Preface

Mix 99 parts water with 1 part microbes, stir, and freeze. What you get is frozen microbes that will be alive and well long after you, your children, your grandchildren, and most of your descendants are gone. Some of the microbes may live on (if kept frozen) for millions of years. Some of the life on Earth has lived through a multitude of catastrophic events on Earth. Events that would have killed most, if not all, of the humans on Earth. Scientists studying ancient ice can measure the amounts of gases that were in the atmosphere, and were entrapped in the ice, hundreds of thousands of years ago. They can measure the temperature of the Earth during those times, as well. Other researchers can examine the microbes, and even larger organisms, that were alive at that time, and reconstruct what parts of the Earth looked like during those times. It is as if recording instruments had existed all over the world during all of human existence, and today, we are able to read those instruments. Ice on Earth, and even on other planets, holds these records, and sometimes it holds living organisms that can be revived and studied.

We started writing the initial portions of this book in 2000, at a time when investigating microbes in ancient ice was in its infancy, and there was very little information to report. At that time, the field of Astrobiology was moving from a small area of research into a well-funded major branch of science. Also, global climate change had been firmly established in the scientific community, but still was debated by politicians and the public. The result of the preliminary nature of all of this resulted in a book manuscript that was thin on data and heavy on speculation. About three years ago, we returned to the book manuscript and established that a great deal of data had been produced over the past two decades, such that it would be possible to produce a stronger book. This was not only caused by the increase in data, but also by the increase in the knowledge of the public in these areas. Many popular press articles have been written, and many programs have been produced discussing ancient organisms, the many aspects of exploring planets and moons in the Solar System, and the big changes that have occurred in greenhouse gases, melting, ice, sea level rise, and the human causes of these. In this book, we detail the discoveries and conclusions in the research on ancient ice, and tie it in with the discoveries in astrobiology, epidemiology, global climate changes, and sea level rises.

While ice contains a valuable record, it also encases microbes that are beneficial (e.g., those that recycle nutrients, those that fix carbon from carbon dioxide, those that help plants to soak up water and nutrients, those that produce antibiotics, and a multitude of other vital processes), as well as those that are dangerous. There are many pathogenic microbes encased in environmental ice around the world. All are released as glaciers melt. With the increases in melting of ice worldwide, more of these organisms are being released. The potential for disease outbreaks, epidemics, and pandemics is real, as is the loss of beneficial microbes. Disease outbreaks have likely occurred before from glacial melting, but it is unknown when and how frequently.

Global climate change threatens the loss of this extremely valuable resource, and at the same time, potentially exposes the world to pathogens. Studies of ancient ice compared to real time measurements of atmospheric gases taken over the past century have led to the realization that humans are in the process of changing the Earth in ways that are causing changes in the land, ocean, and atmospheric composition and temperature, as well as altering precipitation, wind, storms, ocean currents, and melting ice worldwide, which is causing sea levels to rise, and increased heating due to the loss of the reflective nature of snow and ice. As mentioned above, this also is causing unprecedented releases of microbes, including pathogens around the world. Scientists and non-scientists alike are worried. Hopefully, it will not be a deadly pandemic that finally leads people and governments to act decisively to slow or reverse these global changes. With increases in world temperatures, melting of ice, and human population increase, we are approaching a time when the risks of a negative outcome in the near future are growing at an alarming rate.

The science of Astrobiology involves the search for extraterrestrial life. This is directly related to research of microbes in environmental ice and permafrost (frozen soils). During the past half century, a great deal has been learned about the planets and moons in the Solar System and beyond. At one point in time, our vision was limited to telescopes that could help us see the Moon, Mercury, Venus, Mars, and blurry visions of Jupiter, Saturn, Uranus, Neptune, and Pluto. At that time, it looked like Earth was the only planet that could sustain life. No other planet or moon had enough water and the right temperatures to harbor life. Today, we know that this view was wrong. There is a lot of water in our Solar System, although much of it is in the form of ice. But, large lakes and oceans also exist. By studying life in ice on Earth, we can reach conclusions about which planets and moons might have life on them. This provides a guide to help plan missions and probes to search for life in intelligent ways.

During our work with ice cores, we met many researchers. While we cannot name all of them, they were all interesting and helpful, including those from France, Russia, Belgium, Denmark, Canada, Tasmania, the UK, and the US. We also met engineers, electricians, welders, carpenters, drillers, and NSF officials. They should not be forgotten in work obtaining the ice cores. They were just as dedicated, interesting, and helpful as were the researchers. Many students also were involved, and were vitally important to the research endeavors and results. It really does take a community to do this complex, challenging, and often dangerous work.

This book is arranged into 20 chapters. Chapter 1 is an overview of working with ice, and isolating and studying the organisms encased in the ice. Chapter 2 deals primarily with the overall implications of the work, including the importance to studies of evolution, epidemics, applied projects (e.g., antibiotics, food products), and the search for life away from the Earth. Chapter 3 presents a discussion of the properties of water and ice, and why ice is such a great preservative of organisms. Chapter 4 explores the diversity of environmental ice, describing similarities and differences between glaciers, ice fields, ice domes, sea ice, and lake ice. Chapter 5 is all about permafrost, which is simply frozen soil, but as with environmental ice, there are many different types of permafrost. Chapter 6 discusses the definitions of life, and how to identify living and dead microbes. Chapter 7 defines and discusses fossils, both dead and living. Chapter 8 explains some of the steps in the planning, funding, drilling, and analyzing inclusions in ice cores. Chapter 9 outlines some of the major methods for isolating and identifying organisms entrapped in the ice. Chapter 10 outlines the history of the studies of microbes in ice, including the confluence of genetics, evolutionary biology, geology, ice biology, molecular biology, and microbiology. Each of these had to exist for the study of microbes in ice to be possible. Chapter 11 describes the details of what has been found in the ice during the past 60 years. Chapter 12 is a detailed account of what has been found in subglacial Lake Vostok, which has been covered for 15 million years by thousands of meters of glacial ice. The short story is that it contains a diversity of organisms. Chapter 13 discusses other lakes, including subglacial Lake Whillans, as well as ice from Lake Erie and surface lakes in Antarctica. Chapter 14 discusses the types of living organisms that have been extracted from ancient ice. The bottom line is that they are very adaptable to a broad number of conditions, including living through freeze-thaw cycles. Chapter 15 describes the hazardous organisms that have been found in ice, and that are capable of causing disease in animals (including humans), plants, and other organisms. This chapter primarily deals with viruses. Chapter 16 discusses the hazardous bacteria and other microbes that have been found in ice, or that are capable of surviving freezing and thawing. It also discusses the dangers to people who work with the ice. It probably is not a good idea to put a glacial ice cube into your drink. Chapter 17 discusses the process of genome recycling, which is the process whereby an organism is frozen for long periods of time, after which it melts out of the ice and enters a population (or a host) carrying with it the ancient genome that now enters the more recent genome. Chapter 18 is a discussion of where in the Solar System to look for signs of life. There are quite a few planets and moons that have the potential to harbor life. Chapter 19 discusses global climate change, and how it affects the study of microbes in ice, as well as many other aspects of life on Earth. Chapter 20 wraps up and summarizes the major concepts and findings that have come from the study of ice and the microbes within ice.