

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

---

This is the first book to describe the scientific basis for the action of plant polyphenols in a wide range of technologically important phenomena.

Basic understanding of plant polyphenols (vegetable tannins) has increased dramatically over the past 30 years. This has opened the way to an understanding of practical polyphenolic phenomena. The book opens with a general summary of polyphenolic structure and a discussion of the physical and chemical basis of non-covalent molecular interactions (the process of molecular recognition) and the means by which polyphenols initiate the many and varied properties they display. There has been a big increase in interest in our ability to understand the importance of polyphenols in areas as diverse as agriculture, ecology and food selection, foodstuffs and nutrition, beverages (astringency and bitterness), natural medicines (the so-called 'French Paradox'), floral pigmentation, natural glues and varnishes and the age-old methods for the manufacture of leather. The role of polyphenols in all of these areas is discussed.

This book will be of value to a wide range of researchers in chemistry, agriculture, food science, ecology, oenology, plant physiology and pharmacology with an interest in polyphenolics.

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and  
Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

---

**PRACTICAL POLYPHENOLICS**  
From Structure to Molecular Recognition and  
Physiological Action

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and  
Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

---

**PRACTICAL POLYPHENOLICS**  
From Structure to Molecular Recognition and  
Physiological Action

**EDWIN HASLAM**

*University of Sheffield*



**CAMBRIDGE**  
**UNIVERSITY PRESS**

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

CAMBRIDGE UNIVERSITY PRESS

Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press

The Edinburgh Building, Cambridge CB2 2RU, UK

Published in the United States of America by Cambridge University Press, New York

[www.cambridge.org](http://www.cambridge.org)

Information on this title: [www.cambridge.org/9780521465137](http://www.cambridge.org/9780521465137)

© Cambridge University Press 1998

This book is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 1998

This digitally printed first paperback version 2005

*A catalogue record for this publication is available from the British Library*

*Library of Congress Cataloguing in Publication data*

Haslam, Edwin.

Practical polyphenolics: from structure to molecular recognition and physiological action.

p. cm.

Includes bibliographical references.

ISBN 0 521 46513 3 (hb)

1. Phenols. 2. Botanical chemistry. I. Title.

QK898.P57H37 1998

661'.82-dc21 9-8686 CIP

ISBN-13 978-0-521-46513-7 hardback

ISBN-10 0-521-46513-3 hardback

ISBN-13 978-0-521-67559-8 paperback

ISBN-10 0-521-67559-6 paperback

Cambridge University Press  
0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and  
Physiological Action  
Edwin Haslam  
Frontmatter  
[More information](#)

---

For M

*Che faro senza M*

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

## Contents

<i>Preface</i>	page xiii
<i>Introduction</i>	1
<i>'E.C.' – A personal memoir</i>	3
<b>1 Polyphenols – structure and biosynthesis</b>	10
1.1 Phenolic metabolism in plants	10
1.2 Plant polyphenols (vegetable tannins)	18
1.2.1 Properties and classification	20
1.3 Condensed proanthocyanidins	23
1.3.1 Flavan-3-ols and dimeric procyanidins – structure and stereochemistry	24
1.3.2 Proanthocyanidins of the A group	31
1.3.3 Higher oligomeric and polymeric proanthocyanidins	31
1.3.4 Biosynthesis of proanthocyanidins	35
1.4 Shape and conformation of proanthocyanidins	42
1.4.1 Flavan-3-ol conformations	43
1.4.2 <sup>1</sup> H NMR spectroscopy of procyanidin dimers	45
1.4.3 Procyanidin conformations – MM2 calculations	48
1.5 Gallic acid metabolism	51
1.5.1 Biosynthesis of galloyl esters	52
1.5.2 Depside metabolites	55
1.5.3 Hexahydroxydiphenoyl esters and related metabolites	58
1.5.4 Oxidative metabolism – pathway (b)	63
1.5.5 Oxidative metabolism – pathway (c)	68
1.5.6 Oxidative metabolism – pathway (d) – ‘open chain’ derivatives of D-glucose	70
References	76

x	<i>Contents</i>	
<b>2</b>	<b>Molecular recognition</b>	84
2.1	Introduction	84
2.2	Molecules of life – DNA	85
2.3	Molecules of life – proteins	87
2.4	Non-covalent molecular interactions	90
2.5	Hydrogen bonds and hydrogen bonding	93
2.5.1	Carbohydrates	97
2.5.2	Geometric considerations	101
2.5.3	Proton donor and proton acceptor scales	104
2.5.4	Hydrogen bonding and the construction of molecular aggregates	107
2.6	Solvation	109
2.6.1	Reflections on water and ‘hydrophobic effects’	112
2.7	$\pi - \pi$ Interactions	118
2.7.1	‘Face to face’ $\pi - \pi$ interactions	119
2.7.2	‘Edge to face’ $\pi - \pi$ interactions	127
	References	132
<b>3</b>	<b>Molecular recognition – phenols and polyphenols</b>	138
3.1	Introduction	138
3.2	General observations	139
3.2.1	Hydrogen bonding	139
3.2.2	Solvation and ‘hydrophobic effects’	145
3.2.3	Crystal structures of simple phenols	151
3.2.4	Model studies with caffeine	155
3.2.5	Cyclodextrins and polysaccharides	163
3.2.6	Studies with peptides and proteins	168
	References	174
<b>4</b>	<b>Taste, bitterness and astringency</b>	178
4.1	Food selection – ecological implications	178
4.2	Nutritional effects	186
4.3	Phytotoxicity	189
4.4	Pasture bloat	190
4.5	Taste and flavour – fruit and beverages	192
4.5.1	Introduction	192
4.5.2	Astringency	193
4.5.3	Grapes and wines	194
4.5.4	Apples and pears; ciders and perry	196
4.5.5	Beers and lagers	200

<i>Contents</i>		xi
4.5.6	Teas	203
4.5.7	Astringency of teas	209
4.5.8	Tea cream and tea creaming	212
4.5.9	Cocoa	216
	References	219
<b>5</b>	<b>Maturation – changes in astringency</b>	226
5.1	Introduction	226
5.2	Ripening of fruit	227
5.2.1	Persimmon	228
5.3	Moderation of astringency – carbohydrate complexation	231
5.3.1	Algal polysaccharides	235
5.3.2	Pectin	235
5.3.3	Xanthan	236
5.4	Teas, casein and astringency	241
5.5	Ageing of red wines	245
5.5.1	Colour changes	246
5.5.2	Ageing of wines and other alcoholic beverages in oak	252
	References	257
<b>6</b>	<b>Anthocyanin copigmentation – fruit and floral pigments</b>	262
6.1	Introduction	262
6.2	Anthocyanins	263
6.2.1	Natural anthocyanins	267
6.2.2	Location of anthocyanins	269
6.2.3	Self-association of anthocyanins	270
6.3	Copigmentation	274
6.3.1	Intermolecular copigmentation	274
6.3.2	Intramolecular copigmentation	283
6.4	Metalloanthocyanins	286
6.5	The blue rose?	290
	References	294
<b>7</b>	<b>Polyphenols and herbal medicines</b>	298
7.1	Introduction	298
7.1.1	Biological and pharmacological activity	301
7.2	Metal-ion complexation	304
7.3	Antioxidant activity	306
7.3.1	Cellular pro-oxidant states	307
7.3.2	Phenols and polyphenols as antioxidant nutrients	312



Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

xii	<i>Contents</i>	
	7.3.3 Green tea and the 'French paradox'	315
	7.4 Polyphenol complexation	323
	References	330
<b>8</b>	<b>Quinone tanning and oxidative polymerisation</b>	<b>335</b>
8.1	Introduction	335
8.1.1	Quinone intermediates	339
8.1.2	Black tea pigments – thearubigins – thoughts and speculation	344
8.2	Quinone tanning: tanned silks and insect cuticle sclerotisation	354
8.3	Melanins	358
8.4	The mussel byssus: an underwater adhesive	361
8.5	Cocoa	366
8.5.1	Fermentation	367
8.5.2	Drying	368
8.5.3	Roasting	369
	References	371
<b>9</b>	<b>Polyphenols, collagen and leather</b>	<b>374</b>
9.1	Introduction	374
9.2	Vegetable tannage	374
9.2.1	Vegetable tannins of commerce	375
9.2.2	Early ideas on the mechanism of vegetable tannage	377
9.3	Collagen – primary structure and the triple helix	379
9.4	Biosynthesis of collagen (tropocollagen)	383
9.5	Fibrillogenesis	384
9.5.1	Fibrils – molecular organisation	388
9.5.2	Microfibrils	391
9.6	Connective tissue and the structure of skin	391
9.7	Vegetable tannage – some new ideas	396
9.8	Vegetable tannins and the durability of leather	401
	References	407
	<i>Biological index</i>	410
	<i>General index</i>	412

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

## Preface

Over the past three centuries Science has increasingly come to represent one of mankind's most formidable achievements. In areas as diverse as agriculture, materials and medicine its technological applications have transformed the lives of many throughout the world. Science conversely often exacts its own price, for benefits and risks are frequently found to be complementary aspects of the same technological advances; society has to judge between them. A popular misconception fostered by some writers and media pundits is that progress in Science, the accumulation of new and greater knowledge superseding previous discoveries, proceeds exponentially ever upwards and onwards. This is misleading. Science is a human endeavour and scientists are creative beings. Science is therefore spiced with pride and prejudice; it is often subject to personal folly, wrong turns and cul-de-sacs. False dawns, unfortunately not always constrained to the confines of the laboratory, are legion. The odyssey of the science of the vegetable tannins (plant polyphenolics) as it has journeyed from darkness into (comparative) light is littered with examples of the frustrations which underly scientific progress and discovery.

Records show that extracts of a plant origin (vegetable tannins) were employed in Mediterranean regions to convert raw animal hides and skins to durable leathers at least 2000 years ago. Investigations of the chemistry of such extracts, despite the outstanding contributions of the Nobel Laureate Emil Fischer at the turn of the century, merely served to show the complexity of the problems which they posed and by the 1950s this area had become one of the murky and unfashionable corners of organic chemistry. There is often an ebb and flow to scientific research and the advent of new techniques, new ideas and new personnel has, over the past forty years, not only transformed the state of the fundamental knowledge of these compounds but has also revealed their crucial importance to many other areas of science – from ecology and agriculture, nutrition and foodstuffs, to beverages, fruit and floral pigmentation. Thus

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)

xiv

*Preface*

particular attention has focused recently on the possible amelioration of long-term degenerative disorders using beverages (such as teas and red wines) and specific diets rich in anti-oxidants (natural phenolics and polyphenolics).

Guardians of the public purse increasingly demand from scientific research a greater poundage of flesh; the emphasis has shifted to one in which short term exploitation of its discoveries is pre-eminent. This text therefore summarises the established chemical knowledge appertaining to plant polyphenols and seeks to use this information to address and interpret the many, important and wide ranging technological and applied phenomena in which plant polyphenols are intimately involved and which have been noted above. The approach adopted is an all inclusive one and is based upon critical evaluation of the physical forces which underly the '*recognition*' by polyphenols of other molecules, often prior to further irreversible chemical reaction. There seems little doubt that this area and that of the genetic and biochemical control of polyphenol synthesis *in vivo* are the ones which, in the future, will come to dominate scientific research involving plant polyphenols. The period from 1950 to 1990 was one in which public attitudes towards the status of science helped to facilitate fundamental research in seemingly arcane areas, such as that of the plant polyphenols. As the turn of the twentieth century approaches and siren voices increasingly beckon a long past rustic Arcadia it is timely, however, to gently remind those same guardians of a seemingly diminished share of the public purse for pure science of the words of Louis Pasteur (whose father was incidentally a tanner) that 'there are no such things as applied sciences, *only applications of science*'.

We are like dwarfs on the shoulders of giants, so that we can see more than they ... not by virtue of any sharpness of sight on our part, or any physical distinction, but because we are carried high and raised up by their giant size.

As in most scientific fields the expansion in knowledge and ideas is due to the many, amongst whom some major figures stand out. During the past forty years the contributions to the chemistry of plant polyphenols of Schmidt, Mayer and Weinges in Heidelberg, of Okuda and Nishioka in Japan, of Haworth in Sheffield and Roux in Bloemfontein were outstanding. The science of the vegetable tannins also occupies a unique position which borders not only on chemistry, but also botany, food science, agriculture and animal physiology. Two persons, Tony Swain and E. C. Bate-Smith, had the vision to recognise this crucial pivotal relationship and to see the importance which vegetable tannins were destined to play in succeeding years in many areas of applied science. The author had the extreme good fortune to have glimpses of that cherished vision in a long correspondence with one of these figures, E. C.

Cambridge University Press

0521675596 - Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action

Edwin Haslam

Frontmatter

[More information](#)*Preface*

xv

Bate-Smith. The correspondence was not only of inestimable scientific value but it was also full of encouragement and not a little humour. A few extracts are reproduced herein, not only for their scientific but also their human insights. May they stand for all who follow as a reminder of one of the true pioneers and giants of the science of vegetable tannins.

The sixteenth/seventeenth century poet and later Dean of St. Paul's John Donne did not have scientists in mind when he wrote that 'No man is an Island, entire of it self'. However, one of the most satisfying facets of a career in scientific research is the opportunities which it gives to meet and collaborate with others world-wide; to test one's ideas with like-minds thousands of miles distant. Unlike governments, science does not recognise national boundaries, it thrives on the spirit of intellectual challenge which arises from differences of opinion and interpretation. It is entirely appropriate that the author should note therefore the special contributions made by others to his own travails in this field – most notably Professor T. H. Lilley and Dr. M. P. Williamson (Sheffield), Professor L. G. Butler (Purdue University, U.S.A.), Dr. L. J. Porter (New Zealand) and Dr. Zhaobang Shen (China); to numerous postgraduate students from the original eponymous 'Lord Tannin' to the 'Last of the Mohicans'; to friends and acquaintances in the Phytochemical Society of Europe (and the earlier Plant Phenolics Group), the Phytochemical Society of North America and the Groupe Polyphenols (France); to those in industry with whom it has been the author's privilege to collaborate – Mme Daniele Magnolato (Nestlé Suisse), Dr. M. Saltmarsh (Mars G.B.) and Dr. A. Davies and Dr. Y. Cai (Unilever).

The author would also like to express his thanks to those who have helped in the preparation of this text; to Dr. Simon Capelin, Beverley Lawrence and Ian Sherratt (Cambridge University Press) who have overseen the transformation of the manuscript to the printed text; to Dr. Christopher A. Hunter (University of Sheffield) who read and critically evaluated the two chapters on molecular recognition, and who also abstracted and organised the X-ray structures of simple phenols from the Cambridge X-ray data bank; to David Lodge and Reed Books who gave permission to reproduce an extract from the novel *Small World*; to Verlag Carl Ueberreuter (Vienna) for permission to use the illustration by Ulrik Schramm from *Gullivers Travels* and to the other authors who are specifically noted and who gave permission to use figures, at appropriate parts of the text, from their own scientific publications.

Sheffield, U.K.