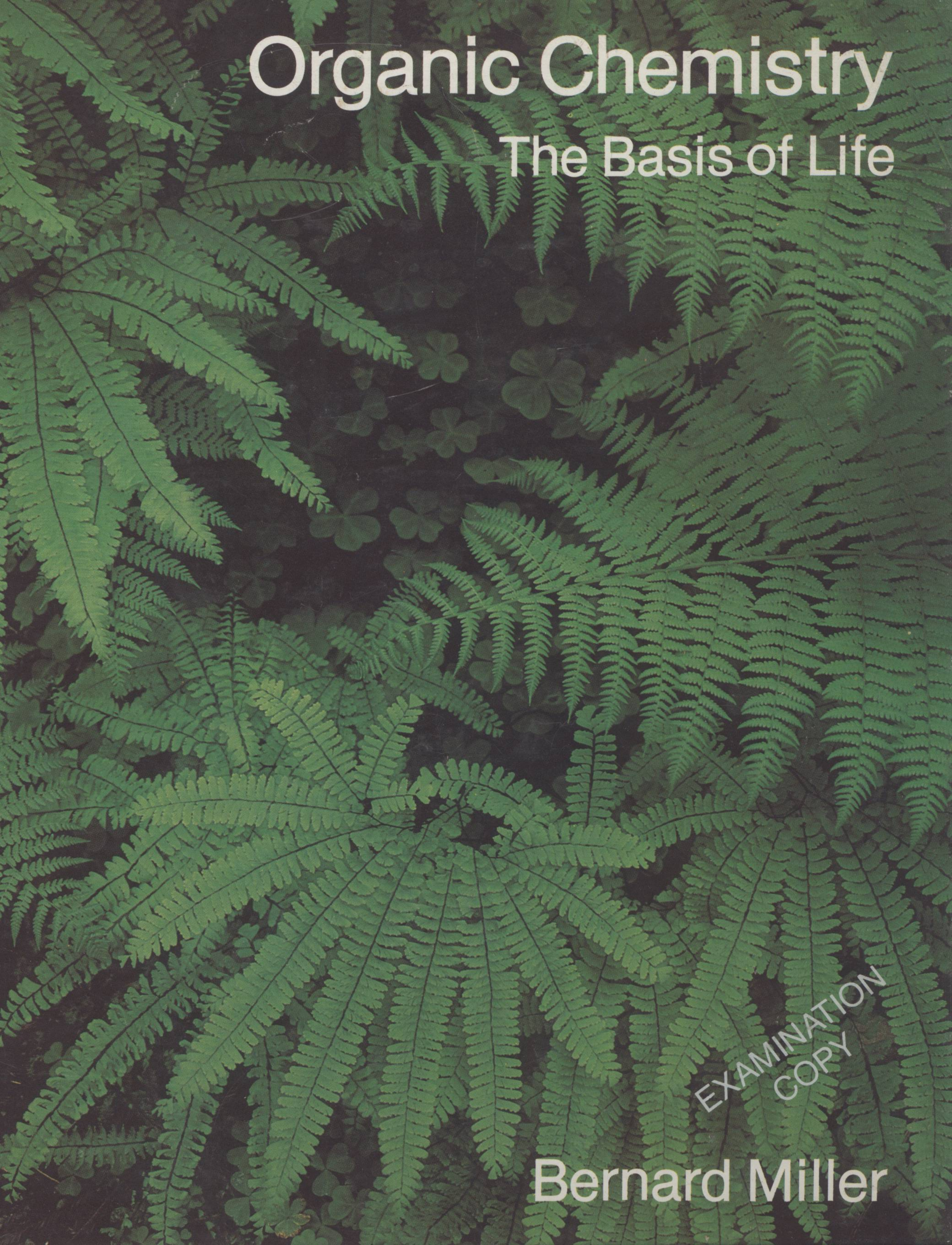

Organic Chemistry

The Basis of Life

Bernard Miller

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Preface

Any introductory course in organic chemistry includes a great deal of information to be learned in a brief period of time. This is particularly true in a "short course" of just one semester or one or two quarters. It is simply impossible to learn much about all the important aspects of organic chemistry in that time. The usual way to handle this problem is the survey approach. In this method, many areas of organic chemistry are briefly introduced, but no attempt is made to have students become really knowledgeable about any of them.

Such an approach, however, is not appropriate for a course in which most students are studying some aspect of the life sciences. Whether students in this course are majoring in forestry, nursing, nutrition, pharmacy, veterinary science, microbiology, soil science, or any other field of applied biology, it is important for them to gain a solid understanding of how reactions of organic molecules proceed in biological systems. A superficial glance over large areas of organic chemistry simply won't meet their needs.

In this book, therefore, you'll find nothing about carbenes, diazonium salts, hydroboration, metallocenes, or recent advances in synthetic techniques. Fascinating as these subjects are, every page devoted to them would reduce the space available for discussion of topics which are more important for the great majority of students in this course. Instead, I have concentrated on reactions of alcohol, carbonyl, and carboxyl groups, which are vitally important in biological processes. For example, I've covered in some detail the reverse aldol and reverse Claisen condensations, as well as reactions of conjugated carbonyl compounds. These topics are often treated very briefly or omitted entirely in other texts—presumably on the grounds that they are too advanced for students in a short course. However, these reactions are important in many biological (as well as industrial) processes. My experience has been that students have no difficulty in understanding them provided that the organization of the course allows sufficient time to study them carefully.

Although it is designed to help students understand processes in living organisms, this book contains no chapters devoted to "biological chemistry" as such. Instead, discussions of biochemical processes and the biological properties of organic molecules are incorporated into chapters on the various functional groups. My object has been to demonstrate that the biological properties of molecules are usually closely related to their normal chemical properties. Most students are fascinated to realize that they can understand why "mineral oil" is indigestible, why allylic halides are lachrymatory, and why many polycyclic aromatic hydrocarbons are carcinogenic. Their interest in the course is sustained by the knowledge that what they are learning is directly relevant to their own concerns and career interests.

Experience has shown that this emphasis on biologically important reactions does not short-change students who are not majoring in one of the life sciences. My own classes, for instance, sometimes include a few students majoring in chemical engineering. I have found that an emphasis on reactions of alcohols, carbonyls, and carboxyl compounds provides a better foundation for their further courses in chemical processes than does a typical survey approach.

Many textbooks treat reaction mechanisms as frills, which can be skipped over lightly by students in a short course. Experience has demonstrated, however, that students will not long remember what they have learned unless what they have learned makes sense to them. When students understand the mechanisms for organic reactions, they see that the reactions do make sense, and are not just equations to be memorized and regurgitated on exams. The basic processes involved in most reaction mechanisms are not complex, and should be easily understood by every student. I have therefore stressed the art of "electron pushing" in this book. The mechanism of almost every reaction studied is discussed, and many problems are devoted to training students to think in mechanistic terms. I hope this book will help kill the old notion that studying organic chemistry requires an endless regimen of memorization.

In writing this book I have tried to keep to a minimum the number of theoretical concepts, and in particular the number of technical terms, that the student has to learn. I have also followed a policy of introducing theoretical concepts only at the points where they are needed to explain the properties of the molecules being discussed. The first chapter covers only those concepts which will actually be employed right from the beginning of the book. Other theoretical concepts introduced in the first chapters of other texts are introduced much later, if necessary, in this book. The theory of resonance, for instance, is not introduced until it is needed to explain the phenomenon of conjugate addition. The idea of aromaticity is carefully distinguished from "ordinary" resonance, and is only introduced when it is necessary to explain the remarkable properties of benzene. The concept of chirality is introduced immediately before the discussion of the stereochemistry of displacement reactions. As a result, all theoretical concepts are seen to have concrete applications, and students are not confronted with a large chunk of theory during their first weeks in the course.

I've done my best to make this a book that *teaches* students about organic chemistry, rather than one that just tells them about the subject. I've tried to point out difficulties that occur to many students, and to show students how to avoid or overcome these difficulties. I have no illusions that any textbook can eliminate the need for a live instructor. Still, I hope that my efforts will reduce the number of times the instructor has to remind students that carbon is tetravalent, or that substituents on the horizontal line in a Fischer projection lie in front of the plane of the paper.

Organic chemistry is a subject which is best studied by working out solutions to problems, rather than by simply rereading the text. I have included a great many problems in this book, ranging from relatively simple questions for which answers can be found directly in the text to rather challenging problems on reaction mechanisms. The answers to all of the problems, as well as learning objectives for each chapter and hints for solving problems, are given in a study guide for students written by Michael McLaughlin of Indiana University Southeast. Additional problems in the form of examinations and quizzes for each chapter are available in an instructor's manual.

I sincerely hope that both instructors and students will enjoy the approach to organic chemistry incorporated in this book. I look forward to hearing from you about your experiences with this book.

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A Few Basic Principles

1.1 Organic Chemistry

Your body is a complex mixture of over 100,000 chemical compounds. With the exception of water and a small number of inorganic salts, all the compounds in your body contain carbon atoms. In many of these compounds, the carbon atoms form the basic framework of the molecules, with other atoms simply hung on a skeleton of carbon atoms.

The relationship between living organisms and the presence of compounds of carbon is so striking that in the nineteenth century the chemistry of carbon compounds was named **organic chemistry**. It was thought that a "vital principle" present only in living organisms was necessary to produce the very complex compounds of carbon found in those organisms. Although it has been known for more than a century that very complex carbon compounds can be prepared in the laboratory as well as in living organisms, we still use the terms *organic chemistry* and *organic compounds* (or *organic molecules*). **Organic compounds are compounds containing carbon, and organic chemistry is the chemistry of compounds containing carbon.**

Carbon dioxide, carbon monoxide, and carbonate salts are sometimes defined as inorganic molecules, for the purely historical reason that they were first encountered in such nonbiological surroundings as rocks and air.

Actually, most "inorganic" carbonates, such as limestone and marble, are derived from living sources. They are the accumulated shells of microscopic marine organisms. Much of the carbon dioxide in the atmosphere also comes from the respiratory activities of living organisms. Part of the atmospheric carbon dioxide is purely inorganic, however, since it comes from fumes of active volcanoes. This is presumably the ultimate source of most carbon presently being used for biological activities.

In order to understand the nature of biological processes, it is essential to understand the reactions of carbon compounds. Since more than 3 million compounds of carbon are now known, understanding organic chemistry might seem to be a Herculean task. Fortunately, the chemistry of carbon is in many ways simpler than that of most other atoms. Almost all organic reactions (particularly those that are biologically important) can be understood on the basis of a small number of basic principles. Once these principles are understood, most organic reactions can be seen to be specific examples of a few basic processes. Memorizing great numbers of disconnected facts will not be necessary, since a comparatively few processes are repeated over and over, in different contexts.

1.2 Bond Formation

Although this is a book about organic chemistry, let us start out by considering the simplest chemical reaction: bond formation between two hydrogen atoms.

A hydrogen atom, like all atoms, consists of a positively charged nucleus (in this case a proton, with a charge of +1) around which a negatively charged electron revolves. Although in principle the electron might be found at any distance from the hydrogen nucleus, it can almost always be found in a small region of space near the nucleus called an **atomic orbital**. For practical purposes, we can consider the electron to be restricted to the orbital. A very important principle of chemistry is that **no more than two electrons can be present in a single orbital at the same time.**

The orbital of a hydrogen atom has the shape of a sphere with the nucleus at the center. If one hydrogen atom approaches another, the nucleus of each atom will attract the electron of the other. As the two atoms draw near each other, the shape of each orbital changes from a sphere to an

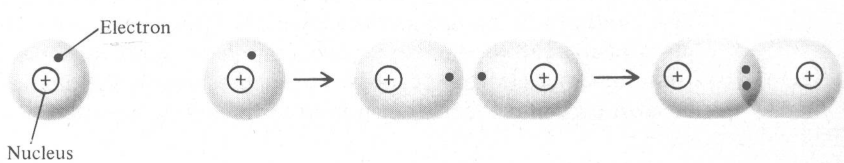

Figure 1.1 Bond formation between two hydrogen atoms.