

Porter
Spurgeon

Biosynthesis of Isoprenoid Compounds

Volume 1

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INTERSCIENCE

Biosynthesis of Isoprenoid Compounds

Volume 1

Edited by

John W. Porter and Sandra L. Spurgeon

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and

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Biosynthesis of Isoprenoid Compounds

Volume 1

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Preface

Isoprenoid compounds are an extremely large and diverse group of natural products that have a common biosynthetic origin. These compounds arise through the condensation of isopentenoid units that are derived from acetate. Therefore, it is appropriate to consider the biosynthesis of these compounds together, in spite of their diverse structures, functions, and origins.

A number of excellent reviews have recently been published covering various aspects of isoprenoid biosynthesis, but none of these covers the complete range of these diverse compounds. The preparation of this book was undertaken to provide a comprehensive review of the current status of information on the biosynthesis of these compounds. Each chapter has been written by an expert in that particular area. It is expected that these volumes will serve as a valuable reference source to professional researchers working in the area of isoprenoid biosynthesis. These volumes will also provide an introduction to what is certainly a complex area of natural product biosynthesis for advanced undergraduate and graduate students.

Because of the large number of topics to be covered, it was decided to publish information on the biosynthesis of polyisoprenoid compounds in two volumes. The first volume includes a brief historical introduction to the subject of isoprenoid biosynthesis. The remainder of the chapters in this volume can be divided roughly into two sections. The early chapters cover aspects of the biosynthesis of isoprenoid compounds that are of significance to more than one class: the formation of the isopentenoid unit, isomerization, and the prenyl transferase reaction. The remaining chapters cover the biosynthesis of the monoterpenes, sesquiterpenes, diterpenes, and triterpenes (sterols). Chapters on the biosynthesis of the longer-chain isoprenoid compounds such as carotenoids, dolichols, and rubber are included in the second volume. This volume also includes chapters on important metabolites of isoprenoid compounds, with the exception of bile acids and steroid hormones that have been extensively covered elsewhere.

This book would not have been possible without the cooperation of the authors who prepared the chapters of these volumes. We are grateful for

their thoroughness in the preparation of their contributions. The editors also wish to express their appreciation to Dr. Stanley Kudzin and the staff of John Wiley & Sons for their help in the preparation of this book.

JOHN W. PORTER
SANDRA L. SPURGEON

Madison, Wisconsin
July 1981

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Biosynthesis of Isoprenoid Compounds

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Introduction

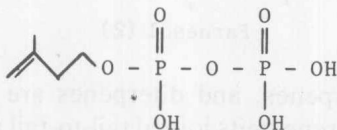
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1 STRUCTURAL RELATIONSHIPS

1.1 Definitions and Nomenclature

The group of natural products known as isoprenoids includes all substances that are derived biosynthetically from the 5-carbon compound isopentenyl pyrophosphate (1). Isoprenoid compounds are also referred to as "ter-



Isopentenyl pyrophosphate (1)

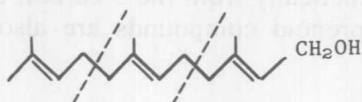
penes" or "terpenoids," which is the term used in the designation of the various classes of these compounds. Originally, the name "terpene" was used to refer only to the group of compounds containing 10 carbon atoms. However, as more compounds were isolated, the term gradually acquired a more general meaning and the name "monoterpene" was used to designate the C_{10} compounds. The major classes of isoprenoids are as follows:

Number of Carbons in Parent Chain	
Monoterpenes	C_{10}
Sesquiterpenes	C_{15}
Diterpenes	C_{20}
Sesterterpenes	C_{25}
Triterpenes	C_{30}
Tetraterpenes	C_{40}
Polyterpenes	$(C_5)_n$

These classes are further subdivided into groups based on various structural features. For example, the monoterpenes can be divided into acyclic, monocyclic, and bicyclic compounds. Most isoprenoid compounds are still known by the common name given to them when they were originally isolated. A systematic nomenclature has been proposed by the International Union of Pure and Applied Chemistry for many of these classes, but the systematic names are rarely used in the literature. The numbering of common skeleta of monoterpenes, sesquiterpenes, diterpenes, and triterpenes can be found in Hanson (1).

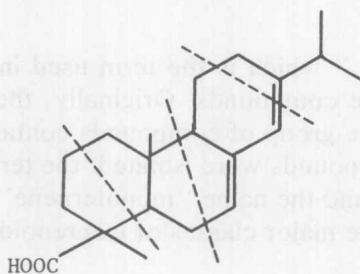
1.2 Structure

Isoprene units may be joined together in a regular or irregular manner. In a regular arrangement isoprene units are joined head-to-tail. This arrangement can readily be seen in the carbon skeleton of farnesol (2). The majority of



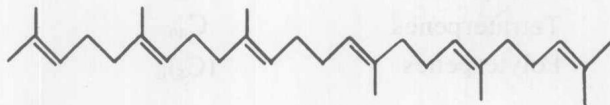
Farnesol (2)

monoterpenes, sesquiterpenes, and diterpenes are of this type. In the irregular arrangement isoprene units joined tail-to-tail are found. For example, in the case of abietic acid (3) three isoprene units are arranged head-to-tail,



Abietic acid (3)

whereas the fourth is attached tail-to-tail. The triterpenes (steroids) and the tetraterpenes (carotenoids) have a unique structural arrangement. In the case of the triterpenes, two C₁₅ farnesyl groups having a regular arrangement of isoprene units are joined tail-to-tail to produce the symmetrical arrangement seen in squalene (4), the acyclic precursor of this group of compounds.



Squalene (4)

The carbon skeleton of the carotenoids is derived from two C₂₀ geranylgeranyl groups in the same manner. Further variation in isoprenoid structure is achieved by the addition of functional groups, cyclization, rearrangements, selective removal of carbon atoms, and other modifications. The majority of monoterpenes, sesquiterpenes, diterpenes, and triterpenes are cyclic compounds. The structures of representatives from each of these