Petroleum Microbiology
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FOREWORD

There does not exist a category of science to which one can give the name applied science. There are science and the applications of science, bound together as the fruit and the tree that bears it.

*Louis Pasteur, 1871*

*P*asteur succinctly summarizes the iterative nature of scientific investigation. Intellectual curiosity leads to the understanding of natural phenomena, and with this understanding comes the ability to manipulate these phenomena for human benefit. Problems encountered with the application of science lead to new scientific discoveries. This iterative process is operative in petroleum exploitation. For example, the increased understanding of the physics of fluid flow in porous matrices led to more efficient petroleum extraction, resulting in petroleum’s becoming the dominant energy source for most industrialized countries. The use of petroleum as an energy source has had a profound effect on the economies and standards of living of industrialized societies. However, the quality and availability of petroleum resources have steadily declined, making it essential that the remaining resource be used wisely. The central theme of this book is to illustrate the pivotal role that microorganisms play in determining the quality and effective use of petroleum resources. The problems encountered with petroleum exploitation should be viewed with microorganisms in mind.

Research in the last 20 years has shown that petroleum reservoirs contain active and diverse microbial communities that influence the quality and quantity of petroleum that can be recovered. Microbial activity can be beneficial or detrimental to petroleum exploitation. It is critical that professionals in the petroleum industry understand the factors that regulate microbial activity in order to enhance the beneficial activities and limit the detrimental ones. This book provides a comprehensive overview of the role of microorganisms in petroleum production and use in order to make the reader aware of how current practices can be altered or controlled for the benefit rather than
the detriment of oil production and use. The complex problems involved in petroleum exploitation require the integration of information from many disciplines, including microbiology, geochemistry, and engineering. This book serves as an important resource to accomplish this goal. Microbiologists will find an up-to-date treatment of an important area of microbiology in which they may choose to study. Professionals from other disciplines such as materials science, geoscience, and petroleum engineering will find a concise but comprehensive presentation of how microbes live and guidelines for their manipulation.

One aim of this book is to change the perception in the industry that petroleum reservoirs are sterile environments inaccessible to microorganisms. In fact, we now know that dynamic and complex microbial communities exist in petroleum reservoirs. The physical, chemical, and microbiological processes that govern the activity of these communities must be understood for optimal and economic exploitation. Section I of the book provides a comprehensive overview of the microbial ecology of petroleum reservoirs and surface facilities. The physiology and ecology of several important groups, such as sulfate-reducing bacteria, methanogenic bacteria, hyperthermophiles, and fermentative and chemolithotrophic bacteria, are discussed to illustrate the diverse and dynamic nature of the resident microorganisms. These chapters provide the reader with insight on how microorganisms act in their natural environment.

Microbial activity can be a double-edged sword in regard to petroleum exploitation. Microbial activity is most often thought of in detrimental terms in relation to the role that microorganisms play in corrosion of piping and surface facilities, plugging of injection wells, biofouling of surface equipment, and souring (hydrogen sulfide production) of reservoirs. Section II provides an in-depth analysis of the mechanisms by which microorganisms detrimentally affect petroleum exploitation and possible solutions for the control of these activities. Section III discusses the other edge of the microbial sword, the beneficial activities of microorganisms. Understanding the factors that govern microbial activities such as sulfate reduction has led to novel approaches such as nitrate or nitrite amendments to control souring. In addition, understanding the mechanisms involved in microbial hydrocarbon metabolism has led to the development of microbial processes to control paraffin deposition and to upgrade the quality of fossil fuels. Manipulation of the ecology and physiology of microbial populations in the reservoir, most often by nutrient amendment, can result in the stimulation of microbial activities that lead to increased oil production.

Section IV provides an up-to-date overview of the biodegradation of petroleum hydrocarbons and refined petroleum products and approaches to manipulate hydrocarbon degradation activity for environmental clean up. Diversity is the theme here. It is clear that the variety and numbers of hydrocarbon-degrading microbial species are very large, as is the variety of chemical structures that microbes metabolize. Within the last 15 years, it has been discovered that the ability to degrade diverse hydrocarbons extends to anaerobic microorganisms. Here, novel reactions such as carboxylation and fumarate addition are used to activate the hydrocarbons for anaerobic decay. The plethora of aerobic and anaerobic hydrocarbon-degrading activities offers
diverse options for remediation. Active intervention by the addition of limiting nutrients and/or oxygen can be used to remediate petroleum spills in environmentally sensitive areas such as beaches, estuaries, or drinking water aquifers. Alternatively, if the risk to the environment and human health is low, natural attenuation can be used to degrade the hydrocarbon. Again, understanding the ecological factors that limit microbial activity (e.g., hydrocarbon metabolism) at the site in question, such as the lack of a suitable electron acceptor or of required nutrients for growth or the presence of the required microbial activity, is fundamental to the success of the remediation endeavor.

This book differs from previous books on petroleum microbiology in one significant way. Earlier books focused almost exclusively on hydrocarbon metabolism and bioremediation of petroleum spills. This book covers these important topics but also provides an up-to-date overview of the ecology of petroleum reservoirs. The realization that petroleum reservoirs are climax microbial communities that respond to change in predictable ways offers the practitioner approaches to control microbial activity. Most practitioners realize that microbes catalyze detrimental activities such as corrosion or souring, but they do not understand the factors that govern these activities or how best to control them. This book shows how microorganisms act, so that steps can be taken to control their activities. This book will be an important resource for microbiologists and other professionals interested in petroleum microbiology.

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