacterial strains. A landmark in this sudden spurt of science was a suggestion by Frau Hess, the wife of a bacteriologist, to use an agar-based jelly to grow bacteria. She made the suggestion at a time when several major bacterial pathogens were under investigation. Agar provided the most effective means for culturing bacteria but excluded bacteria that would not grow on agar-based media. Reductionists seized on the superiority of agar and ignored the many bacteria that cannot grow on agar. Today the science of bacteriology is dominated by reductionist thinking and the premise (in common with botany and zoology) that any microorganism must be cultured as pure strain, free from contamination by other strains.

During the 20th century, bacteriology underwent a number of changes arising from advances in chemistry and medicine. Two breakthroughs in chemistry were the recognition of the immune system as an organic chemical neutralization process and the development of the sulfonamide drugs to control infestations. Observations of antibiotics generated by microorganisms (particularly fungi) were reported from the start of the century, then ignored. In the late 1920s, Sir Alexander Fleming developed penicillin, but it was ignored in favor of sulfonamides until World War II created an urgent demand for controlling wound infections. This demand brought penicillin out of the closet and it became a major life saver for wounded troops. After the war, the focus was on developing more antibiotics from natural sources and eventually led to molecular manipulation of the classic antibiotics and today most antibiotics have been refined through biochemistry and genetics.

In the 1950s a chemical tsunami swept through all the biological sciences with the discovery of the chemical structures of nucleic acids, most notably deoxyribonucleic acid (DNA). This discovery allowed precise classification and categorization of genetic material. In bacteriology, the advance led to frenetic reductionist activity as the genetic and biochemical aspects of selected strains were developed. Lost in this research stampede were the bacteria perceived as insignificant: they did not grow on standard cultures or they functioned collectively with other strains only within community structures. They were considered inconspicuous, irrelevant, and unworthy of attention. Who would care about a crust of rust, a mound of slime, or a glistening sheen? The 21st century is another reductionist era in bacteriology when all bacterial functions occur within a cell wall bag of chemicals dominated by nucleic acids, enzymes, and energy drivers.

Most environmental settings present two issues that must be addressed, The first is that the functioning of each bacterial cell is influenced by the heterogeneous community within which it functions. Such communities commonly involve 8 to 64 individual strains of bacteria, all performing different tasks in an integrated and intelligent manner. The second issue is the dispersal of cells in water that is bound by an extracellular polymeric matrix that creates volumes that exceed the volumes of incumbent cells by two to three orders of magnitude.

Maturation profoundly influences the heterogeneous nature of this bacterial growth. Maturation generally involves reduction of the numbers of active bacterial strains present, reduction of the bound water surrounding the incumbent community,

and increases of bioaccumulated materials "stockpiled" within the bound water. The result is that a bacterial population active within a growth declines and incumbent cells may assume states of suspended animation (such as those generated by endospores or ultramicrobacterial cells). When this state is reached, a growth may contain no active bacteria but continue to support large populations of bacteria that are in a resting (suspended animation) state.

For the applied microbial ecologist seeking to identify bacteriologically influenced growth, one requirement is the precise identification of the observed growth based on holistic approaches, not on cultured isolates that can create considerable bias. This second edition of the *Practical Atlas for Bacterial Identification* has been written to provide a means to categorize bacterial growths into larger heterogeneous communities based on form, function, and location of growing biomass. No attempt is made to define individual species; doing so would require manipulation of the biomass of interest to remove samples for biochemical or sequential cultural analysis and thus affect the value and utility of the data generated. This atlas has been constructed as a guide to the identification of the principal consorms (integrated bacterial communities) in specific environments, with emphasis on the forms, function and locations of the definable consorms.

The first (2000) edition of this atlas was based on the premise that all the major bacterial genera could be located on two-dimensional maps that would show the genera as "cities" and groups of like genera as "countries." No formulation for the grid that would allow positioning with a greater level of precision was included in the first edition. The second edition includes a bacteriological positioning system in which the oxidation–reduction potential (in millivolts) serves as the longitudinal (x) axis and the viscosity of the water within the consormial biomass measured in log centipoise represents the latitudinal (y) axis—an approach that allows positioning of each consormial biomass within a grid system. This edition focuses on differentiating the major consormial biomass groups recognized by observation or speculated upon based on the recognition of their diversity and durability within the various environments of the biosphere.

This edition contains 12 chapters and an appendix to guide readers through this approach to the identification of bacterial consorms. It follows the less popular practice of "lumping" groups of bacteria together rather than the more expedient and popular "splitting" of bacteria into the smallest grouping that allows activity and growth to occur. This second edition is designed to be used by practitioners who design and manage engineered systems and find that bacteria are the causes of some of the economic and sustainability challenges, whether chemical, metallurgic, or physical. For example, corrosion is often caused by bacterial consorms that either generate acids or create electrolytic conditions that compromise materials of concern. In groundwater, consormial biomasses tend to concentrate around the oxidative–reductive interface and cause clogging if sufficient bioaccumulations are present or plugging if higher water content obstructs water flows.

Chapters 1 and 2 deal with the locations and functions of bacterial communities that can form consorms and the common events they initiate within natural or engineered ecosystems. Chapter 3 defines six major alpha groupings of bacteria consorms and generates the concepts employed in the gridded atlas positioning system used to differentiate the major bacteria consorms. Chapter 4 expands on the

differentiation described in Chapter 3 and details the positioning of major defined bacterial consorms. Chapter 5 examines the environmental dynamics that influence the manner in which bacterial consorms will develop. Chapter 6 addresses the challenges in defining the forms, functions, and habitats of the consorms categorized and listed in Chapter 7.

Chapter 8 covers biochemical methods used to identify consorms. Cultural identification methods based on bacteriological activity reactions are addressed in Chapter 9. Explanation of the gridded atlas location system is covered in Chapter 10. Chapter 11 discusses linkages of the bacterial consorms and bacteriologically influenced events such as plugging, corrosion, biogeneration of natural gases and oils, and natural systems. Chapter 12 illustrates consormial events by specific examples. The appendix is an update of Chapter 10 from the first edition and includes the original format for alpha two bacteria presented as genera with no attempts to map them into consormial structures.

In 1830 when bacteriology was gradually dominated by reductionist thinking, Linnaean concepts relevant to classifications of plants and animals were employed for bacterial identification. These concepts have only limited value for identifying bacteria that are active in consorms. This atlas goes back to that time because that was when the concept of intelligent, coordinated bacterial consorm activity was lost in the 100-year stampede to find the causes of bacteriologically influenced diseases, but only if they grew easily on agar plates! How many diseases are consormial in origin? How many more have not been discovered because they cannot be cultured by agar methods? Bacterial consorms are visible. Their locations tell a story, and their forms and functionalities allow identification without the need to isolate a single species of bacteria.

This atlas contains no references, footnotes, or endnotes simply because they would turn this book into another boring reference source. The suggestions for further reading may be useful but my hope is that all readers begin to see that bacterial consorms are as evolved as humans to the degree that they act with intelligence to acquire and maintain their homes.

SOME FURTHER THOUGHTS

If I could but sit just still in one spot and let the world surround me with truth, then and only then would I smile. Greyness is the color that I wear. Everywhere will I look for questions for which there are no answers. The only thing about here is now. Beyond this now there lies pent up the forces of the future waiting to be released. Perhaps I am tired of treading the pathways of thoughts running through the thickets of dogma. Perhaps I will never see the harvest from the seeds of science that I did sow. But I say to them, may they grow and swirl out of the soils of uncertainty into pleasant moments of reality then that, for me, will be enough. This story is my story of why things have come to be and why science will always remain that haven for mystery. That is the why I gaze at the sky, ponder into a wall, never kick the soil, and enjoy the pleasures of breathing.

D. Roy Cullimore