



Cite this: DOI: 10.1039/d4fo06152g

Extended recommendations on the nomenclature for microbial catabolites of dietary (poly)phenols, with a focus on isomers†

Claudio Curti,^a Michael N. Clifford,^{b,c} Colin D. Kay,^d Pedro Mena,^{e,f} Ana Rodriguez-Mateos,^g Daniele Del Rio,^{e,f} Gordon J. McDougall,^h Gary Williamson,^c Cristina Andres-Lacueva,^{i,j} Letizia Bresciani,^e Britt Burton Freeman,^k Aedin Cassidy,^l Yves Desjardin,^m Cesar G. Fraga,ⁿ Chris. C. I. Gill,^o Paul A. Kroon,^p Nikolai Kuhnert,^q Iziar A. Ludwig,^r Claudine Manach,^s Dragan Milenkovic,^t Cláudia Nunes dos Santos,^u Patricia I. Oteiza,^v Gema Pereira-Caro,^v Francisco A. Tomás Barberán,^w David S. Wishart^x and Alan Crozier^{y,z}

There is an increasing body of evidence indicating that phenolic compounds derived from microbiota-mediated breakdown of dietary (poly)phenolics in the colon are at least partially responsible for the beneficial effects of a plant-based diet. Investigating the role of these catabolites and defining their particular biological effects is challenging due to the complex microbial pathways and the diversity of structures that are produced. When reviewing the data this is further exacerbated by the inconsistency and lack of standardization in naming the microbial phenolics. Here we update the nomenclature of colonic catabolites of dietary (poly)phenols, extending the proposals of Kay *et al.* (*Am. J. Clin. Nutr.*, 2020, **112**, 1051–1068, DOI: 10.1093/ajcn/nqaa204), by providing additional structures, and addressing the difficulties that can arise when investigating regioisomers and stereoisomers, where subtle differences in structure can have a substantial impact on bioactivity. The information provided will help to better harmonize the literature, facilitate data retrieval and provide a reference for researchers in several fields, especially nutrition and biochemistry.

Received 11th December 2024,
Accepted 12th February 2025

DOI: 10.1039/d4fo06152g

rsc.li/food-function

^aBioOrganic Synthesis Unit, Department of Food and Drug, University of Parma, Parma, Italy^bSchool of Bioscience and Medicine, University of Surrey, Guildford, UK^cDepartment of Nutrition, Dietetics and Food, Monash University, Notting Hill, Victoria, Australia^dDepartment of Pediatrics, University of Arkansas Medical School, Little Rock, AR, USA^eHuman Nutrition Unit, Department of Food and Drug, University of Parma, Parma, Italy^fMicrobiome Research Hub, University of Parma, Parma, Italy^gDepartment of Nutritional Sciences, Kings College, London, UK^hThe James Hutton Research Institute, Invergowrie, Dundee, UKⁱDepartment of Nutrition, Food Science and Gastronomy, University of Barcelona, Barcelona, Spain^jCIBER Frailty and Healthy Aging (CIBERfes), Institute of Health Carlos III, Barcelona, Spain^kDepartment of Food Science and Nutrition, Illinois Institute of Technology, Chicago, ILL, USA^lInstitute for Food Security, Queen's University, Belfast, Northern Ireland, UK^mInstitute for Nutrition and Functional Food, Laval University, Québec, CanadaⁿDepartment of Nutrition, University of California, Davis, CA, USA^oNutrition Innovation Centre for Food and Health, Ulster University, Coleraine, UK^pQuadram Institute, Norwich, UK^qSchool of Science, Constructor University, Bremen, Germany^rCenter for Nutrition Research, University of Navarra, Pamplona, Spain^sUniversité Clermont Auvergne, INRAE, Human Nutrition Unit, Clermont-Ferrand, France^tPlants for Human Health Institute, Food Bioprocessing and Nutrition Sciences Department, North Carolina State University, Kannapolis, NC, USA^uNOVA Medical School, NOVA University of Lisbon, Lisbon, Portugal^vDepartment of Food Science and Health, Andalusian Institute of Agricultural and Fisheries Research and Training, Córdoba, Spain^wQuality, Safety and Bioactivity of Plant-Derived Foods CEBAS-CSIC, Espinardo University Campus, Murcia, Spain^xDepartment of Biological Sciences, University of Alberta, Edmonton, Canada^yDepartment of Chemistry, King Saud University, Riyadh, Saudi Arabia.

E-mail: alan.crozier44@gmail.com

^zSchool of Medicine, Dentistry and Nursing, University of Glasgow, Glasgow, UK† Electronic supplementary information (ESI) available. See DOI: <https://doi.org/10.1039/D4FO06152G>

1. Introduction

Growing attention is being focussed on the involvement of dietary (poly)phenols, including flavan-3-ols, anthocyanins and caffeoylquinic acids, in the protective effects of diets rich in fruits and vegetables on the development of a number of non-communicable chronic conditions including coronary heart disease, inflammation, diabetes, and reduced cognitive function.^{1–6} Following ingestion, a portion of these compounds, many of which have a C₆–C₃–C₆ structure, are absorbed in the small intestine and appear in the circulation as phase-II glucuronide, methoxy and sulfate metabolites.⁷ However, substantial amounts of the parent compounds pass to the lower bowel where they are broken down by the resident microbiota yielding a complex array of phenolic catabolites,⁸ a number of which have been shown to exhibit properties in model systems related to anti-inflammatory, anti-adhesive, anti-estrogenic and angiotensin-converting enzyme inhibitory activities, as well as a reduction of neural cell oxidative damage, prevention of cancer and improvement of markers of gut barrier integrity.^{9–23}

Investigations of the catabolism of dietary (poly)phenols in the lower gastrointestinal tract and the elucidation of protective effects of the resultant phenolic catabolites, and their use as biomarkers to modulate human health,^{24–28} are compounded by the sheer number of catabolites involved, not just in biofluids but also plants and derived foods. This is further complicated by the variety of nomenclatures and trivial names used to describe the phenolic compounds involved.

In October 2020 a consortium of researchers published proposals for a convenient and unambiguous nomenclature for dietary (poly)phenol catabolites.²⁹ The current paper is an extension of this publication providing an expanded list of phenolics, accompanied by figures illustrating the listed structures. It is the natural consequence of testing the proposed standardized nomenclature and addresses some of the difficulties arising when naming catabolites that were not included in the first version. It also sheds light on the potential problems arising when dealing with regioisomers and stereoisomers. Isomers are known to differ in absorption, metabolism, pharmacokinetics and associated biological effects and these differences are an important topic that is frequently overlooked. The nomenclature of glutathione derivatives, which are produced in the upper GI tract, and the microbial catabolites of lignans, the so-called enterolignans, are also reviewed. This paper will serve as a new guideline for harmonized research approaches in the field of dietary (poly)phenols. The main groups of phenolics that are included are outlined in ESI.†

2. Nomenclature

Table 1 was established based on cross-referencing the following databases: PubChem (<https://pubchem.ncbi.nlm.nih.gov>), NIST Chemistry WebBook (<https://webbook.nist.gov>), ChemIDPlus (<https://chem.nlm.nih.gov/chemidplus>), HMDB (<https://www.hmdb.ca>), ChemSpider (<https://www.chemspider.com>), ChemicalBook (<https://www.chemicalbook.com>), and ChEMBL (<https://www.ebi.ac.uk>) and follows the format adopted in the 2020 recommendations.²⁸ The recommended nomenclature is presented in column 1. The hyphenation of the compound names in this column has been standardized. However, whatever nomenclature system has been used in publications, the hyphenation can vary for many reasons, including typesetting, house style, lack of space in table columns, line breaks, *etc.*, and is beyond the control of the authors. As a result, when searching for specific compounds in databases such as Web of Science or PubChem, it is essential to use “wildcards” or more than one system of hyphenation in the search term to locate as many occurrences as possible of the compound of interest. In future, it would be extremely helpful if search engines were designed to accommodate such variations in hyphenation.

Column 2 in Table 1 lists examples in bold of alternative “non-prime” nomenclature, followed by common synonyms, and often reported inaccurate nomenclature in italicized square brackets which should be avoided to prevent further confusion in the literature and in on-line databases.

When dealing with compounds such as 2,3-dihydroxybenzene-1-sulfate, a phase-II metabolite of 1,2,3-trihydroxybenzene (aka pyrogallol), for convenience, rather than using the full nomenclature throughout the text, it is acceptable to use the synonym pyrogallol-1-sulfate provided the recommended nomenclature is used on its first occurrence in the article. All glucuronic acid conjugations are β -D-configured and, as only oxygen-linked glucuronides have been detected, it is not necessary to include the O-linkage in the recommended name, *i.e.*, 3-(phenyl)propanoic acid-4'-glucuronide is sufficient. However, some journal editors/reviewers insist that the O-linkage is specified and, because it is not an incorrect notation it can, if necessary, be used.

Column 3 in Table 1 quotes the Chemical Abstracts Service (CAS) Registry Number which is a numeric identifier that can contain up to 10 digits, divided by hyphens into three parts. Each number is intended to be a unique numeric identifier that can link to information about the substance it refers to but has no chemical significance *per se* (<https://www.cas.org/support/documentation/chemical-substances/>). In principle, all compounds should have a distinct number, but some do not, presumably because they have a limited occurrence and/or no commercial source. Some compounds appear to have two numbers for reasons which are unclear.

In principle, each isomer should have a distinct number, with an additional number for a racemic mixture or a preparation where the constituent isomer(s) has not been determined, as illustrated in Table 1 with CAS numbers for 5-(3',4'-dihydroxyphenyl)- γ -valerolactone (21618-92-8 (racemic), 1108192-01-3 (4*S*) and 191666-22-5 (4*R*)). This is also the case for geometric isomers, for example *trans*-cinnamic acid (140-10-3) and *cis*-cinnamic acid (102-94-3), where CAS 621-82-9 is used when geometry is not specified. However, 501-16-6 and 331-39-5 are both associated with *trans*-3',4'-dihydroxycinnamic acid (aka caffeic acid), and “racemic 2-hydroxy-2-(4'-hydroxy-3'-methoxyphenyl)acetic acid” is associated with 2394-20-9 and 55-10-7.



Table 1 Recommendations for standardizing nomenclature for dietary (poly)phenol catabolites. Structures of the listed compounds are illustrated in (Fig. 1–10)

Recommended names	Non-prime names, synonyms and incorrect nomenclature <i>[italics]</i>	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
1. Hydroxybenzenes (C ₆ -C ₆)			
1,2-Dihydroxybenzene [1.1]	Benzene-1,2-diol Catechol Pyrocatechol	120-80-9	Benzene-1,2-diol (YCIMNLLNPGFGHC-UHFFFAOYSA-N; 110.036779 g mol ⁻¹)
1,3-Dihydroxybenzene [1.2]	Brenzcatechin	108-46-3	Benzene-1,3-diol (GHMLBKRAJ-CXXBS-UHFFFAOYSA-N; 110.036779 g mol ⁻¹)
1,2,3-Trihydroxybenzene [1.3]	Benzene-1,3-diol Resorcinol	87-66-1	Benzene-1,2,3-triol (WQGWDDVZFFDIG-UHFFFAOYSA-N; 126.031694 g mol ⁻¹)
1,3,5-Trihydroxybenzene [1.4]	Pyrogallol	108-73-6	Benzene-1,3,5-triol (QCDYQQDYXPDABM-UHFFFAOYSA-N; 126.031694 g mol ⁻¹)
4-Methyl-1,2-dihydroxybenzene [1.5]	Benzene-1,3,5-triol Phloroglucinol	452-86-8	4-Methylbenzene-1,2-diol (ZBCATMYQYDCTIZ-UHFFFAOYSA-N; 124.052429 g mol ⁻¹)
2-Hydroxybenzene-1-sulfate [1.6]	4-Methylcatechol <i>[3,4-Dihydroxytoluene]</i> <i>[Catechol-2-sulfate pyrocatechol sulfate]</i>	4918-96-1	(2-Hydroxyphenyl) hydrogen sulfate (MZPWKJZDOCIALD-UHFFFAOYSA-N; 189.993594 g mol ⁻¹)
2-Hydroxybenzene-1-glucononide [1.7]	<i>[catechol-2-glucononide catechol-glucononide]</i>	28623-57-6	(2 <i>S</i> ,3 <i>S</i> ,4 <i>S</i> ,5 <i>R</i> ,6 <i>S</i>)-3,4,5-Trihydroxy-6-(2-hydroxyphenoxy)oxane-2-carboxylic acid (ICPYZEFSLTYID-GOVZDWNOSA-N; 286.068867 g mol ⁻¹)
2,3-Dihydroxybenzene-1-sulfate [1.8]	<i>[pyrogallol-3-sulfate pyrogallol-1-sulfate]</i>	—	(2,3-Dihydroxyphenyl) hydrogen sulfate (NGVLEQPKHLWZLN-UHFFFAOYSA-N; 205.988509 g mol ⁻¹)
2,3-Dihydroxybenzene-1-glucononide [1.9]	<i>[pyrogallol-3-glucononide pyrogallol-1-glucononide]</i>	—	— (302.066378 g mol ⁻¹)
2-Hydroxybenzene-1-glucononide-3-sulfate [1.10]	<i>[pyrogallol-2-sulfate-3-glucononide]</i>	—	— (382.02060 g mol ⁻¹)
2. Benzaldehydes (C ₆ -C ₁)			
4-Hydroxybenzaldehyde [2.1]	4-Formylphenol	123-08-0	4-Hydroxybenzaldehyde (RGHHSNMVTDWUBI-UHFFFAOYSA-N; 122.036779 g mol ⁻¹)
3,4-Dihydroxybenzaldehyde [2.2]	Protocatechualdehyde	139-85-5	3,4-Dihydroxybenzaldehyde (IBGBGRVKPALMCQ-UHFFFAOYSA-N; 138.031694 g mol ⁻¹)
2,4,6-Trihydroxybenzaldehyde [2.3]	Phloroglucinaldehyde	487-70-7	2,4,6-Trihydroxybenzaldehyde (BTQAJGSMXCDDAJ-UHFFFAOYSA-N; 154.026609 g mol ⁻¹)
3-Hydroxy-4-methoxybenzaldehyde [2.4]	Isovanillin	621-59-0	3-Hydroxy-4-methoxybenzaldehyde (JVTFYHCGSXJV-UHFFFAOYSA-N; 152.047344 g mol ⁻¹)
4-Hydroxy-3-methoxybenzaldehyde [2.5]	3-Methoxy-4-hydroxybenzaldehyde Vanillin	121-33-5	4-Hydroxy-3-methoxybenzaldehyde (MWOOGQJBHIAIRFG-UHFFFAOYSA-N; 152.047344 g mol ⁻¹)
3. Benzoic acids (C ₆ -C ₁)			
3-Hydroxybenzoic acid [3.1]	3-Hydroxybenzene carboxylic acid	99-06-9	3-Hydroxybenzoic acid (JFJXRHURBJZNAO-UHFFFAOYSA-N; 138.031694 g mol ⁻¹)
4-Hydroxybenzoic acid [3.2]	4-Hydroxybenzene carboxylic acid	99-96-7	4-Hydroxybenzoic acid (FJKROLUGYXJWQON-UHFFFAOYSA-N; 138.031694 g mol ⁻¹)
2,5-Dihydroxybenzoic acid [3.3]	Gallic acid	490-79-9	2,5-Dihydroxybenzoic acid (WXTMDXOMEHJXQO-UHFFFAOYSA-N; 154.026611 g mol ⁻¹)
3,4-Dihydroxybenzoic acid [3.4]	Genticic acid	99-50-3	3,4-Dihydroxybenzoic acid (YQUCSBJEUQKSH-UHFFFAOYSA-N; 154.026609 g mol ⁻¹)
3,5-Dihydroxybenzoic acid [3.5]	5-Hydroxy-salicylic acid hydroquinone carboxylic acid protocatechuic acid	99-10-5	3,5-Dihydroxybenzoic acid (UYEMGAFJZZIFP-UHFFFAOYSA-N; 154.026609 g mol ⁻¹)
3,4,5-Trihydroxybenzoic acid [3.6]	α-Resorcylic acid	149-91-7	3,4,5-Trihydroxybenzoic acid (LNTHTITQWFMDLML-UHFFFAOYSA-N; 170.021523 g mol ⁻¹)
5-Hydroxy-2-aminobenzoic acid [3.7]	Gallic acid 5-Hydroxyanthranilic acid	394-31-0	2-Amino-5-hydroxybenzoic acid





Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIkey; Monoisotopic Mass Da.)
Benzoic acid-4-glucuronide [3.8]	—	—	(HYNQTSZBTIOFKH-UHFFFAOYSA-N; 153.042593 g mol ⁻¹)
Benzoic acid-4-sulfate [3.9]	[4-Hydroxybenzoic acid-4-O-sulfate]	3233-38-3	6-(4-Carboxyphenoxy)-3,4,5-trihydroxane-2-carboxylic acid (DKNOHNCMCYDVL-UHFFFAOYSA-N; 314.063782 g mol ⁻¹)
3-Hydroxybenzoic acid-4-glucuronide [3.10]	[Protocatechuic acid-4-glucuronide]	—	4-(Sulfooxy)benzoic acid (RJTYXVYCZAUHE-UHFFFAOYSA-N; 217.988509 g mol ⁻¹)
4-Hydroxybenzoic acid-3-glucuronide [3.11]	[protocatechuic acid-3-glucuronide]	953037-17-7	6-(4-Carboxy-2-hydroxyphenoxy)-3,4,5-trihydroxane-2-carboxylic acid (NLBCVCGRBFNE-UHFFFAOYSA-N; 330.058697 g mol ⁻¹)
3-Hydroxybenzoic acid-4-sulfate [3.12]	[protocatechuic acid-4-sulfate]	38339-04-7	2-[3-Hydroxy-4-(sulfooxy)phenyl]acetic acid (CXNFDJSOANKSU-UHFFFAOYSA-N; 330.058697 g mol ⁻¹)
4-Hydroxybenzoic acid-3-sulfate [3.13]	[Protocatechuic acid-3-sulfate]	76496-11-2	(ZQJYJTSZJNFQJ-UHFFFAOYSA-N; 233.983423 g mol ⁻¹)
3-Hydroxy-4-methoxybenzoic acid [3.14]	Isovanillic acid	645-08-9	4-Hydroxy-3-(sulfooxy)benzoic acid (GSFKEOSQCKWCLH-UHFFFAOYSA-N; 233.983423 g mol ⁻¹)
4-Methoxybenzoic acid-3-glucuronide [3.15]	[Isovanillic acid-3-glucuronide]	—	3-Hydroxy-4-methoxybenzoic acid (LBKFGYZQBSGRHY-UHFFFAOYSA-N; 168.042259 g mol ⁻¹)
4-Methoxybenzoic acid-3-sulfate [3.16]	[isovanillic acid-3-sulfate]	—	6-(5-Carboxy-2-methoxyphenoxy)-3,4,5-trihydroxane-2-carboxylic acid (WREVRVHLTSMIJ-UHFFFAOYSA-N; 344.074347 g mol ⁻¹)
4-Hydroxy-3-methoxybenzoic acid [3.17]	Vanillic acid	121-34-6	4-methoxy-3-(sulfooxy)benzoic acid (VSFJSSUGMYRMP-UHFFFAOYSA-N; 247.999073 g mol ⁻¹)
3-Methoxybenzoic acid-4-glucuronide [3.18]	[Vanillic acid-4-glucuronide]	—	4-hydroxy-3-methoxybenzoic acid (WKOLLVMJNQZCI-UHFFFAOYSA-N; 168.042259 g mol ⁻¹)
3-Methoxybenzoic acid-4-sulfate [3.19]	[Vanillic acid-4-sulfate]	71235-86-4	(2S,3S,4R,5R,6S)-6-(4-Carboxy-2-methoxyphenoxy)-3,4-dihydroxy-5-methylxane-2-carboxylic acid (MBNPZIKKDDLLL-QGZCQISNSA-N; 344.074347 g mol ⁻¹)
4-Hydroxy-3,5-dimethoxybenzoic acid [3.20]	Syringic acid	530-57-4	3-Methoxy-4-sulfooxybenzoic acid (TXRKUXPAEPOCIX-UHFFFAOYSA-N; 247.999073 g mol ⁻¹)
3,4-Dimethoxybenzoic acid [3.21]	veratric acid	93-07-2	4-Hydroxy-3,5-dimethoxybenzoic acid (JMSVCTWVEWCHDZ-UHFFFAOYSA-N; 198.052823 g mol ⁻¹)
4-Cinnamic acids (C₆-C₃ unsaturated)^a cinnamic acid [4.1]	<i>trans</i> -Cinnamic acid	—	3,4-Dimethoxybenzoic acid (DAUAQNGYDSHRET-UHFFFAOYSA-N; 182.057909 g mol ⁻¹)
2'-Hydroxycinnamic acid [4.2]	<i>trans</i> -Cinnamic acid	621-82-9	(2E)-3-Phenylprop-2-enoic acid
	<i>o</i> -Coumaric acid	140-10-3	(WBYWAXJHAXSJNI-VOTSOKGWSA-N; 148.052429 g mol ⁻¹)
	<i>trans</i> -2-Coumaric acid	614-60-8	(2E)-3-(2-Hydroxyphenyl)prop-2-enoic acid
	<i>trans</i> -2-Hydroxycinnamic acid	—	(PMOWTIHVNWZYFI-AATRIKPKSA-N; 164.047344 g mol ⁻¹)
3'-Hydroxycinnamic acid [4.3]	<i>m</i> -Coumaric acid	588-30-7	(2E)-3-(3-Hydroxyphenyl)prop-2-enoic acid
	<i>3</i> -Coumaric acid	—	(KKSJDGJDHHZEWEPE-SNAWJCMRSA-N; 164.047344 g mol ⁻¹)
	<i>trans</i> -3-Coumaric acid	—	
	3-(3-Hydroxyphenyl)acrylic acid	—	
4'-Hydroxycinnamic acid [4.4]	4-hydroxycinnamic acid	501-98-4	(2E)-3-(4-Hydroxyphenyl)prop-2-enoic acid
	Coumaric acid	—	(NGSWKAQJWVESNS-ZZXXKVVIFSA-N; 164.047344 g mol ⁻¹)
	<i>p</i> -Coumaric acid	—	
	<i>trans</i> -4-Hydroxycinnamic acid	—	
	4-Hydroxyphenylacrylic acid	—	

Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIkey; Monoisotopic Mass Da.)
3',4'-Dihydroxycinnamic acid [4.5]	3,4-Dihydroxycinnamic acid Caffeic acid <i>trans</i> -Caffeic acid 3-(3,4-Dihydroxyphenyl)acrylic acid	331-39-5 501-16-6	(2E)-3-(3,4-dihydroxyphenyl)prop-2-enoic acid (QAIPRVGONGVQAS-DUXYPHPUSA-N; 180.042259 g mol ⁻¹)
Cinnamic acid-4'-glucuronide [4.6]	Cinnamic acid-4'-glucuronide	—	(2S,3S,4R,5R,6S)-6-(4-[(1E)-2-Carboxyeth-1-en-1-yl]phenoxy)-3,4,5-trihydroxyoxane-2-carboxylic acid (SOJXKPKWKYKR-LZJCFMAWSA-N; 340.079432 g mol ⁻¹) (2E)-3-(4-Hydroxy-3-methoxyphenyl)prop-2-enoic acid (KSEBMYQBYZTDHS-HWKANZROSA-N; 194.057909 g mol ⁻¹)
4'-Hydroxy-3'-methoxycinnamic acid [4.7]	[<i>p</i> -Coumaric acid-4'-glucuronide] 4-Hydroxy-3'-methoxycinnamic acid Ferulic acid <i>trans</i> -Ferulic acid	537-98-4	— 370.089996 g mol ⁻¹ (E)-3-(3-Methoxy-4-sulfoxyphenyl)prop-2-enoic acid (PZPATWACAAOHTJ-HWKANZROSA-N; 274.014723 g mol ⁻¹)
3'-Methoxycinnamic acid-4'-glucuronide [4.8]	3-(4-Hydroxy-3-methoxyphenyl)acrylic acid 3-Methoxycinnamic acid-4'-glucuronide	86321-24-6	— 370.089996 g mol ⁻¹
3'-Methoxycinnamic acid-4'-sulfate [4.9]	[<i>Ferulic acid</i> -4'-glucuronide] 3-Methoxycinnamic acid-4'-sulfate [<i>Ferulic acid</i> -4'-sulfate] <i>Ferulic acid</i> -4'-sulfate	86321-29-1	(E)-3-(3-Methoxy-4-sulfoxyphenyl)prop-2-enoic acid (PZPATWACAAOHTJ-HWKANZROSA-N; 274.014723 g mol ⁻¹)
3'-Hydroxy-4'-methoxycinnamic acid [4.10]	3-hydroxy-4'-methoxycinnamic acid Isoferulic acid Hesperetate	537-73-5	(2E)-3-(3-Hydroxy-4-methoxyphenyl)prop-2-enoic acid (QURCVMIKCOAJU-HWKANZROSA-N; 194.057909 g mol ⁻¹)
4'-Methoxycinnamic acid-3'-glucuronide [4.11]	3-(3-Hydroxy-4-methoxyphenyl)acrylic acid 4-Methoxycinnamic acid-3'-glucuronide	1065272-10-7	(2S,3S,4S,5R,6S)-6-[5-[(E)-2-carboxyethenyl]-2-methoxyphenoxy]-3,4,5-trihydroxyoxane-2-carboxylic acid (SHJZLGVIOYFHCB-MBAOVNHDSA-N; 370.089996 g mol ⁻¹)
4'-Methoxycinnamic acid-3'-sulfate [4.12]	[<i>Isoferulic acid</i> -3'-glucuronide] [<i>Isoferulic acid</i> -3'-glucuronide] 4-methoxycinnamic acid-3'-sulfate [<i>Isoferulic acid</i> -3'-sulfate] [<i>Isoferulic acid</i> -3'-sulfate]	1258842-19-1	(E)-3-(4-Methoxy-3-sulfoxyphenyl)prop-2-enoic acid (DCMKMHVTKFJMAU-HWKANZROSA-N; 274.014723 g mol ⁻¹)
5. Phenylpropanoic acids (C ₆ -C ₃) 3-Phenylpropanoic acid [5.1]	3-(Phenyl)propanoic acid [<i>Dihydrocinnamic acid</i>] <i>Hydrocinnamic acid</i>	501-52-0	3-Phenylpropanoic acid (XMIIGOLPHOKFGH-UHFFFAOYSA-N; 150.06808 g mol ⁻¹)
3-(3'-Hydroxyphenyl)propanoic acid [5.2]	3-(3-Hydroxyphenyl)propanoic acid 3-Hydroxy-dihydrocinnamic acid <i>m</i> -Hydroxy-dihydrocinnamic acid	621-54-5	3-(3-Hydroxyphenyl)propanoic acid (QVWAEZJXDYOKEH-UHFFFAOYSA-N; 166.062994 g mol ⁻¹)
3-(4'-Hydroxyphenyl)propanoic acid [5.3]	3-(4-Hydroxyphenyl)propanoic acid 3-(4-Hydroxyphenyl)propionic acid 4-Hydroxy-dihydrocinnamic acid <i>m</i> -Hydroxy-dihydrocinnamic acid <i>m</i> -Hydroxy-hydrocinnamic acid Phloretic acid	501-97-3	3-(4-Hydroxyphenyl)propanoic acid (NMHMNPHRMNGLLB-UHFFFAOYSA-N; 166.062994 g mol ⁻¹)
3-(3',4'-Dihydroxyphenyl)propanoic acid [5.4]	3-(3,4-Dihydroxyphenyl)propanoic acid 3-(3,4-Dihydroxyphenyl)propionic acid Dihydrocaffeic acid Hydrocaffeic acid 3,4-Dihydroxybenzenepropanoic acid 3,4-Dihydroxy-dihydrocinnamic acid	1078-61-1	3-(3,4-Dihydroxyphenyl)propanoic acid (DZAUWHDJUNRCTT-UHFFFAOYSA-N; 182.057909 g mol ⁻¹)
3-(3',5'-Dihydroxyphenyl)propanoic acid [5.5]	3-(3,5-Dihydroxyphenyl)propanoic acid 3-(3,5-Dihydroxyphenyl)propionic acid 3,5-Dihydroxybenzenepropanoic acid 3,5-Dihydroxy-dihydrocinnamic acid 3,5-Dihydroxy-hydrocinnamic acid	26539-01-5	3-(3,5-Dihydroxyphenyl)propanoic acid (ITPFIKQWINDGLG-UHFFFAOYSA-N; 182.057909 g mol ⁻¹)



Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIkey; Monoisotopic Mass Da.)
3-(Phenyl)propanoic acid-4'-glucuronide [5.6]	3-(Phenyl)propanoic acid-4'-glucuronide [4-Hydroxy-dihydrocinnamic acid-4'-glucuronide] <i>p</i> -Hydroxy-dihydrocinnamic acid-glucuronide]	—	— 342.095082 g mol ⁻¹
3-(3'-Methoxyphenyl)propanoic acid [5.7]	3-(3-Methoxyphenyl)propanoic acid 3-Methoxy-dihydrocinnamic acid	10516-71-9	3-(3-Methoxyphenyl)propanoic acid (BIJQ)LOZWBEGA-UHFFFAOYSA-N; 180.07864425 g mol ⁻¹)
3-(4'-Methoxyphenyl)propanoic acid [5.8]	3-(4-Methoxyphenyl)propanoic acid 4-Methoxy-dihydrocinnamic acid	1929-29-9	3-(4-Methoxyphenyl)propanoic acid (FIUFLISGGHNPSM-UHFFFAOYSA-N; 180.078644 g mol ⁻¹)
3-(3'-Hydroxy-4'-methoxyphenyl)propanoic acid [5.9]	3-(3-Hydroxy-4-methoxyphenyl)propanoic acid Dihydro-isoferulic acid	1135-15-5	3-(3-Hydroxy-4-methoxyphenyl)propanoic acid (ZVJITQTLXXGJA-UHFFFAOYSA-N; 196.073559 g mol ⁻¹)
3-(4'-Hydroxy-3'-methoxyphenyl)propanoic acid [5.10]	3-(4-Hydroxy-3-methoxyphenyl)propanoic acid Dihydroferulic acid [Hydroferulic acid]	1135-23-5	3-(4-hydroxy-3-methoxyphenyl) propanoic acid (BOLQJTPHPDZHR-UHFFFAOYSA-N; 196.073559 g mol ⁻¹)
3-(4'-Hydroxyphenyl)propanoic acid-3'-glucuronide [5.11]	3-(4-Hydroxyphenyl)propanoic acid-3'-glucuronide [Dihydrocaffeic acid-3'-glucuronide] Dihydrocaffeic acid-3'-glucuronide]	1187945-71-6	(2S,3S,4S,5R,6S)-6-[5-(2-Carboxyethyl)-2-hydroxyphenoxy]-3,4,5-trihydroxane-2-carboxylic acid
3-(3'-Hydroxyphenyl)propanoic acid-4'-glucuronide [5.11]	3-(3-Hydroxyphenyl)propanoic acid-4'-glucuronide [Dihydrocaffeic acid-4'-glucuronide] Dihydrocaffeic acid-4'-glucuronide]	—	(AELQNMHOLDHBFA-DKBO KBLXSA-N; 358.089997 g mol ⁻¹) (2S,3S,4S,5R)-6-[4-(2-CARBOXYETHYL)-2-hydroxyphenoxy]-3,4,5-trihydroxane-2-carboxylic acid
3-(3'-Hydroxyphenyl)propanoic acid-4'-sulfate [5.13]	3-(3-Hydroxyphenyl)propionic acid-4'-sulfate [Dihydrocaffeic acid-4'-sulfate] Dihydrocaffeic acid-4'-sulfate]	—	(DUTJMLCURMYWCW-HXMBFPRCSA-N; 358.089997 g mol ⁻¹) 3-(3-Hydroxy-4-sulfooxyphenyl)propanoic acid (WEPNMLSXEBATJK-UHFFFAOYSA-N; 262.014723 g mol ⁻¹)
3-(4'-Hydroxyphenyl)propanoic acid-3'-sulfate [5.14]	3-(4-Hydroxyphenyl)propionic acid-3'-sulfate [Dihydrocaffeic acid-3'-sulfate] Dihydrocaffeic acid-3'-sulfate]	1187945-70-5	3-[4-Hydroxy-3-(sulfooxy)phenyl]propanoic acid (MIMULQQHBAZGER-UHFFFAOYSA-N; 262.014724 g mol ⁻¹)
3-(3'-Methoxyphenyl)propanoic acid-4'-glucuronide [5.15]	3-(3-Methoxyphenyl)propionic acid-4'-glucuronide [Dihydroferulic acid-4'-glucuronide] Dihydroferulic acid-4'-glucuronide]	86321-28-0	(2S,3S,4S,5R,6S)-6-[4-(2-carboxyethyl)-2-methoxyphenoxy]-3,4,5-trihydroxane-2-carboxylic acid (KYERCTIKYSSKPA-JHZJYKESA-N; 372.105646 g mol ⁻¹)
3-(3'-Methoxyphenyl)propanoic acid-4'-sulfate [5.16]	3-(3-Methoxyphenyl)propionic acid-4'-sulfate [Dihydroferulic acid-4'-sulfate] Dihydroferulic acid-4'-sulfate]	86321-33-7	3-(3-Methoxy-4-sulfooxyphenyl)propanoic acid (UMCDDDPBPQWQP-UHFFFAOYSA-N; 276.030374 g mol ⁻¹)
3-(4'-Methoxyphenyl)propanoic acid-3'-glucuronide [5.17]	3-(4-Methoxyphenyl)propanoic acid-3'-glucuronide [Dihydroferulic acid-3'-glucuronide] Dihydroferulic acid-3'-glucuronide]	1187945-72-7	(2S,3S,4S,5R,6S)-6-[5-(2-Carboxyethyl)-2-methoxyphenoxy]-3,4,5-trihydroxane-2-carboxylic acid



Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
3-(4'-Methoxyphenyl)propanoic acid-3'-sulfate [5.18]	3-(4-Methoxyphenyl)propionic acid-3-Glucuronide [Dihydro-isoferrulic acid-3-glucuronide]	1258842-21-5	(SYLIYWIQUHQPCY-UHFFFAOYSA-N; 372.105647 g mol ⁻¹) 3-(4-Methoxy-3-sulfooxyphenyl)propanoic acid (QZIVZVFIROFZCV-UHFFFAOYSA-N; 276.030374 g mol ⁻¹)
6. Hydroxy-3-(phenyl)propanoic acids (C ₆ -C ₃) (R/S)-3-Hydroxy-3-(phenyl)propanoic acid [6.1]	3-(Phenyl)hydroxypropionic acid	3480-87-3	3-Hydroxy-3-phenylpropanoic acid (AYOLELPCNDVZKZ-UHFFFAOYSA-N; 166.062994 g mol ⁻¹)
(R/S)-3-Hydroxy-3-(3'-hydroxyphenyl)propanoic acid [6.2]	3-Hydroxy-3-(3-hydroxyphenyl)propanoic acid 3-(3-Hydroxyphenyl)-3-hydroxypropionic acid 3-Hydroxy-3-(3'-hydroxyphenyl)propionic acid β, m-Dihydroxyphenylpropionic acid β, meta-dihydroxyphenylpropionic acid 3-(3-Hydroxyphenyl)hydracrylic acid 3-(3'-Hydroxyphenyl)hydracrylic acid m-Hydroxyphenylhydracrylic acid	3247-75-4	3-Hydroxy-3-(3-hydroxyphenyl)propanoic acid (KHTAGVZYUZYMF-UHFFFAOYSA-N; 182.057909 g mol ⁻¹)
(R/S)-2-Hydroxy-3-(3'-hydroxy-4'-methoxyphenyl)propanoic acid [6.3]	3-Hydroxy-3-(3-hydroxy-4-methoxyphenyl)propionic acid 3-(3-Hydroxy-4-methoxyphenyl)-3-hydroxypropanoic acid 3-(3-Hydroxy-4-methoxyphenyl)-3-hydroxypropionic acid	28030-22-0	3-Hydroxy-3-(3-hydroxy-4-methoxyphenyl)propanoic acid (JEXBTMWMYGBBHO-UHFFFAOYSA-N; 212.068473 g mol ⁻¹)
(R/S)-2-Hydroxy-3-(phenyl)propanoic acid [6.4]	2-Hydroxy-3-(phenyl)propionic acid 3-(Phenyl)-2-hydroxypropionic acid 3-(Phenyl)lactic acid	828-01-3	2-Hydroxy-3-phenylpropionic acid; (VOXWSYKYCBWHO-UHFFFAOYSA-N; 166.062994 g mol ⁻¹)
(R/S)-2-Hydroxy-3-(4'-hydroxyphenyl)propanoic acid [6.5]	2-Hydroxy-3-(4-hydroxyphenyl)propanoic acid 3-(4-Hydroxyphenyl)-2-hydroxypropanoic acid 2-Hydroxy-3-(4-hydroxyphenyl)propionic acid 3-(4-Hydroxyphenyl)-2-hydroxypropionic acid 3-(4-Hydroxyphenyl)lactic acid	306-23-0	2-Hydroxy-3-(4-hydroxyphenyl)propanoic acid (JVGVDSSUAVXRDY-UHFFFAOYSA-N; 182.057909 g mol ⁻¹)
(R/S)-2-Hydroxy-3-(3',4'-dihydroxyphenyl)propanoic acid [6.6]	3-(3,4-Dihydroxyphenyl)-2-hydroxypropanoic acid 2-Hydroxy-3-(3',4'-dihydroxyphenyl)propionic acid 3-(3,4-Dihydroxyphenyl)-2-hydroxypropionic acid 3-(3',4'-Dihydroxyphenyl)lactic acid 3-(3,4-Dihydroxyphenyl)lactic acid Danshensu Salviamic acid	23028-17-3	3-(3,4-Dihydroxyphenyl)-2-hydroxypropanoic acid (PAFLSMZLRSPALU-UHFFFAOYSA-N; 198.052823 g mol ⁻¹)
7. Phenylacetic acids (C ₆ -C ₂) phenylacetic acid [7.1]	Phenylethanoic acid 2-Phenylethanoate	103-82-2	2-Phenylacetic acid (WLJYXDMOQOGPHL-UHFFFAOYSA-N; 136.052429 g mol ⁻¹)



This article is licensed under a Creative Commons Attribution 3.0 Unported Licence.

Open Access Article. Published on 23 April 2025. Downloaded on 4/30/2025 10:12:08 AM.

Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature <i>[italics]</i>	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
3'-Hydroxyphenylacetic acid [7.2]	3-Hydroxyphenylacetic acid	621-37-4	2-(3-Hydroxyphenyl)acetic acid (FVMDYYGIDFPZAX-UHFFFAOYSA-N; 152.047344 g mol ⁻¹)
3'-Methoxyphenylacetic acid [7.3]	3-Methoxyphenylacetic acid	1798-09-0	2-(3-Methoxyphenyl)acetic acid (LEGPZHPSIPPYIO-UHFFFAOYSA-N; 166.062994 g mol ⁻¹)
4'-Hydroxyphenylacetic acid [7.4]	3-Methoxyphenylethanoic acid 4-Hydroxyphenylacetic acid	156-38-7	2-(4-Hydroxyphenyl)acetic acid (XQXPVVBIMDBYFF-UHFFFAOYSA-N; 152.047344 g mol ⁻¹)
3',4'-Dihydroxyphenylacetic acid [7.5]	4-Hydroxyphenylethanoic acid 3,4-Dihydroxyphenylacetic acid Homoprotocatechuic acid	102-32-9	2-(3,4-Dihydroxyphenyl)acetic acid (CFZDZCDUFSOFZ-UHFFFAOYSA-N; 168.042259 g mol ⁻¹)
4'-Hydroxy-3'-methoxyphenylacetic acid [7.6]	DOPAC 4-Hydroxy-3-methoxyphenylacetic acid 4-Hydroxy-3-methoxyphenylethanoic acid Homovanillic acid	306-08-1	2-(4-Hydroxy-3-methoxyphenyl)acetic acid (QRMZSPESDQBLIX-UHFFFAOYSA-N; 182.057909 g mol ⁻¹)
8. Hippuric acids (phenyl)acetic acids (C₆-C₂) (R/S)-2-Hydroxy-2-(3'-hydroxyphenyl)acetic acid [8.1]	2-Hydroxy-2-(3-hydroxyphenyl)acetic acid (3-Hydroxyphenyl)-2-hydroxyacetic acid	17119-15-2	2-Hydroxy-2-(3-hydroxyphenyl)acetic acid (OLSDAJRAVOVKLG-UHFFFAOYSA-N; 168.042259 g mol ⁻¹)
(R/S)-2-Hydroxy-2-(4'-hydroxyphenyl)acetic acid [8.2]	2-Hydroxy-2-(3-hydroxyphenyl)ethanoic acid (3-Hydroxyphenyl)-2-hydroxyethanoic acid 2-Hydroxy-2-(4'-hydroxyphenyl)acetic acid (4-Hydroxyphenyl)-2-hydroxyacetic acid 2-Hydroxy-2-(4'-hydroxyphenyl)ethanoic acid (4-Hydroxyphenyl)-2-hydroxyethanoic acid 4'-Hydroxymandelic acid 4-Hydroxymandelic acid 4-Hydroxy-D-mandelic acid 4-Hydroxy-L-mandelic acid	1198-84-1	2-Hydroxy-2-(4-hydroxyphenyl)acetic acid (YXHKYRQLYQUIH-UHFFFAOYSA-N; 168.042259 g mol ⁻¹)
(R/S)-2-hydroxy-2-(4'-hydroxy-3'-methoxyphenyl)acetic acid [8.3]	2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)acetic acid (4-Hydroxy-3-methoxyphenyl)-2-hydroxyacetic acid 2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)ethanoic acid (4-Hydroxy-3-methoxyphenyl)-2-hydroxyethanoic acid 4'-Hydroxymandelic acid 4-Hydroxy-D-mandelic acid 4-Hydroxy-L-mandelic acid	2394-20-9 55-10-7	2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)acetic acid (GGCQWMIAPPEHNQ-UHFFFAOYSA-N; 198.052823 g mol ⁻¹)
9. Hippuric acids (C₆-C₁-N<) and other amino acid conjugates hippuric acid [9.1]	2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)acetic acid (4-Hydroxy-3-methoxyphenyl)-2-hydroxyacetic acid 2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)ethanoic acid (4-Hydroxy-3-methoxyphenyl)-2-hydroxyethanoic acid 4'-Hydroxy-3'-methoxymandelic acid 4-Hydroxy-3-methoxymandelic acid 3-Methoxy-4-hydroxymandelic acid 4-Hydroxy-3-methoxy-L-mandelic acid Vanillylmandelic acid	495-69-2 487-54-7	2-Benzamidoacetic acid (QJAFMBKCNZACKA-UHFFFAOYSA-N; 179.058243 g mol ⁻¹) 2-[(2-Hydroxybenzoyl)amino]acetic acid (ONJSZLXSECQROL-UHFFFAOYSA-N; 195.053158 g mol ⁻¹)
2'-Hydroxyhippuric acid [9.2]	2-Hydroxyhippuric acid 2-(2-Hydroxybenzamido)acetic acid N-(2-Hydroxybenzoyl)glycine Salicylic acid	1637-75-8	2-[(3-hydroxybenzoyl)amino]acetic acid (XDQFWMYJRHEW-UHFFFAOYSA-N; 195.053158 g mol ⁻¹)
3'-Hydroxyhippuric acid [9.3]	3-Hydroxyhippuric acid 2-(3-Hydroxybenzamido)acetic acid N-(3-Hydroxybenzoyl)glycine	2482-25-9	2-[(4-Hydroxybenzoyl)amino]acetic acid (ZMHLUFWWWWPBITU-UHFFFAOYSA-N; 195.053158 g mol ⁻¹)
4'-Hydroxyhippuric acid [9.4]	4-Hydroxyhippuric acid 2-(4-Hydroxybenzamido)acetic acid N-(4-Hydroxybenzoyl)glycine		



Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
4-Methoxyhippuric acid [9.5]	4-Methoxyhippuric acid 2-(4-Ethoxybenzamido)acetic acid	13214-64-7	2-[(4-Methoxybenzoyl)amino]acetic acid (SIEIOUWSTGWJGE-UHFFFAOYSA-N; 209.068808 g mol ⁻¹)
(R/S)-2-Hydroxyhippuric acid [9.6]	<i>N</i> -(4-Methoxybenzoyl)glycine α -Hydroxyhippuric acid α -Hydroxybenzoyl-glycine [2-Hydroxyhippuric acid]	16555-77-4	2-Hydroxy-2-(phenylformamido)acetic acid (GCWCVCCEIQXUQU-UHFFFAOYSA-N; 195.053158 g mol ⁻¹)
4'-Hydroxy-3'-methoxyhippuric acid [9.7]	4'-Hydroxy-3'-methoxybenzoyl-glycine vanilloyl-glycine	1212-04-0	2-[(4-Hydroxy-3-methoxybenzoyl)amino]acetic acid (LOODYTDRRLQNH-UHFFFAOYSA-N; 225.063722 g mol ⁻¹)
3'-Hydroxy-4'-methoxyhippuric acid [9.8]	3'-Hydroxy-4'-methoxybenzoyl-glycine Isovanilloyl-glycine	22005-43-2	2-[(3-Hydroxy-4-methoxybenzoyl)amino]acetic acid (HOZJFFMWTLPBGS-UHFFFAOYSA-N; 225.063722 g mol ⁻¹)
Phenylacetyl-glycine [9.9]	Phenacetic acid [Phenylacetic acid]	500-98-1	2-[(2-Phenylacetyl)amino]acetic acid (UTYVDVMYQPLQB-UHFFFAOYSA-N; 193.073893 g mol ⁻¹)
4'-Hydroxyphenylacetyl-glycine [9.10]	4-Hydroxyphenylacetyl-glycine 2-[2-(4-Hydroxyphenyl)acetamido]acetic acid	28116-23-6	2-[[2-(4-Hydroxyphenyl)acetyl]amino]acetic acid (CPDWYIPKSSNNM-UHFFFAOYSA-N; 209.068808 g mol ⁻¹)
(S)-Phenylacetyl-glutamine [9.11]	(2S)-5-Amino-5-oxo-2-(2-phenylacetamido)pentanoic acid Phenylacetyl-L-glutamine	28047-15-6	(2S)-5-Amino-5-oxo-2-(2-phenylacetamido)pentanoic acid (JFLIEFSWGNOPJ-JTQLQJEISA-N; 264.111007 g mol ⁻¹)
(S)-4'-Hydroxyphenylacetyl-glutamine [9.12]	4-Hydroxyphenylacetyl-glutamine 2-[2-(4-Hydroxyphenyl)acetamido]pentanedioic acid	—	2-[[2-(4-Hydroxyphenyl)acetyl]amino]pentanedioic acid (CYRKYXZJUIBBJX-UHFFFAOYSA-N; 281.089937 g mol ⁻¹)
Cinnamoyl-glycine [9.13]	2-Cinnamamidoacetic acid	16534-24-0	2-[[E]-3-Phenylprop-2-enyl]amino]acetic acid (YAADMLWHGMUGQL-VOTSOKGWSA-N; 205.073893 g mol ⁻¹)
4'-Hydroxycinnamoyl-glycine [9.14]	4-Hydroxycinnamoyl-glycine <i>p</i> -coumaroyl-glycine	—	2-[[E]-3-(4-Hydroxyphenyl)prop-2-enyl]amino]acetic acid (NZSACLXQEHBCNF-ZZXXKVVVISA-N; 221.068807 g mol ⁻¹)
4'-Hydroxy-3'-methoxycinnamoyl-glycine [9.15]	4-Hydroxy-3'-methoxycinnamoyl-glycine	1220-05-9	2-[[E]-3-(4-Hydroxy-3-methoxyphenyl)prop-2-enoyl]amino]acetic acid (CLGNQAIRBLDHHN-HWKANZROSA-N; 251.079373 g mol ⁻¹)
3-(Phenyl)propanoyl-glycine [9.16]	Feruloyl-glycine <i>N</i> -(3-Methoxycoumaroyl)-glycine 2-(3-Phenylpropanoylamino)acetic acid <i>N</i> -(3-Phenylpropanoyl)glycine 2-(3-Phenylpropanoylamino)acetic acid 2-(3-Phenylpropanoyl)glycine 2-(3-Phenylpropanoylamino)acetic acid 5-(3,4-Dihydroxyphenyl)- γ -valerolactone δ -(3,4-Dihydroxyphenyl)- γ -valerolactone	56613-60-6 21618-92-8 1108192-01-3 (4S) 191666-22-5 (4R)	2-(3-Phenylpropanoylamino)acetic acid (YEIQSAXUPKPPEN-UHFFFAOYSA-N; 207.089543 g mol ⁻¹) 5-[(3,4-Dihydroxyphenyl)methyl]oxolan-2-one (ZNXWXWTPQHVLMTQT-UHFFFAOYSA-N; 208.073559 g mol ⁻¹)
(R/S)-5-(4'-Hydroxyphenyl)-γ-valerolactone-3'-glucuronide [10.2]	5-(dihydroxyphenyl)- γ -valerolactone 5-(dihydroxyphenyl)-valerolactone [M6]	—	3,4,5-Trihydroxy-6-[2-hydroxy-5-[(5-oxoxolan-2-yl)methyl]phenoxy]oxane-2-carboxylic acid (UVGDTVGPBRLMQY-UHFFFAOYSA-N; 384.105647 g mol ⁻¹)
(R/S)-5-(3'-Hydroxyphenyl)-γ-valerolactone-4'-glucuronide [10.3]	[M6-glucuronide 5-(3',4'-dihydroxyphenyl)- γ -valerolactone-3'-glucuronide]	—	3,4,5-Trihydroxy-6-[2-hydroxy-4-[(5-oxoxolan-2-yl)methyl]phenoxy]oxane-2-carboxylic acid (OTBJYBQGMPIKIK-UHFFFAOYSA-N; 384.105647 g mol ⁻¹)
(R/S)-5-(4'-Hydroxyphenyl)-γ-valerolactone-3'-sulfate [10.4]	[M6-glucuronide-5-(3',4'-dihydroxyphenyl)- γ -valerolactone-4'-glucuronide] 5-(4-Hydroxyphenyl)- γ -valerolactone-3-sulfate	—	[2-Hydroxy-5-[(5-oxoxolan-2-yl)methyl]phenyl]hydrogen sulfate



Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
(R/S)-5-(3'-Hydroxyphenyl)- γ -valerolactone-4'-sulfate [10.5]	[M6-sulfate 5-(3',4'-dihydroxyphenyl)- γ -valerolactone-3'-sulfate] 5-(3-Hydroxyphenyl)- γ -valerolactone-4-sulfate	—	(YAXFVDUJDAQPTJ-UHFFFAOYSA-N; 288.030374 g mol ⁻¹) [2-Hydroxy-4-[(5-oxoxolan-2-yl)methyl]phenyl] hydrogen sulfate (WAXYAOJFDCCESK-UHFFFAOYSA-N; 288.030374 g mol ⁻¹)
(R/S)-5-(3'-Methoxyphenyl)- γ -valerolactone-4'-glucuronide [10.6]	[M6-sulfate 5-(3',4'-dihydroxyphenyl)- γ -valerolactone-4'-sulfate] 5-(3-Methoxyphenyl)- γ -valerolactone-4-glucuronide	—	3,4,5-Trihydroxy-6-[2-methoxy-4-[(5-oxoxolan-2-yl)methyl]phenoxy]oxane-2-carboxylic acid (NGMVEYPQYAGEI-UHFFFAOYSA-N; 398.121297 g mol ⁻¹)
(R/S)-5-(3'-Methoxyphenyl)- γ -valerolactone-4'-sulfate [10.7]	[methyl-M6-glucuronide 5-(4'-hydroxy-3'-methoxyphenyl)- γ -valerolactone-4'-glucuronide 5-(3',4'-dihydroxyphenyl)- γ -valerolactone-3'-methoxy-4'-glucuronide] 5-(3-Methoxyphenyl)- γ -valerolactone-4-sulfate	—	[2-Methoxy-4-[(5-oxoxolan-2-yl)methyl]phenyl] hydrogen sulfate (FYRRHCSCZYSADR-UHFFFAOYSA-N; 302.046024 g mol ⁻¹)
(R/S)-5-(4'-Methoxyphenyl)- γ -valerolactone-3'-glucuronide [10.8]	[methyl-M6-sulfate 5-(4'-hydroxy-3'-methoxyphenyl)- γ -valerolactone-4'-sulfate 5-(3',4'-dihydroxyphenyl)- γ -valerolactone-3'-methoxy-4'-sulfate] 5-(4-Methoxyphenyl)- γ -valerolactone-3-glucuronide	—	—
(R/S)-5-(Phenyl)- γ -valerolactone-3'-sulfate-4'-glucuronide [10.9]	[5-(3',4'-Dihydroxyphenyl)- γ -valerolactone-4'-methoxy-3'-glucuronide] 5-(Phenyl)- γ -valerolactone-3-sulfate-4-glucuronide	—	398.121297 g mol ⁻¹ —
11. 4-Hydroxy-5-(phenyl)valeric acids (All compounds may occur as R- and S-enantiomers)	[M6-sulfate-glucuronide 5-(3',4'-dihydroxyphenyl)- γ -valerolactone-3'-sulfate-4'-glucuronide] 5-(Phenyl)- γ -valerolactone-3-sulfate-4-glucuronide	—	464.062461 g mol ⁻¹ —
(R/S)-4-hydroxy-5-(3',4'-dihydroxyphenyl)valeric acid [11.1]	4-Hydroxy-5-(3,4-dihydroxyphenyl)valeric acid	—	5-(3,4-Dihydroxyphenyl)-4-hydroxypentanoic acid (JDBYFCLHVYVXCX-UHFFFAOYSA-N; 226.084124 g mol ⁻¹)
(R/S)-4-Hydroxy-5-(4'-hydroxyphenyl)valeric acid-3'-glucuronide [11.2]	5-(3,4-Dihydroxyphenyl)-4-hydroxyvaleric acid 4-Hydroxy-5-(3,4-dihydroxyphenyl)pentanoic acid 5-(3,4-Dihydroxyphenyl)-4-hydroxypentanoic acid [5-(3,4-Dihydroxyphenyl)- γ -hydroxyvaleric acid 5-(3,4-dihydroxyphenyl)- γ -hydroxypentanoic acid] 4-Hydroxy-5-(4-hydroxyphenyl)valeric acid-3-glucuronide	—	6-[5-(4-Carboxy-2-hydroxybutyl)-2-hydroxyphenoxy]-3,4,5-Trihydroxyoxane-2-carboxylic acid (BKJQCPRDWDNBIN-UHFFFAOYSA-N; 402.116212 g mol ⁻¹)
(R/S)-4-Hydroxy-5-(3'-hydroxyphenyl)valeric acid-4'-glucuronide [11.3]	4-hydroxy-5-(4-hydroxyphenyl)pentanoic acid-3-glucuronide 5-(4-hydroxyphenyl)-4-hydroxypentanoic acid-3-glucuronide [5-(3,4-dihydroxyphenyl)-4-hydroxyvaleric acid-3-glucuronide] 4-Hydroxy-5-(3-hydroxyphenyl)valeric acid-4-glucuronide	—	6-[4-(4-Carboxy-2-hydroxybutyl)-2-hydroxyphenoxy]-3,4,5-Trihydroxyoxane-2-carboxylic acid





Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
(<i>R/S</i>)-4-Hydroxy-5-(4'-hydroxyphenyl)valeric acid-3'-sulfate [11.4]	4-Hydroxy-5-(3-hydroxyphenyl)pentanoic acid-4-glucuronide 5-(4-Hydroxyphenyl)-4-hydroxyvaleric acid-4-glucuronide [5-(3',4'-Dihydroxyphenyl)-4-hydroxyvaleric acid-4'-glucuronide]	—	(LLKUARGHINZMSRT-UHFFFAOYSA-N; 402.116212 g mol ⁻¹)
(<i>R/S</i>)-4-Hydroxy-5-(3'-hydroxyphenyl)valeric acid-4'-sulfate [11.5]	4-Hydroxy-5-(4-hydroxyphenyl)valeric acid-3-sulfate 5-(4-Hydroxyphenyl)-4-hydroxyvaleric acid-3-sulfate 4-Hydroxy-5-(4-hydroxyphenyl)pentanoic acid-3-sulfate 5-(4-Hydroxyphenyl)-4-hydroxypentanoic acid-3-sulfate [5-(3',4'-Dihydroxyphenyl)-4-hydroxyvaleric acid-3'-sulfate]	—	4-Hydroxy-5-(4-hydroxy-3-sulfoxyphenyl)pentanoic acid (HROSNTXKMPHTSL-UHFFFAOYSA-N; 306.040939 g mol ⁻¹)
(<i>R/S</i>)-4-Hydroxy-5-(3'-hydroxyphenyl)valeric acid-4'-sulfate [11.6]	5-(3-Hydroxyphenyl)-4-hydroxyvaleric acid-4-sulfate 4-Hydroxy-5-(3-hydroxyphenyl)pentanoic acid-4-sulfate 5-(3-Hydroxyphenyl)-4-hydroxypentanoic acid-4-sulfate [5-(3',4'-Dihydroxyphenyl)-4-hydroxyvaleric acid-4'-sulfate]	—	306.040938 g mol ⁻¹
(<i>R/S</i>)-4-Hydroxy-5-(3'-methoxyphenyl)valeric acid-4'-glucuronide [11.7]	4-Hydroxy-5-(3-methoxyphenyl)valeric acid-4-glucuronide 5-(3-Methoxyphenyl)-4-hydroxyvaleric acid-4-glucuronide 4-Hydroxy-5-(3-methoxyphenyl)pentanoic acid-4-glucuronide 5-(3'-Methoxyphenyl)-4-hydroxypentanoic acid-4-glucuronide [4-Hydroxy-5-(3',4'-dihydroxyphenyl)-valeric acid-3'-methoxy-4'-glucuronide]	—	6-[4-(4-Carboxy-2-hydroxybutyl)-2-methoxyphenoxy]- 3,4,5-Trihydroxyoxane-2-carboxylic acid (WOBDOUCWWPCYBL-UHFFFAOYSA-N; 416.131862 g mol ⁻¹)
(<i>R/S</i>)-4-Hydroxy-5-(3'-methoxyphenyl)valeric acid-4'-sulfate [11.8]	5-(3-Methoxyphenyl)-4-hydroxyvaleric acid-4-sulfate 4-Hydroxy-5-(3-methoxyphenyl)pentanoic acid-4-sulfate 5-(3-Methoxyphenyl)-4-hydroxypentanoic acid-4-sulfate [4-Hydroxy-5-(3,4-dihydroxyphenyl)-valeric acid-3-methoxy-4-sulfate]	—	4-Hydroxy-5-[3-methoxy-4-(sulfoxy)phenyl]pentanoic acid (GUEAZORXKSCMA-UHFFFAOYSA-N; 320.056589 g mol ⁻¹)
(<i>R/S</i>)-4-Hydroxy-5-(4'-methoxyphenyl)valeric acid-3'-sulfate [11.8]	4-Hydroxy-5-(4-methoxyphenyl)valeric acid-3-sulfate	—	—

Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
(R/S)-5-(3,4'-Dihydroxyphenyl)valeric acid-4-sulfate [11.9]	5-(4-Methoxyphenyl)-4-hydroxyvaleric acid-3-sulfate 4-Hydroxy-5-(4'-methoxyphenyl)pentanoic acid-3'-sulfate 5-(4-Methoxyphenyl)-4-hydroxypentanoic acid-3-sulfate [4-hydroxy-5-(3,4'-dihydroxyphenyl)-valeric acid-3-methoxy-4-sulfate] 4-Sulfoxy-5-(3,4'-dihydroxyphenyl)valeric acid	—	5-(3,4'-Dihydroxyphenyl)-4-sulfoxy-pentanoic acid (NBKHZVHBUVNGQF-UHFFFAOYSA-N; 306.040939 g mol ⁻¹)
(R/S)-5-(4'-Hydroxy-3'-methoxyphenyl)valeric acid-4-sulfate [11.10]	5-(3,4'-Dihydroxyphenyl)-4-sulfoxyvaleric acid 4-Sulfoxy-5-(3,4'-dihydroxyphenyl)pentanoic acid 5-(3,4'-Dihydroxyphenyl)-4-sulfoxy-pentanoic acid [5-(3'-Hydroxyphenyl)-4-sulphoxyvaleric acid] 4-Sulfoxy-5-(4'-hydroxy-3'-methoxyphenyl)valeric acid	—	5-(4-Hydroxy-3-methoxyphenyl)-4-(sulfoxy)pentanoic acid (JQISKEAFUDWLCF-UHFFFAOYSA-N; 320.056589 g mol ⁻¹)
12. 5-Phenylvaleric acids (C ₆ -C ₅) 5-(3',5'-Dihydroxyphenyl)valeric acid [12.1]	5-(4-Hydroxy-3-methoxyphenyl)-4-sulfoxy-pentanoic acid 4-Sulfoxy-5-(4-hydroxy-3-methoxyphenyl)pentanoic acid 5-(4-Hydroxy-3-methoxyphenyl)-4-sulfoxy-pentanoic acid [4-Hydroxy-5-(3,4'-dihydroxyphenyl)-valeric acid-3-methoxy-4-sulfate]	74356-41-5	5-(3,5'-Dihydroxyphenyl)pentanoic acid (QHXNJIMVPAFCPR-UHFFFAOYSA-N; 210.089203 g mol ⁻¹)
5-(3',4',5'-Trihydroxyphenyl)valeric acid [12.2]	5-(3,4,5-Trihydroxyphenyl)valeric acid 5-(3,4,5-Trihydroxyphenyl)pentanoic acid [5-(Trihydroxyphenyl)valeric acid]	—	5-(3,4,5-Trihydroxyphenyl)pentanoic acid (MASHJSDLKLZLA-UHFFFAOYSA-N; 226.084124 g mol ⁻¹)
13. Urolithins (6H-dibenzo[b,d]pyran-6-ones) 3-Hydroxy-urolithin [13.1]	urolithin B	1139-83-9	3-Hydroxy-6H-benzo[c]chromen-6-one (WXUQMTRHPNOXBV-UHFFFAOYSA-N; 212.047344 g mol ⁻¹)
Urolithin-3-glucuronide [13.2]	Urolithin B-3-glucuronide [Urolithin B-glucuronide]	823806-74-2	(2S,3S,4S,5R,6S)-3,4,5-trihydroxy-6-({[6-oxo-6H-benzo[c]chromen-3-yl]oxy}oxane-2-carboxylic acid
Urolithin-3-sulfate [13.3]	Urolithin B-3-sulfate [Urolithin B-sulfate]	—	(MHBWCULXQBVPQT-KSPMYQCISA-N; 388.079432 g mol ⁻¹) 6-Oxobenzol[c]chromen-3-yl) hydrogen sulfate (LRRVKQFQHEMSA-UHFFFAOYSA-N; 292.004159 g mol ⁻¹)
3,8-Dihydroxy-urolithin [13.4]	Urolithin A	1143-70-0	3,8-Dihydroxy-6H-benzo[c]chromen-6-one (RIUPLDUFCXCHM-UHFFFAOYSA-N; 228.042259 g mol ⁻¹)
3,9-Dihydroxy-urolithin [13.5]	Isourolithin A	174023-48-4	3,9-Dihydroxy-6H-benzo[c]chromen-6-one (WDGSXHQNUPEHA-UHFFFAOYSA-N; 228.042259 g mol ⁻¹)
8-Hydroxy-urolithin-3-glucuronide [13.6]	Urolithin A-3-glucuronide [urolithin A-glucuronide 3,8-dihydroxy-urolithin 3-glucuronide]	—	3,4,5-Trihydroxy-6-(8-hydroxy-6-oxo-6H-benzo[c]chromen-3-yl)oxane-2-carboxylic acid (KCBXNRJGUDTJQS-UHFFFAOYSA-N; 404.074347 g mol ⁻¹)
3-Hydroxy-urolithin-8-glucuronide [13.7]	urolithin A-8-glucuronide	1365982-52-0	(2S,3S,4S,5R,6S)-3,4,5-trihydroxy-6-(3-hydroxy-6-oxobenzol[c]chromen-8-yl)oxane-2-carboxylic acid



Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature [italics]	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
8-Hydroxy-uroolithin-3-sulfate [13.8]	[Urolithin A-glucuronide 3,8-dihydroxy-uroolithin 8-glucuronide] Urolithin A-3-sulfate	—	(QMPHAAAMUHRNZSL-KSPMYQCISA-N; 404.074347 g mol ⁻¹)
3-Hydroxy-uroolithin-8-sulfate [13.9]	[Urolithin A-sulfate 3,8-dihydroxy-uroolithin 3-sulfate] Urolithin A-8-sulfate	—	(8-Hydroxy-6-oxobenzol[c]chromen-3-yl) hydrogen sulfate (WMPNMQVWVZFTJQ-UHFFFAOYSA-N; 307.999074 g mol ⁻¹) (3-Hydroxy-6-oxo-6H-benzol[c]chromen-8-yl)oxidanesulfonic acid (307.999074 g mol ⁻¹)
9-Hydroxy-uroolithin-3-glucuronide [13.10]	[Urolithin A-sulfate 3,8-dihydroxy-uroolithin 8-sulfate] Isourolithin A-3-glucuronide	—	—
3-Hydroxy-uroolithin-9-glucuronide [13.11]	[Isourolithin A-glucuronide 3,9-dihydroxy-uroolithin-3-glucuronide] isourolithin A-9-glucuronide	1268248-75-4	404.074347 g mol ⁻¹
Urolithin-3,8-diglucuronide [13.12]	[Isourolithin A-glucuronide, 3,9-dihydroxy-uroolithin 9-glucuronide] Urolithin A-3,8-diglucuronide	—	404.074347 g mol ⁻¹
Urolithin-3-sulfate-8-glucuronide [13.13]	[Urolithin A-diglucuronide 3,8-dihydroxy-uroolithin-diglucuronide] [Urolithin A-sulfate-glucuronide 3,8-dihydroxy-uroolithin 3-sulfate-8-glucuronide]	—	(2S,3S,4S,5R,6S)-6-[3-[(2S,3R,4S,5S,6S)-6-carboxy-3,4,5-trihydroxyoxan-2-yl]oxy-6-oxobenzol[c]chromen-8-yl]oxy-3,4,5-trihydroxyoxane-2-carboxylic acid (SXM)SEFKPOZNAT-ILJCXFEASA-N; 580.106435 g mol ⁻¹)
3,8,9-Trihydroxy-uroolithin [13.14]	Urolithin C [Hydroxyuroolithin A trihydroxyuroolithin] Urolithin M7	165393-06-6	— 484.03116 g mol ⁻¹
3,8,10-Trihydroxy-uroolithin [13.15]	Urolithin M7	531512-26-2	3,8,9-Trihydroxy-6H-benzol[c]chromen-6-one (HHXMEZVPEJFAJ-UHFFFAOYSA-N; 244.037173 g mol ⁻¹)
8,9-Dihydroxy-uroolithin-3-glucuronide [13.16]	Urolithin C-3-glucuronide	1268248-76-5	3,8,10-Trihydroxy-6H-benzol[c]chromen-6-one (AKJHSPPAOUUDFT-UHFFFAOYSA-N; 244.037173 g mol ⁻¹)
3,4,8,9-Tetrahydroxy-uroolithin [13.17]	[Urolithin C-glucuronide] Urolithin D	131086-98-1	(2S,3S,4S,5R,6S)-6-[(8,9-Dihydroxy-6-oxo-6H-benzol[c]chromen-3-yl)oxy]-3,4,5-trihydroxyoxane-2-carboxylic acid (DDAQYQCCOWZGDO-KSPMYQCISA-N; 420.069261 g mol ⁻¹)
3,8,9,10-Tetrahydroxy-uroolithin [13.18]	Urolithin M6	1006683-97-1	3,4,8,9-Tetrahydroxy-6H-benzol[c]chromen-6-one (NEZDQSKPNRYAW-UHFFFAOYSA-N; 260.032088 g mol ⁻¹) (LGXFTZDSEIQMMP-UHFFFAOYSA-N; 260.032088 g mol ⁻¹)
14. Stilbenoids^c dihydroresveratrol [14.1]	Dihydro-resveratrol 5-(4-Hydroxyphenethyl)benzene-1,3-diol 3,4',5-Trihydroxybibenzyl	58436-28-5	5-[2-(4-Hydroxyphenyl)ethyl]benzene-1,3-diol (HITJFUSPLYBJPE-UHFFFAOYSA-N; 230.094294 g mol ⁻¹)
lunularin [14.2]	Dihydro-3,4',5-trihydroxybibenzyl 3-(4-Hydroxyphenethyl)phenol 3,4'-Dihydroxydihydrostilbene	37116-80-6	3-[2-(4-Hydroxyphenyl)ethyl]phenol (ILEYXPCRQKRNIJ-UHFFFAOYSA-N; 214.099380 g mol ⁻¹)
3,4'-Dihydroxy-trans-stilbene [14.3]	3,4'-Ethylenebisphenol 3,4'-Dihydroxybibenzyl	62574-04-3	3-[2-(4-Hydroxyphenyl)ethyl]phenol (UFGKEGYNRJGO-UHFFFAOYSA-N; 212.083730 g mol ⁻¹)
4-Hydroxydibenzyl [14.4]	3,4'-Dihydroxystilbene Stilbene-3,4'-diol 4-Phenylethylphenol p-Phenylethylphenol	6335-83-7	4-(2-Phenylethyl)phenol (YTLSTADDHJMUMW-UHFFFAOYSA-N; 198.104465 g mol ⁻¹)
15. Anthranilic acid (2-aminobenzoic acid) derivatives Dihydroavenanthramide D [15.1]	2-[[3-(4-Hydroxyphenyl)-1-oxopropyl]amino]benzoic acid 2-(3-(4-Hydroxyphenyl)propanamido)benzoic acid Hydroxyphenyl propamidobenzoic acid	697235-49-7	2-[3-(4-Hydroxyphenyl)propanoylamino]benzoic acid (DLFOKZQWYFNKCL-UHFFFAOYSA-N; 285.100108 g mol ⁻¹)
2-Acetamido-5-hydroxybenzoic acid [15.2]	2-(Acetylamino)-5-hydroxybenzoic acid	1882-76-4	2-Acetamido-5-hydroxybenzoic acid



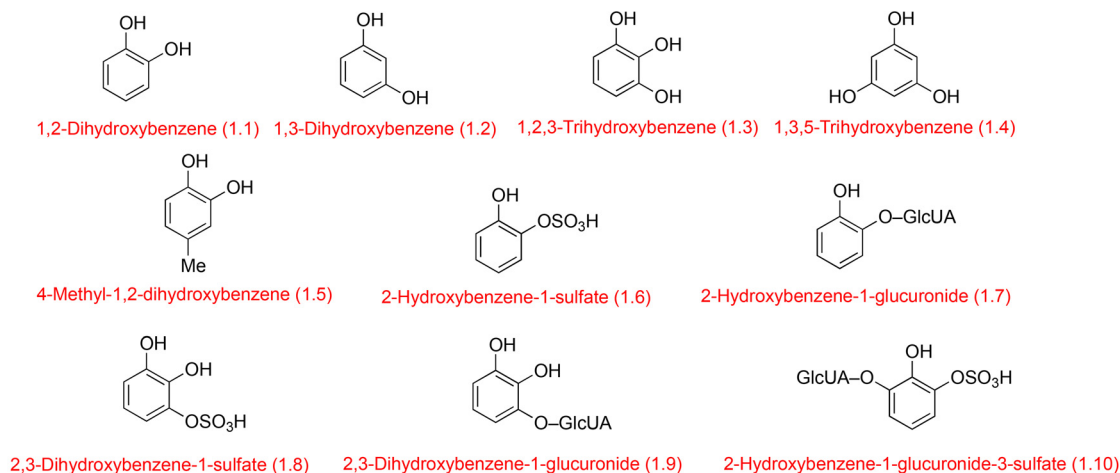
Table 1 (Contd.)

Recommended names	Non-prime names, synonyms and incorrect nomenclature <i>[italics]</i>	CAS	IUPAC (InChIKey; Monoisotopic Mass Da.)
5-Hydroxy-2-aminobenzoic acid [15.3]	2-Amino-5-hydroxybenzoic acid 5-Hydroxyanthranilic acid	394-31-0	(DXKBECZFNWKKJC-UHFFFAOYSA-N; 195.053157 g mol ⁻¹) 2-Amino-5-hydroxybenzoic acid (HYNQTSZBTIOFKH-UHFFFAOYSA-N; 153.042593 g mol ⁻¹)
16. Phenylethanols (C ₆ -C ₂) 2-(4'-Hydroxyphenyl)ethanol [16.1]	2-(4-Hydroxyphenyl)ethanol 4-Hydroxyphenyl alcohol 4-Hydroxyphenethyl alcohol Tyrosol <i>p</i> -HPEA	501-94-0	4-(2-Hydroxyethyl)phenol (YCCILVSKPBXXVIP-UHFFFAOYSA-N; 138.06808 g mol ⁻¹)
2-(3'-4'-Dihydroxyphenyl)ethanol [16.2]	2-(3,4-Hydroxyphenyl)ethanol 3'-Hydroxytyrosol 3,4-Dihydroxyphenylethanol 3,4-Dihydroxyphenethyl alcohol DOPET Homoprotocatechuy alcohol	10597-60-1	4-(2-Hydroxyethyl)-1,2-benzenediol (UUBCHWRXWPFPH-UHFFFAOYSA-N; 154.062994 g mol ⁻¹)
2-(Phenyl)ethanol-4'-glucuronide [16.3]	2-(Phenyl)ethanol-4'-glucuronide	28116-28-1	(2S,3S,4S,5R,6S)-3,4,5-Trihydroxy-6-[4-(2-hydroxyethyl)]phenoxyloxane-2-carboxylic acid (HEIHXCGBRTPYOMU-BYNIDDDHOSA-N; 314.100167 g mol ⁻¹)
2-(Phenyl)ethanol-4'-sulfate [16.4]	Tyrosol-4'-glucuronide Tyrosol-4'-glucuronide 2-(Phenyl)ethanol-4'-sulfate Tyrosol-4'-sulfate Tyrosol-4'-sulfate	—	[4-(2-Hydroxyethyl)phenyl] hydrogen sulfate (VCRXMIQBQGCAAL-UHFFFAOYSA-N; 218.024895 g mol ⁻¹)
2-(4'-Hydroxyphenyl)ethanol-3'-glucuronide [16.5]	2-(4-Hydroxyphenyl)ethanol-3'-glucuronide	425408-50-0	(2S,3S,4S,5R,6S)-3,4,5-Trihydroxy-6-[2-hydroxy-5-(2-hydroxyethyl)]phenoxyloxane-2-carboxylic acid (CPHMFZSEPDNJAZ-BYNIDDDHOSA-N; 330.095082 g mol ⁻¹)
2-(3'-Hydroxyphenyl)ethanol-4'-glucuronide [16.6]	Hydroxytyrosol-3'-glucuronide Hydroxytyrosol-3'-glucuronide 2-(3-Hydroxyphenyl)ethanol-4'-glucuronide	—	(2S,3S,4S,5R,6S)-3,4,5-Trihydroxy-6-[2-hydroxy-4-(2-hydroxyethyl)]phenoxyloxane-2-carboxylic acid (JMDNSUMWVYKARS-BYNIDDDHOSA-N; 330.095082 g mol ⁻¹)
2-(4'-Hydroxyphenyl)ethanol-3'-sulfate [16.7]	Hydroxytyrosol-4'-glucuronide Hydroxytyrosol-4'-glucuronide 2-(4-Hydroxyphenyl)ethanol-3'-sulfate Hydroxytyrosol-3'-sulfate Hydroxytyrosol-3'-sulfate	844639-92-5	[2-hydroxy-5-(2-hydroxyethyl)phenyl] hydrogen sulfate (BZTHVCCNFBAISK-UHFFFAOYSA-N; 234.019809 g mol ⁻¹)
2-(3'-Hydroxyphenyl)ethanol-4'-sulfate [16.8]	Hydroxytyrosol-3'-sulfate Hydroxytyrosol-4'-sulfate Hydroxytyrosol-4'-sulfate	425408-51-1	[2-Hydroxy-4-(2-hydroxyethyl)phenyl] hydrogen sulfate (VNPXBLBTQURCHO-UHFFFAOYSA-N; 234.019809 g mol ⁻¹)

^a Cinnamic acids and stilbenes have *cis* (*Z*) and *trans* (*E*) geometric isomers. In nature the *trans* isomer is more common. ^b In rare instances compounds appear to have two different InChIKey formulas in online databases which are generally associated with different CAS or registry numbers and possibly reflect uncharacterized isomeric configuration. For example: 5-(3',4'-dihydroxyphenyl)- γ -valerolactone or IUPAC 5-[(3,4-dihydroxyphenyl)methyl]oxolan-2-one is listed as having two different CAS/RN, 21618-92-8 and 191666-22-5, two different standard 27 character InChIKey ZNXXWTPQHVLMOQT-UHFFFAOYSA-N and ZNXXWTPQHVLMOQT-MRXPVSSYSA-N and sharing the same SMILES formula C1CC(=O)OC1CC2=CC(=C(C=C2)O)O. In this case each structure has a unique Full InChIKey (using the SHA-256 algorithm) InChI = 1S/C11H12O4/c12-9-3-1-7(6-10(9)13)5-8-2-4-11(14)15-8/h1,3,6,8,12-13H/2,4-5H2, and 1S/C11H12O4/c12-9-3-1-7(6-10(9)13)5-8-2-4-11(14)15-8/h1,3,6,8,12-13H/2,4-5H2, and 1S/C11H12O4/c12-9-3-1-7(6-10(9)13)5-8-2-4-11(14)15-8/h1,3,6,8,12-13H/2,4-5H2/h1,3,6,8,12-13H/2,4-5H2, which should be used in cases where two isomers require distinction. Similarly, 5-(3'-hydroxyphenyl)- γ -valerolactone-4'-glucuronide or IUPAC 3,4,5-trihydroxy-6-(2-hydroxy-4-[(5-oxoxolan-2-yl)methyl]phenoxy)loxane-2-carboxylic acid, has two different standard InChIKey: OTBJYBQGMPIK-GHPVWUPISA-N, and different SMILES formula and full InChIKey.



Hydroxybenzenes



Benzaldehydes

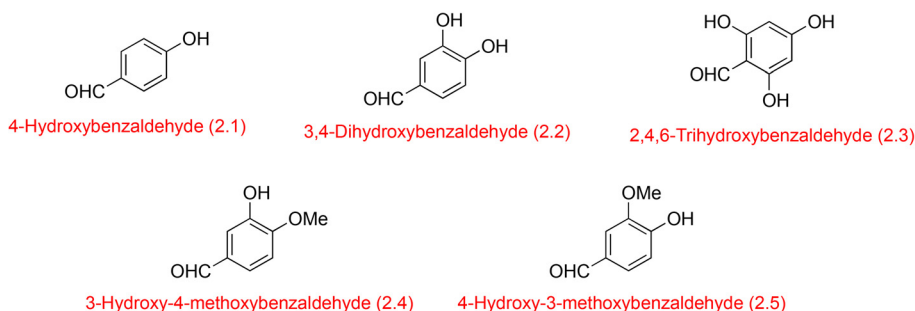


Fig. 1 Structures of hydroxybenzenes (1.1–1.10) and benzaldehydes (2.1–2.5). GlcUA – β -D-glucuronide.

The International Union of Pure and Applied Chemistry (IUPAC) is described as the world authority on chemical nomenclature and terminology (<https://iupac.org/who-we-are/>). This nomenclature is found in column 4 together with the InChIKey, which is the IUPAC standard textual unique chemical identifier, along with the isotopic mass in daltons (Table 1).

New compounds in Table 1 since Kay *et al.*²⁹ include the resveratrol catabolites dihydroresveratrol (14.1), lunularin (14.2), 3,4'-dihydroxy-*trans*-stilbene (14.3) and 4-hydroxydibenzyl (14.4)^{30,31} (see Fig. 9). For these stilbenes we recommend adoption of the IUPAC numbering system which uses numbers with primes for the acetate-derived, *meta*-hydroxylated A-ring. Other additions include catabolites of anthranilic acid (15.1–15.3)^{32,33} (Fig. 9).

The structures of 4'-hydroxyphenylethanol (tyrosol) and 3',4'-dihydroxyphenylethanol (3'-hydroxytyrosol) (16.1–16.2) are illustrated in Fig. 10. These phenylethanols are hydrolysis products of oleuropein and presumably of the glycosides which occur in bottle gourd. It has been reported that hydrolysis of oleuropein may occur at gastric pH, independent of the gut microbiota.^{34,35} Phase-II metabolites of the phenylethanols (16.3–16.8) are also illustrated in Fig. 10.

3. Complications associated with isomers when dealing with microbial and endogenous phenolics and the parent compounds from which they are derived

Regioisomers have the same molecular formula but differ in the sequence in which the atoms are connected. Stereoisomers are not superimposable isomers. They have the same molecular formula and same connectivity but differ in how their atoms are oriented in three-dimensional space. Stereoisomers can be divided into enantiomers and diastereomers. Enantiomers, also known as optical isomers, are non-superimposable mirror images. Diastereomers are stereoisomers which are not mirror images and include, in addition to chiral derivatives, achiral molecules such as symmetrical *meso*-isomers and geometric isomers due to double bond configurations (*cis* and *trans* or *Z* and *E* for the cinnamic acids).

Enantiomers (optical isomers) have the same “scalar” physical properties but opposite “pseudo-scalar” ones such as specific rotation. Regioisomers and diastereomers can have dis-



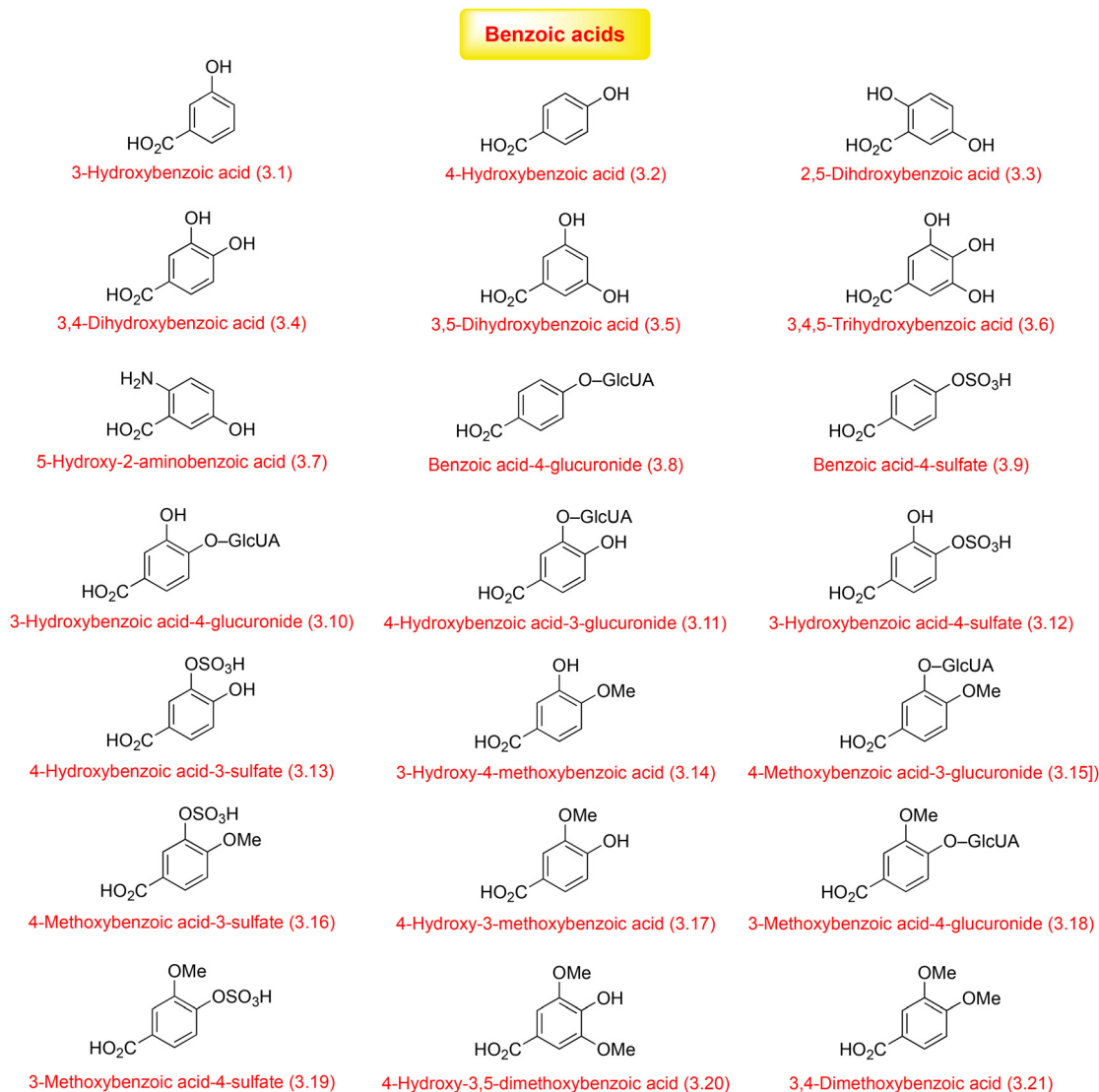


Fig. 2 Structures of benzoic acids (3.1–3.21). GlcUA – β -D-glucuronide.

tinct physical and chemical properties, often including different molar absorbance values as well as a different intensity of ionization in mass spectrometry, which potentially can make quantitative estimates of one isomer inaccurate if quantified with the alternative isomer. Regioisomers sometimes have different fragmentation patterns which facilitate identification. Proteins, receptors, and enzymes are chiral biomolecules that discriminate regioisomers and stereoisomers, which can therefore differ in their metabolism and physiological effects.

Enantiomers share the same connectivity but specular 3D-arrangement of atoms: namely, they present opposite “absolute” configuration. Such configuration, usually defined with one or more specific descriptors, such as *R*- or *S*-, which are assigned to every stereogenic element present in the molecule, does not vary with respect to how we rotate the molecule in a plane. Using a γ -valerolactone metabolite as an example, Fig. 11 illustrates how perspective influences the appearance

of an enantiomer’s 3D structure presented in two dimensions, in this case whether the lactone oxygen projects out from the plane of the page or projects into the plane, and whether the aryl ring is on the right or on the left. Note that the position of the aryl ring does not alter the chirality at C4.

When dealing with pure, chiral bioactive substances, the issue of defining the stereoisomeric composition of the sample is crucial: indeed, two stereoisomers, being diastereomer or enantiomers will also interact differently with another chiral, enantiopure (bio)molecule such as a protein or a sugar, enabling different, sometimes even opposite, (bio)activities. As an example, (*R*)-ibuprofen (see Fig. 12) does not inhibit prostaglandin synthesis but is metabolized to a CoA-thioester, whereas (*S*)-ibuprofen does not form a CoA-thioester and is an inhibitor of prostaglandin synthesis in humans, with significant enantiomeric differences in human pharmacodynamics.^{36,37} Also, (*S*)-ibuprofen is *ca.* 2.5-times more



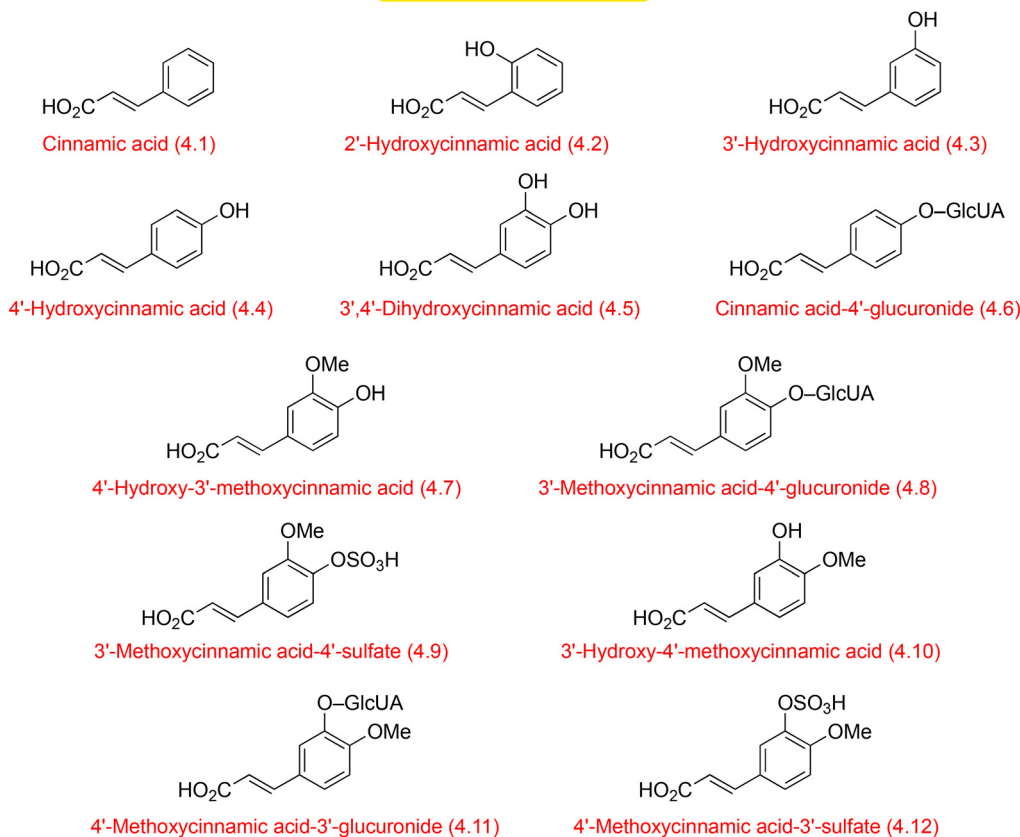
trans-Cinnamic acids

Fig. 3 Structures of *trans*-cinnamic acids (4.1–4.12). Cinnamic acids may have *cis* (*Z*) or *trans* (*E*) geometries. In nature the *trans* isomers, which are illustrated, are the more common. GlcUA – β -D-glucuronide.

efficiently absorbed through healthy skin and is a more efficient inhibitor of the human organic anion transporter (*hOAT1*): 2.84 mM for (*S*)-Ibuprofen for 50% inhibition compared with 6.14 mM for (*R*)-Ibuprofen.³⁸ The (*S*)-isomer is also a slightly more potent inhibitor of lactic acid uptake by the mono-carboxylic acid transporter,³⁹ and potentially also benzoic acid, 2-hydroxy-, 3-hydroxy and 4-hydroxybenzoic acid. There are also differences in the metabolism of the enantiomers of (*R/S*)-2-hydroxy-2-(phenyl)acetic acid in primary rat hepatocytes. The main metabolite of the (*2S*)-enantiomer is phenyl-glyoxylic acid, whereas the (*2R*)-enantiomer yields predominantly benzoic acid and hippuric acid (Fig. 12).⁴⁰

We have located only two publications on the physiological effects of pure phenyl- γ -valerolactone enantiomers.^{41,42} Both reports used a numbering system different to that recommended by Kay *et al.*²⁹ as the heterocyclic lactone oxygen was designated 1 and the centre of chirality was designated 5. For consistency with our recommendations for the various C₆–C₅ metabolites, this has been adjusted in the account which follows with the center of chirality designated 4 (see Fig. 7).

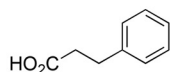
(*S*)-5-(3',4'-Dihydroxyphenyl)- γ -valerolactone at 25 $\mu\text{mol L}^{-1}$ is slightly more active *in vitro* than its (*4R*)-isomer in pro-

tecting rat intestinal epithelial IEC-6 cells against LPS-induced inflammation by inhibiting NF- κ B activation.⁴¹ In a second investigation, 1 $\mu\text{mol L}^{-1}$ of the (*4S*)-enantiomer reduced UV-induced MMP-1 protein expression in human dermal fibroblasts by *ca.* 50%, relative to control, whereas the (*4R*)-enantiomer was ineffective.⁴² The relative amounts of the (*4R*)- and (*4S*)-enantiomers in the human circulation are not known, but as (+)-catechin and (–)-epicatechin are commonly consumed together, it is likely that both enantiomers will be present.

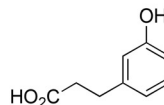
Mandelic, phenyl-lactic, phenyl-hydracrylic, 4-hydroxy-5-phenylvaleric acids and associated γ -valerolactones are frequently reported metabolites, but apart from the examples given above, the metabolism and physiological effects of their enantiomers have not been compared, and such investigations are required. Many papers present metabolite structures where the 'wiggly' bond is not used to designate a centre of chirality when the chirality is unknown, and this is doubtless one factor which has led to reduced awareness of such isomers and a failure to investigate the associated phenomena. We recommend marking the centre of chirality with an asterisk for racemates or when the absolute configuration is unknown.



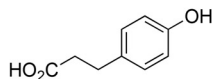
Phenylpropanoic acids



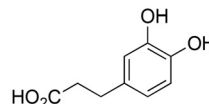
3-(Phenyl)propanoic acid (5.1)



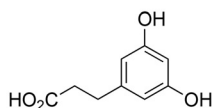
3-(3'-Hydroxyphenyl)propanoic acid (5.2)



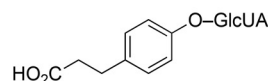
3-(4'-Hydroxyphenyl)propanoic acid (5.3)



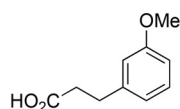
3-(3',4'-Dihydroxyphenyl)propanoic acid (5.4)



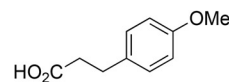
3-(3',5'-Dihydroxyphenyl)propanoic acid (5.5)



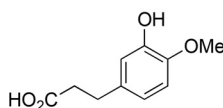
3-(Phenyl)propanoic acid-4'-glucuronide (5.6)



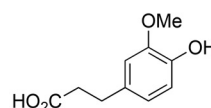
3-(3'-Methoxyphenyl)propanoic acid (5.7)



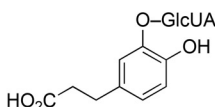
3-(4'-Methoxyphenyl)propanoic acid (5.8)



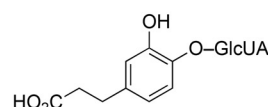
3-(3'-Hydroxy-4'-methoxyphenyl)propanoic acid (5.9)



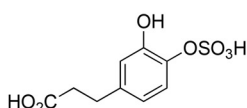
3-(4'-Hydroxy-3'-methoxyphenyl)propanoic acid (5.10)



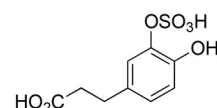
3-(4'-Hydroxyphenyl)propanoic acid-3'-glucuronide (5.11)



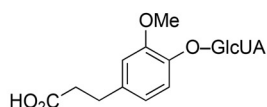
3-(3'-Hydroxyphenyl)propanoic acid-4'-glucuronide (5.12)



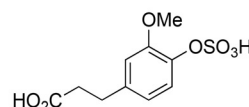
3-(3'-Hydroxyphenyl)propanoic acid-4'-sulfate (5.13)



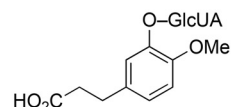
3-(4'-Hydroxyphenyl)propanoic acid-3'-sulfate (5.14)



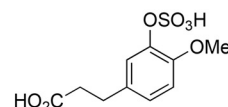
3-(3'-Methoxyphenyl)propanoic acid-4'-glucuronide (5.15)



3-(3'-Methoxyphenyl)propanoic acid-4'-sulfate (5.16)



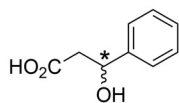
3-(4'-Methoxyphenyl)propanoic acid-3'-glucuronide (5.17)



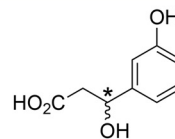
3-(4'-Methoxyphenyl)propanoic acid-3'-sulfate (5.18)

Fig. 4 Structures of (phenyl)propanoic acids (5.1–5.18). GlcUA – β -D-glucuronide.

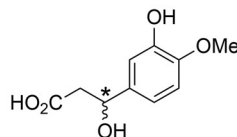
3-Hydroxy-3-(phenyl)propanoic acids [(Phenyl)hydracrylic acids]



(*R/S*)-3-Hydroxy-3-(phenyl)propanoic acid [6.1]

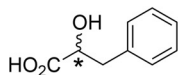


(*R/S*)-3-Hydroxy-3-(3'-hydroxyphenyl)propanoic acid [6.2]

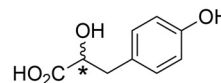


(*R/S*)-3-Hydroxy-3-(3'-hydroxy-4'-methoxyphenyl)propanoic acid [6.3]

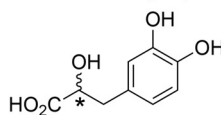
2-Hydroxy-3-(phenyl)propanoic acids [(Phenyl)lactic acids]



(*R/S*)-2-Hydroxy-3-(phenyl)propanoic acid [6.4]

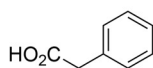


(*R/S*)-2-Hydroxy-3-(4'-hydroxyphenyl)propanoic acid [6.5]

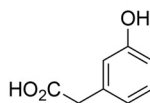


(*R/S*)-2-Hydroxy-3-(3',4'-dihydroxyphenyl)propanoic acid [6.6]

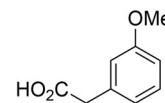
Phenylacetic acids



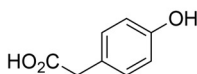
Phenylacetic acid [7.1]



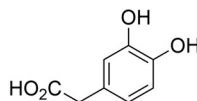
3'-Hydroxyphenylacetic acid [7.2]



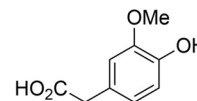
3'-Methoxyphenylacetic acid [7.3]



4'-Hydroxyphenylacetic acid [7.4]

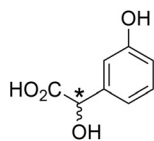


3',4'-Dihydroxyphenylacetic acid [7.5]

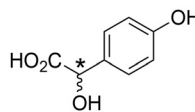


4'-Hydroxy-3'-methoxyphenylacetic acid [7.6]

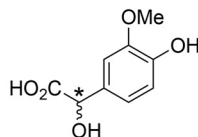
2-Hydroxy-2-(phenyl)acetic acids (Mandelic acids)



(*R/S*)-2-Hydroxy-(3'-hydroxyphenyl)acetic acid [8.1]



(*R/S*)-2-Hydroxy-(4'-hydroxyphenyl)acetic acid [8.2]



(*R/S*)-2-Hydroxy-(4'-hydroxy-3'-methoxyphenyl)acetic acid [8.3]

Fig. 5 Structures of 3-hydroxy-(phenyl)propanoic acids (6.1–6.3), 2-hydroxy-3-(phenyl)propanoic acids (6.4–6.6), phenylacetic acids (7.1–7.6) and 2-hydroxy-2-(phenyl)acetic acids (8.1–8.3). The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*).



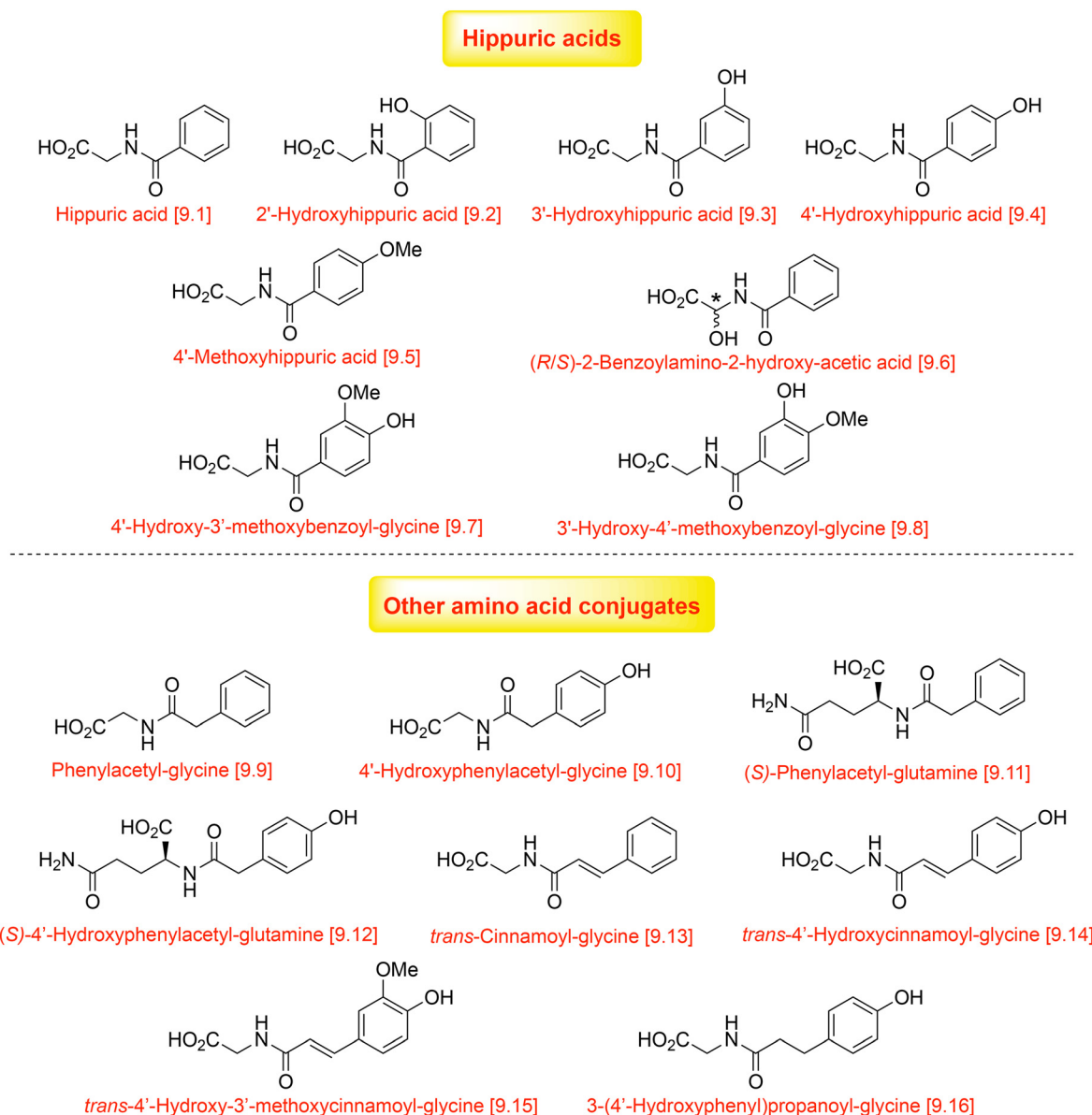


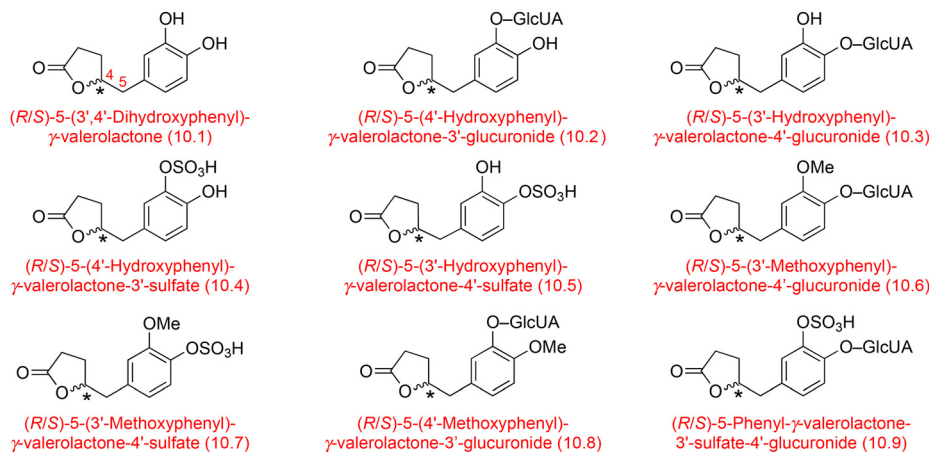
Fig. 6 Structures of hippuric acids (9.1–9.8) and other amino acid conjugates (9.9–9.16). The asterisk “*” represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*).

The limited number of commercially available pure enantiomers (see Table 2) and the impossibility of resolving the enantiomers on achiral reversed phase column packings (*i.e.* embedding stationary phases lacking any chiral discriminating groups) exacerbate the problem. Even if a standard of defined stereochemistry is believed to have been used, it does not automatically follow that the sample contains that specific enantiomer as it could be a mixture or merely the alternative enantiomer. To solve this problem, chiral column packings are available, but they are not well suited to the analysis of samples also containing fifty or more achiral metabolites as tedious fraction collection and reanalysis are required to determine if both enantiomers are present. However, in the absence of stan-

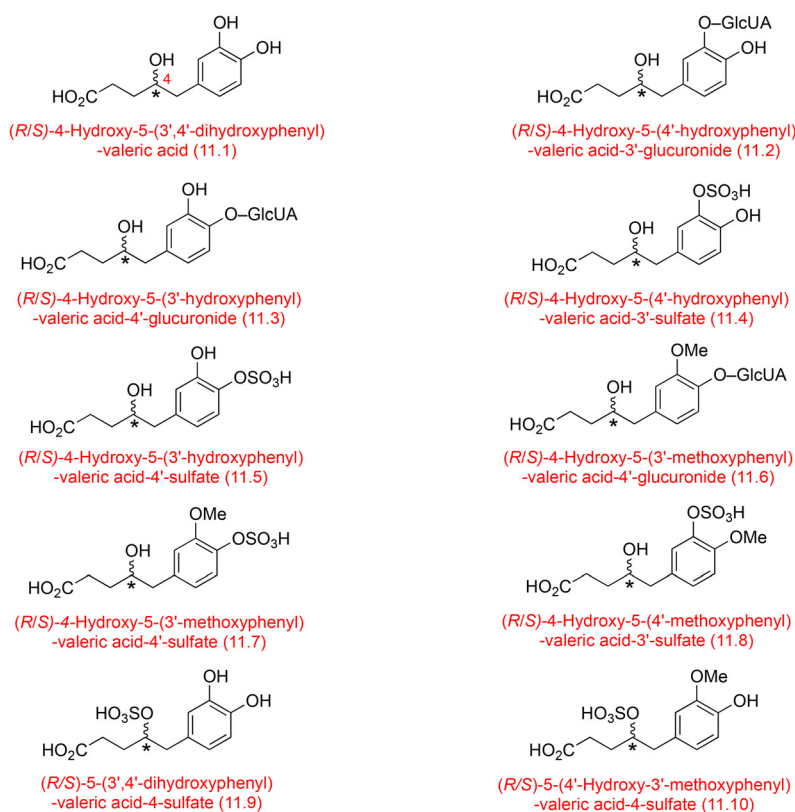
dards, further investigation is required to fully assign any enantiomer(s) that are detected. Interestingly, when such enantiomers are phase-II conjugated with a chiral, enantiopure β -D-glucuronic acid moiety, as is the norm at least for the C₆–C₅ enantiomers,⁴³ and possibly for (*R/S*)-3-hydroxy-3-(3'-hydroxyphenyl)propanoic acid,⁴⁴ the two enantiomers become diastereomers, and as such, they could potentially be resolved on an achiral column packing although we are not aware of any reports of the presence of both isomers and possibly these have been overlooked.

Of note, the resolution of both diastereomers of (*R/S*)-3-hydroxy-3-(3',4'-dihydroxycinnamoyl)quinic acid on an achiral, reversed phase column has been noted: here, the quinic acid



5-(Phenyl)- γ -valerolactones

4-Hydroxy-5-(phenyl)valeric acids



5-(Phenyl)valeric acids



Fig. 7 Structures of 5-(phenyl)- γ -valerolactones (10.1–10.9), 4-hydroxy-5-(phenyl)valeric acids (11.1–11.10) and 5-(phenyl)valeric acids (12.1–12.2). GlcUA – β -D-glucuronide. The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*).



Urolithins

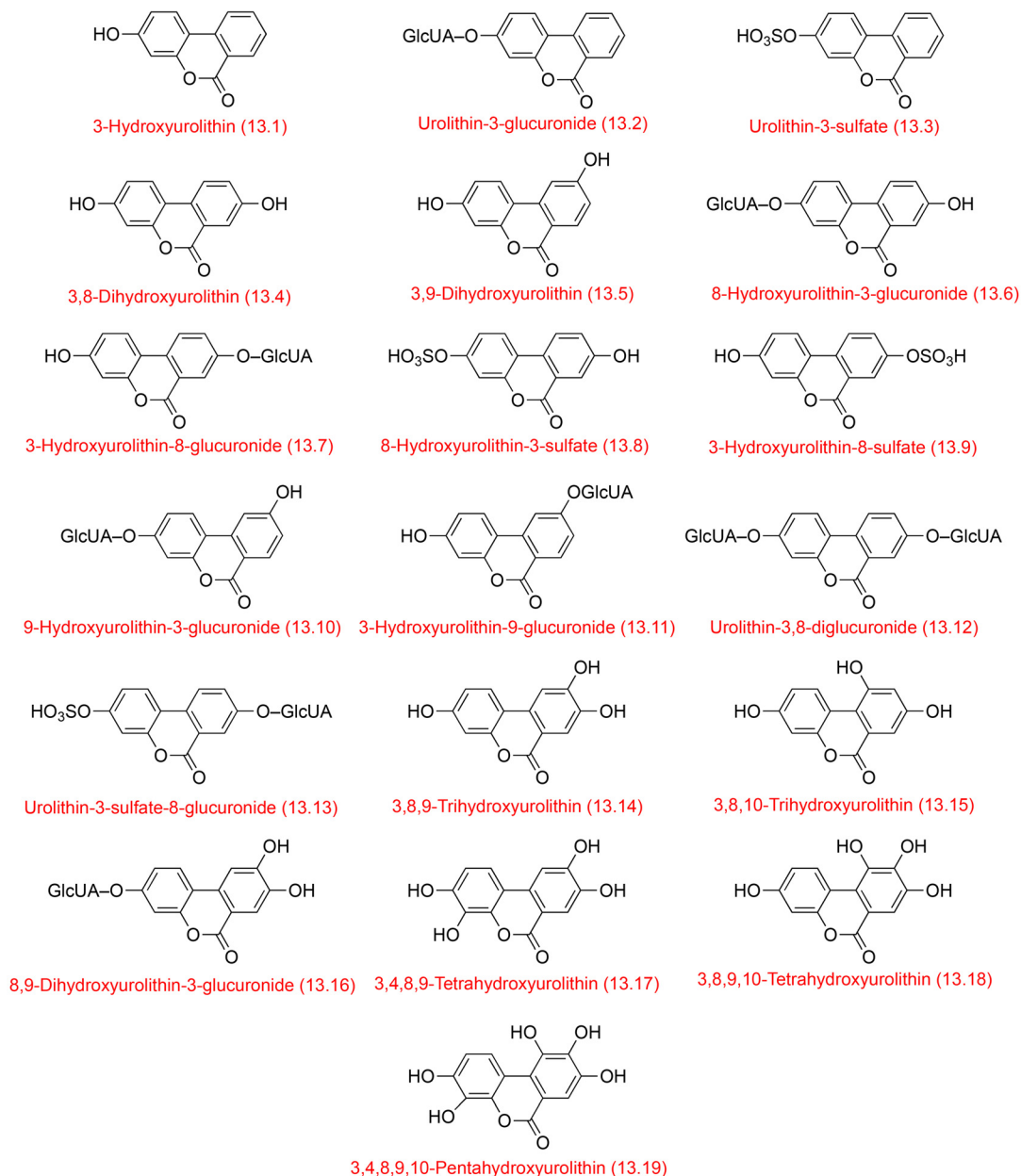
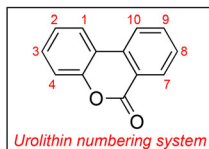


Fig. 8 Structures of urolithins (13.1–13.19). GlcUA – β -D-glucuronide.

moiety effectively acted as a covalent chiral resolving agent, enabling the formal separation (identification) of both enantiomers of 3-hydroxy-3-(3',4'-dihydroxyphenyl)cinnamic acid.⁴⁵ This indicates that a similar resolution of the C₆–C₅-glucuronide conjugates is feasible.

3.1. C₆–C₅ phenyl- γ -valerolactones and phenyl-valeric acids

As stated above, few pure enantiomers are available, and vendors' catalogues can be confusing and may sometimes be incorrect. For example, the Shanghai Ichemical



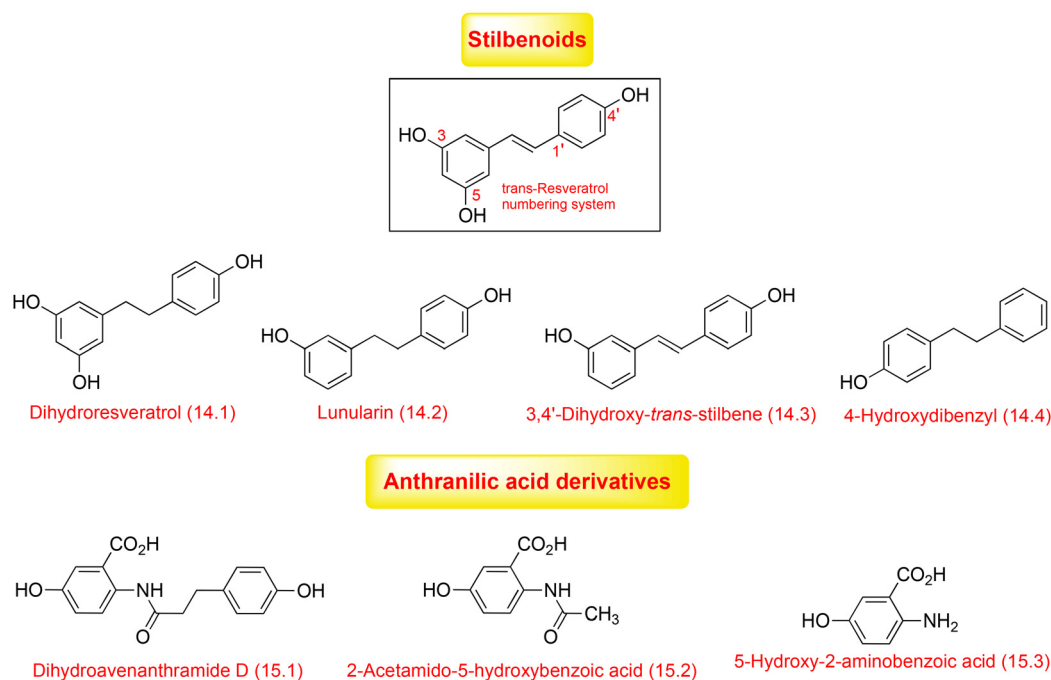


Fig. 9 Structures of stilbenoids [14.1–14.4] and anthranilic acid derivatives [15.1–15.3].

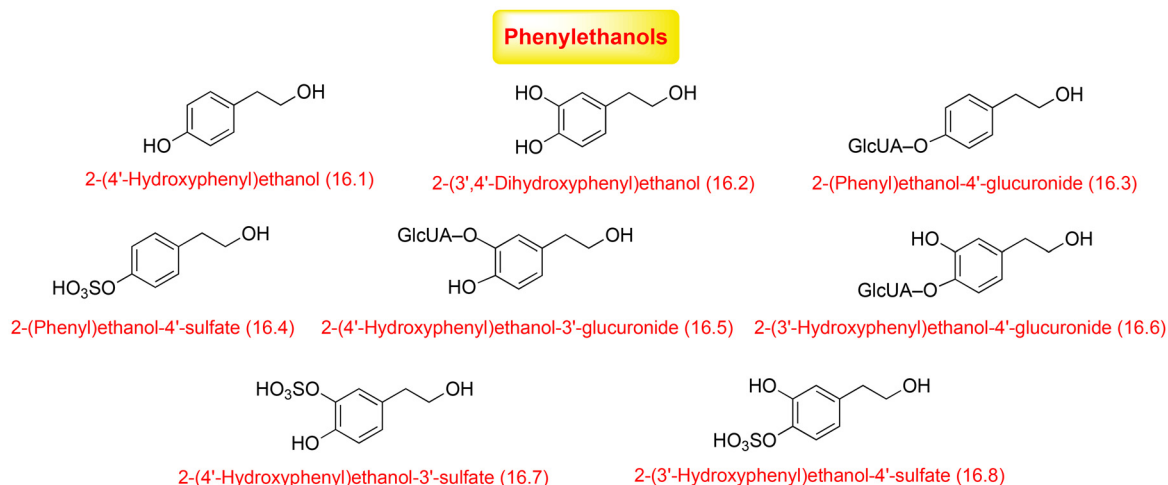


Fig. 10 Structures of phenylethanols [16.1–16.8]. GlcUA – β -D-glucuronide.

Co., Ltd‡ refer to the CAS Registry number 21618-92-8 for their product (*S*)-5-(3',4'-dihydroxy)phenyl- γ -valerolactone, whereas Toronto Research Chemicals§ use CAS Registry number 191666-22-5 for the same compound and both suppliers provide the correct structure for the listed isomer on their website. In contrast, many other suppliers, for example Alfa Chemistry¶, use an enantiomerically undefined structure for

21618-92-8, possibly suggesting that their material is uncharacterized or racemic despite using the (4*S*) CAS Registry number. Santa Cruz Biotechnology|| provide no structure for 191666-22-5 but its explicit description as a '*minus-epicatechin-metabolite*' implies that it is the (4*R*)-isomer. Fig. 13 illustrates the relationship between (+)-catechin and (–)-epicatechin and the

‡ <https://www.ichemical.com/products/21618-92-8.html>

§ <https://www.tre-canada.com/product-detail/?D454525>

¶ https://www.chemicalbook.com/ProdSupplierGWCB21302752_EN.htm

|| <https://www.scbt.com/p/4r-5-3prime-4prime-dihydroxyphenyl-gamma-valerolactone-minus-epicatechin-metabolite-191666-22-5>



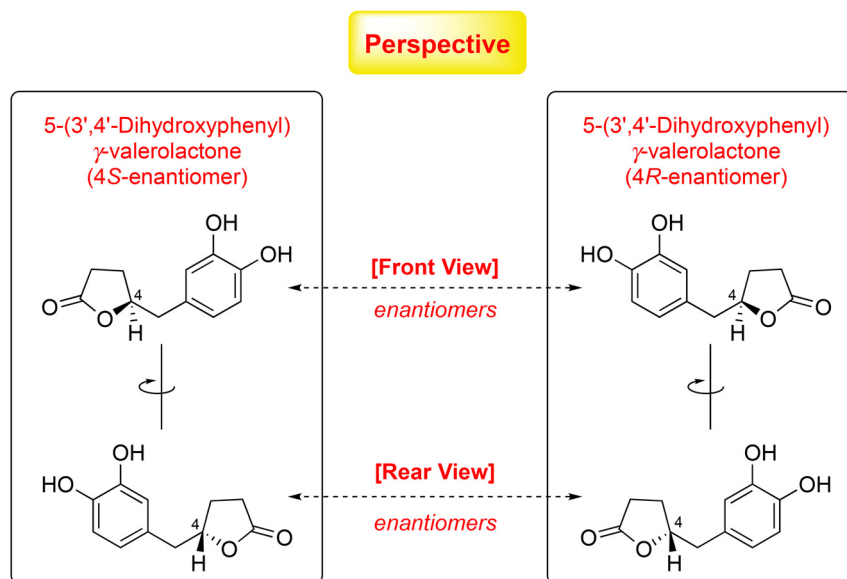


Fig. 11 Structures of the (4*S*)- and (4*R*)-enantiomers of 5-(3,4-dihydroxyphenyl)- γ -valerolactone from a front and rear perspective.

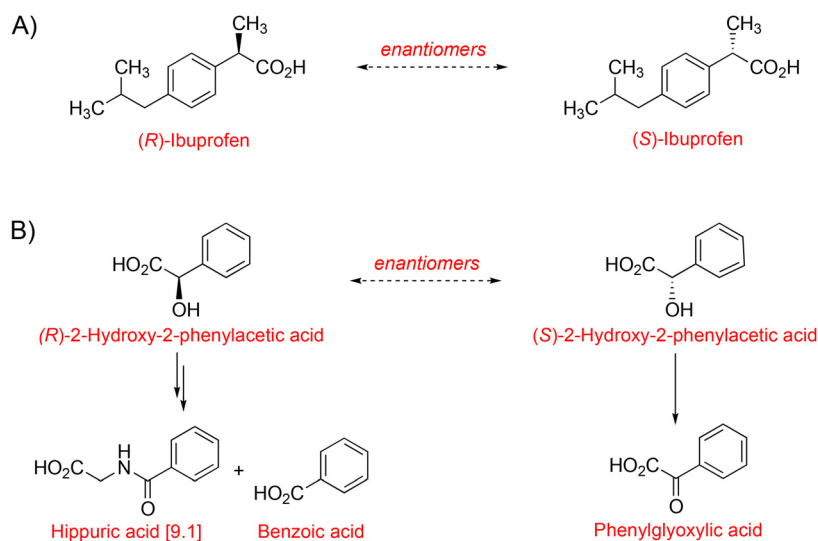


Fig. 12 (A) Structures of (*R*)- and (*S*)-ibuprofen (2-(4'-isobutyl-phenyl)propanoic acid aka isobutylphenylpropionic acid) and (B) the differential metabolism of (*R*)- and (*S*)-2-hydroxy-2-(phenyl)acetic acid by primary rat hepatocytes.

associated phenyl- γ -valerolactone and phenyl-valeric acid gut microbiota catabolites. It is not known whether there is a mammalian racemase enzyme interconverting (*R*)- and (*S*)-forms for these C_6 - C_5 lactones and acids.

To confound the confusion, Phytohub** lists three CAS numbers, 21618-92-8, 191666-22-5 and 1108192-01-3, all

for a compound described as "5-(3',4'-dihydroxyphenyl)- γ -valerolactone". CAS 1108192-01-3 is also used by the Royal Society of Chemistry's Chemspider†† which lists 11 suppliers, all of whom associate it with the structure having undefined stereochemistry.

** <https://phytohub.eu/entries/PHUB001993>

†† <https://www.chemspider.com/Chemical-Structure.134347.html?rid=d203472f-cd06-48d1-ab43-18cd7d078353>



Table 2 Commercially available enantiomers^b

CAS Number	Recommended name	Supplier ^a	Supplier's webpage
<i>C₆-C₅ acids and lactones</i>			
21618-92-8	(S)-4-Hydroxy-5-(3',4'-dihydroxy)phenyl-γ-valerolactone	1	https://www.ichemical.com/products/21618-92-8.html
191666-22-5	(R)-4-Hydroxy-5-(3',4'-dihydroxy)phenyl-γ-valerolactone	2	https://www.tre-canada.com/product-detail/?D454525
1190403-76-9	(R)-4-Hydroxy-5-(3',4'-dihydroxyphenyl)valeric acid	2	https://www.tre-canada.com/product-detail/?D454580
<i>Mandelic acids</i>			
17119-29-0	(S)-2-Hydroxy-2-(phenyl)acetic acid	3	https://ambeed.com/products/17119-15-2.html
611-71-2	(R)-2-Hydroxy-2-(phenyl)acetic acid	4	https://www.sigmaaldrich.com/GB/en/search/611-71-2?focus=products&page=1&perpage=30&sort=relevance&term=611-71-2&type=cas_number
90-64-2	(R/S)-2-Hydroxy-2-(phenyl)acetic acid undefined	4	https://www.sigmaaldrich.com/GB/en/search/90-64-2?focus=products&page=1&perpage=30&sort=relevance&term=90-64-2&type=cas_number
13244-78-5	(R)-2-Hydroxy-2-(4'-hydroxyphenyl)acetic acid	3	https://ambeed.com/products/17119-15-2.html
<i>Phenyl-hydracrylic acids</i>			
2768-42-5	(R)-3-Hydroxy-3-(phenyl)propanoic acid	5	https://www.fishersci.com/shop/products/r-3-hydroxy-3-phenylpropionic-acid-98-thermo-scientific/AAL19040MD
36567-72-3	(S)-3-Hydroxy-3-(phenyl)propanoic acid	4, 6	https://www.sigmaaldrich.com/GB/en/product/aldrich/56193 https://www.thermofisher.com/order/catalog/product/L19041.03
<i>Phenyl-lactic acids</i>			
7326-19-4	(R)-2-hydroxy-3-(phenyl)propanoic acid	7	https://www.aechemsc.com/info_products/AE1-008987.php
20312-36-1	(S)-2-hydroxy-3-(phenyl)propanoic acid	8	https://www.selleckchem.com/products/s-2-hydroxy-3-phenylpropionic-acid.html
828-01-3	(R/S)-2-hydroxy-3-(phenyl)propanoic acid	9	https://www.simsophonma.com/product/dl-2-hydroxy-3-phenylpropionic-acid

^a 1 – Shanghai Ichemical Co., Ltd; 2 – Toronto Research Chemicals; 3 – Ambeed; 4 – Sigma Aldrich; 5 – Sigma Aldrich; 6 – ThermoFischer Scientific; 7 – AECHEM Scientific Corporation; 8 – SelleckChem.com; 9 – Simson Pharma Ltd. ^b This table was prepared purely for the convenience of readers and the authors have no connection with these companies and make no claims regarding the quality of the materials they supply. There may be other providers and compendia such as Chempidder <https://www.chemspider.com/> and Pubchem <https://pubchem.ncbi.nlm.nih.gov/> should also be consulted, particularly for the racemates.

3.2. The enantiomeric mandelic, phenyl-hydracrylic, phenyl-lactic and hydrotropic acids

3.2.1. Mandelic acids. Mandelic acids such as (*R/S*)-2-hydroxy-2-(phenyl)acetic acid are often sold as *racemic compounds* known to contain both enantiomers and such preparations should be identified by the prefix '*rac*'. The designated structures are illustrated in Fig. 14. It is of note, however, that there is a difference between a preparation that is known to be a '*racemate*' and a preparation or chromatographic peak of 'unknown chirality', which might be a single isomer or a mixture of both enantiomers.

(*S*)-Mandelic acid is epimerized by humans but the enzyme responsible has not been identified. It is not the 2-arylpropanoyl-CoA epimerase (EC 5.1.99.4) which accepts ibuprofen and the isoflavone metabolite (*R*)-2-hydroxy-2-(4'-hydroxyphenyl)propanoic acid.⁴⁶

Matrix Fine Chemicals have an entry on their website^{‡‡} for '*rac*-(2*R*)-2-hydroxy-2-(4-hydroxyphenyl)acetic acid' which is internally inconsistent with '*rac*' indicating racemic and '2*R*' implying enantiomeric purity. Prospective purchasers who require a specific enantiomer are advised to obtain written confirmation of the identity of the product offered before making an expensive purchase.

3.2.2. Phenyl-hydracrylic acids. In 1957 Armstrong *et al.*⁴⁷ reported the presence of a phenyl-hydracrylic acid described as "(*-*)-3-hydroxy-3-(phenyl)propanoic acid" in human urine. They determined the (*-*)-rotation but did not assign *R/S*. There is no direct and predictable relationship between the optical activity and the arrangement of the substituents around the center of chirality (see Fig. 15). This must be determined experimentally on a case-by-case basis. The (+)-optical isomer is now available commercially,^{§§} and is the (*R*)-enantiomer, indicating that the Armstrong *et al.* isolate must be (*-*)-(*S*)-3-hydroxy-3-(phenyl)propanoic acid. This enantiomer would be expected for a metabolite produced by mitochondrial β-oxidation.⁴⁸ However, it is not known if there is a mammalian racemase enzyme for phenyl-hydracrylic acids. It is of note that the β-oxidation-associated racemase requires at least four carbons in the side chain and, thus, cannot accommodate the phenyl-hydracrylic acid.⁴⁸

3.2.3. Phenyl-lactic acids. Both enantiomers of the phenyl-lactic acids such as (*R/S*)-2-hydroxy-3-(phenyl)propanoic acid (Fig. 16) can be expected in human plasma and urine because some anaerobes, for example *Clostridium sporogenes*, convert *L*-phenylalanine to (*R*)-2-hydroxy-3-phenylpropanoic acid⁴⁹ while (*S*)-2-hydroxy-3-(4'-hydroxyphenyl)propanoic acid is an endogenous metabolite of *L*-tyrosine (Fig. 17).⁵⁰ Again, it is not known whether there is a mammalian racemase enzyme for phenyl-lactic acids.

3.2.4. Hydrotropic acids. (*R/S*)-2-(Phenyl)propanoic acids are C₆-C₃ phenolics with a methyl group at C2 on the side

^{‡‡} <https://www.matrix-fine-chemicals.com/products/catalog/secondary-alcohols/mm1704>

^{§§} <https://www.fishersci.com.uk/shop/products/r-3-hydroxy-3-phenylpropionic-acid-98-thermo-scientific/11349575>



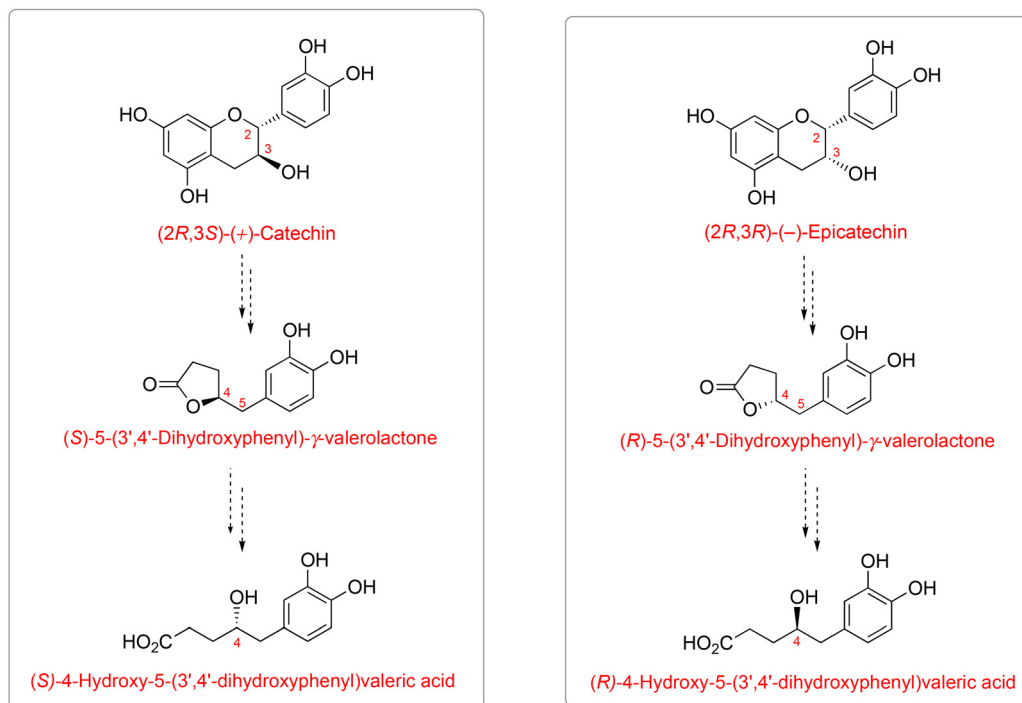


Fig. 13 The relationship between (+)-catechin and (-)-epicatechin and their associated phenyl- γ -valerolactone and phenyl-valeric acid gut microbiota catabolites. The structures viewed from the front are usually preferred in publications.

Mandelic acids

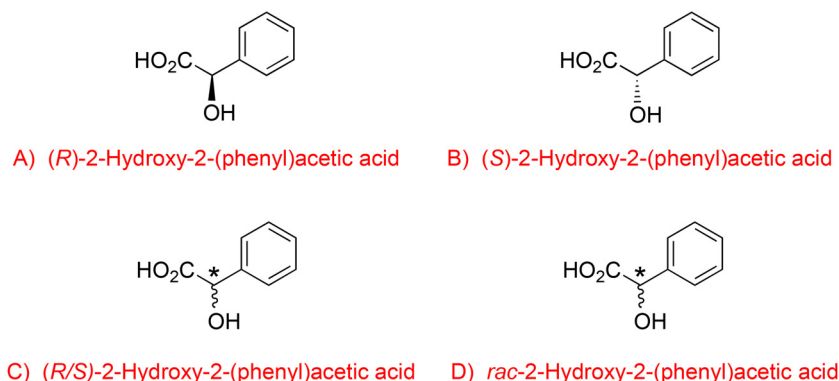


Fig. 14 *(R)*-, *(S)*- and *(R/S)*- and *rac*-mandelic acids. (A) *(R)*-enantiomer, (B) *(S)*-enantiomer, (C) *(R/S)*- a compound of unknown chirality which might prove to be a mixture of both enantiomers, (D) '*rac*'- a preparation known to contain both enantiomers. The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*). Phenyl ring substituents do not alter the chirality, but the CAS Registry number will change.

chain and are referred to as hydrotropic acids. *(R)*-2-Phenylpropanoic acids are produced from isoflavones by gut microbiota⁵¹ and can be racemized by human α -methylacyl-CoA racemase (2-aryl-propanoyl-CoA epimerase; EC 5.1.99.4).⁴⁶ Achiral 3-phenylpropanoic acids with various phenyl ring substituents (Fig. 4) are produced from most other flavonoids, including flavan-3-ols and proanthocyanidins. The structures

of the different types of (phenyl)propanoic acids are illustrated in Fig. 18.

3.3. Cinnamic acids

Cinnamic acids occur *in planta* predominantly as *trans*-isomers that are readily converted to *cis*-isomers when exposed to UV light (Fig. 19),⁵² and are increasingly being



(Phenyl)hydracrylic acids

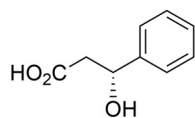
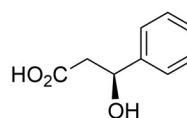
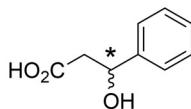
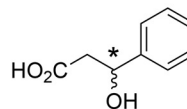
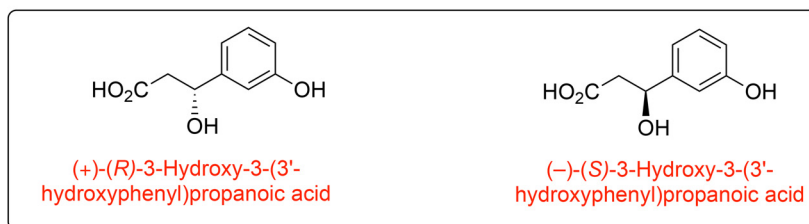
a) (*R*)-3-Hydroxy-3-(phenyl)propanoic acidb) (*S*)-3-Hydroxy-3-(phenyl)propanoic acidc) (*R/S*)-3-Hydroxy-3-(phenyl)propanoic acidd) (*R/S*)-3-Hydroxy-3-(phenyl)propanoic acid

Fig. 15 (*R*)-, (*S*)- and (*R/S*)- and *rac*-(phenyl)hydracrylic acids. (a) (*R*)-enantiomer, (b) (*S*)-enantiomer, (c) (*R/S*)- a compound of unknown chirality which might prove to be a mixture of both enantiomers, (d) '*rac*'- a preparation known to contain both enantiomers. The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*). Phenyl ring substituents do not alter the chirality, but the CAS Registry number will change. In the box: the two enantiomers of (3'-hydroxyphenyl)hydracrylic acid: the (–)-*S*-enantiomer was found in urine.⁴⁵

3-(Phenyl)lactic acids

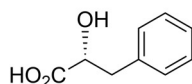
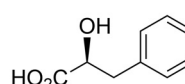
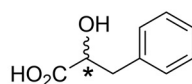
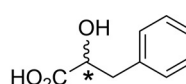
A) (*R*)-2-Hydroxy-3-(phenyl)propanoic acidB) (*S*)-2-Hydroxy-3-(phenyl)propanoic acidC) (*R/S*)-2-Hydroxy-3-(phenyl)propanoic acidD) *rac*-2-Hydroxy-3-(phenyl)propanoic acid

Fig. 16 (*R*)-, (*S*)- and (*R/S*)- and *rac*-3-(phenyl)lactic acids. (A) (*R*)-enantiomer, (B) (*S*)-enantiomer, (C) (*R/S*)- a compound of unknown chirality which might prove to be a mixture of both enantiomers, (D) '*rac*'- a preparation known to contain both enantiomers. The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*).

reported in leafy tissues, flowers and the surface tissues of fruit and vegetables. *cis*-Isomers have been detected in human feces and urine, possibly preformed before consumption.^{53–55} There is evidence for metabolic *trans* to *cis* isomerization by (i) rats,⁵⁶ (ii) *Lactobacillus reuteri*, a component of the human gut microbiota,⁵⁷ (iii) everted rat gut sacs, and (iv) Caco-2/HT29-MTX co-cultures where a putative *cis*-3'-methoxycinnamic acid-4'-glucuronide (Fig. 19) has

been detected.⁵⁸ In such circumstances, nomenclature should follow the existing recommendations of Kay *et al.*²⁹ repeated in the present document (Table 1) but replacing '*trans*' with '*cis*'.

3.4. Hippuric acids

4'-Hydroxy-hippuric acid has a single CAS registry number, 2482-25-9, and along with other hippuric acids, elutes as a



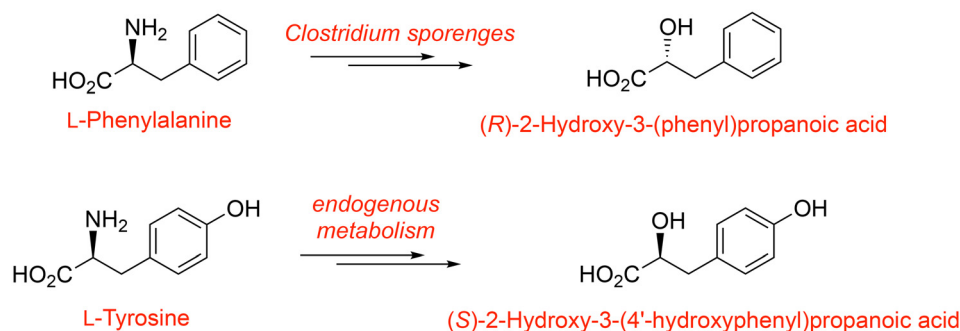


Fig. 17 Gut microbiota metabolites of L-phenylalanine and endogenous metabolites of L-tyrosine.

(Phenyl)propanoic acids

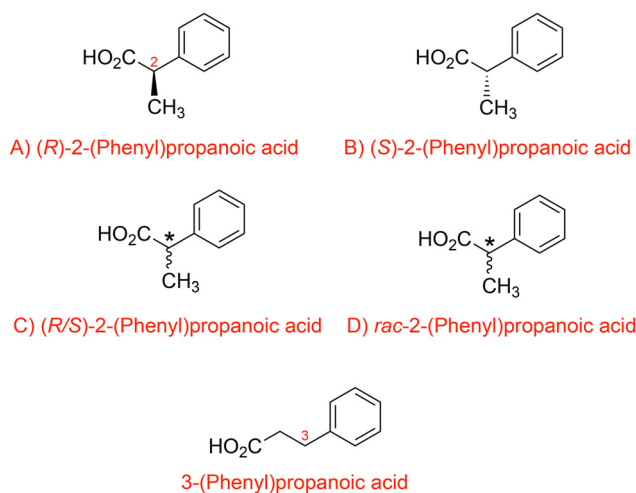


Fig. 18 Chiral 2-(phenyl)propanoic acids (aka hydrotropic acids) and achiral 3-(phenyl)propanoic acids are catabolites of several flavonoids. (A) (R)-enantiomer, (B) (S)-enantiomer, (C) (R/S)- a compound of unknown chirality which might prove to be a mixture of both enantiomers, (D) '*rac*'- a preparation known to contain both enantiomers. The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (R or S), (E) a chiral 3-(phenyl)propanoic acid.

single peak from reversed phase HPLC column packings. However, after derivatization for GC-MS analysis, hippuric acids typically form two peaks, the amide- and imidic acid-tautomers. The relative yields depend on the derivatizing agent

and conditions, as well as the position of the equilibrium associated with each hippuric acid, and areas of both peaks must be utilized in quantitative studies.⁵⁹ The amide-tautomer is derivatized on the carboxyl whereas the imidic acid-tautomer is derivatized on the carboxyl and the side chain hydroxyl, plus, for both tautomers, any hydroxy groups attached to the ring (Fig. 20).⁵⁹

3.5. Glutathione conjugates

One of the actions of the tripeptide glutathione (L-γ-glutamyl-L-cysteinyl-glycine) (Fig. 21) is to scavenge electrophilic species, often toxicants or potential toxicants, such as the quinones generated by cytochrome P450 2E1 and 3A4 from phenolic metabolites of dietary or pharmaceutical origin (for example paracetamol aka acetaminophen, and N-(4'-hydroxyphenyl)acetamide) (Fig. 21). Scavenging may occur enzymically *via* glutathione-S-transferase (EC 2.5.1.18), or by purely chemical interaction such as addition to the

Hippuric acid tautomerism

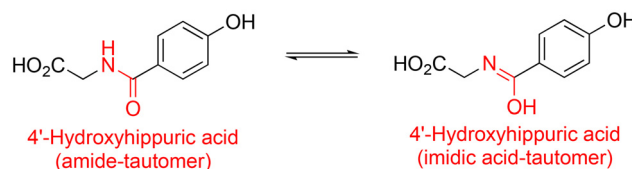


Fig. 20 The amide- vs. imidic acid-tautomer of 4'-hydroxyhippuric acid.

Cinnamic Acids

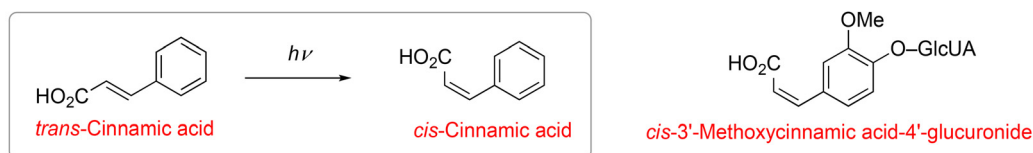


Fig. 19 *trans*- and *cis*-cinnamic acid and *cis*-3'-methoxycinnamic acid-4'-glucuronide. GlcUA – β-D-glucuronide, $h\nu$ – UV irradiation.



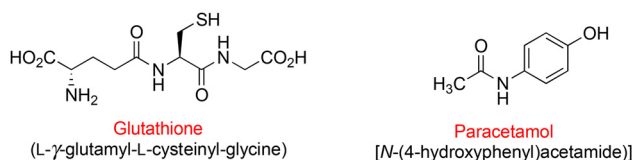


Fig. 21 Glutathione and paracetamol.

α,β -conjugated double bond of cinnamic acids.⁶⁰ Such conjugates may be undetectable at normal dietary (poly)phenol intake but have been observed after experimental diets rich in (poly)phenols⁶¹ and, based on animal and *in vitro* studies, they may be increased under conditions of oxidative stress and/or when catechol-*O*-methyl transferase (EC 2.1.1.6) activity is impaired.⁶² *In vivo* conjugation is followed by hydrolysis of the glutathione moiety yielding the cysteinyl conjugate which is *N*-acetylated producing the mercapturic acid conjugate. Glutathionyl-conjugates are usually excreted in bile whereas the mercapturic acid conjugates are generally excreted in urine.

Note that glutathione conjugates of caffeoylquinic acids and caftaric acids may also occur in foods and wine,^{63,64} but their presence in biological fluids at a normal dietary (poly)phenol intake could be more related to hepatic conjugation rather than direct absorption at gastrointestinal level. Indeed, single mercapturic acid conjugates of 3-(3',4'-dihydroxyphenyl)propanoic acid, 3,4-dihydroxybenzaldehyde and 1,2-dihydroxy-4-methylbenzene, plus two isomeric conjugates of 3',4'-dihydroxyphenylacetic acid, and three isomeric conjugates of 3',4'-dihydroxycinnamic acid have been detected in urine after volunteers consumed 200 g cooked onion containing *ca.* 250 μ moles of quercetin glycosides.⁶¹

This bolus intake from onions is approximately an order of magnitude higher than the typical human daily consumption of quercetin glycosides from all sources throughout the day.

In vitro studies with 3',4'-dihydroxycinnamic acid indicate that glutathione conjugation may occur at C2', C5' and C6' on the phenyl ring, and at C3 of the side chain, theoretically producing two diastereomers, although whether both are formed is not known. The phenyl ring conjugates can be assigned to regioisomers only by NMR, but the benzylic side chain conjugates are saturated and distinguishable by their increased mass and fragmentation.^{62,63,65} Hence it might be possible to distinguish between the aromatic mercapturic acid adducts of 3-(3',4'-dihydroxyphenyl)propanoic acid ($M_r = 343.07257$ amu) and the benzylic mercapturic acid adduct of 3',4'-dihydroxycinnamic acid, ($M_r = 341.05692$ amu) (Fig. 22). Until authentic glutathione and mercapturic acid conjugates are available, or such phenyl-ring adducts are isolated and fully characterised, these metabolites can only be described as mercapturic acid (glutathionyl) conjugates of X, where X is described using the recommendations already established.

3.6. Lignans and enterolignans

Several classes of lignans and enterolignans are illustrated in Fig. 23 and 24. Secoisolariciresinol can occur as a pair of C_2 -symmetric, optically active enantiomers as well as an optically inactive symmetrical *meso*-isomer (Fig. 23). The optically active (2*R*,3*R*)-lignans are predominant in foods. Zálezák *et al.*⁶⁶ listed 10 classes of lignans and 15 classes of neolignans, all of which originate *in planta* from the dimerization of two *trans*-cinnamoyl alcohol moieties which are commonly glycosylated on the side chain alcohols. The human gut microbiota catabolism of five classes of lignans associated

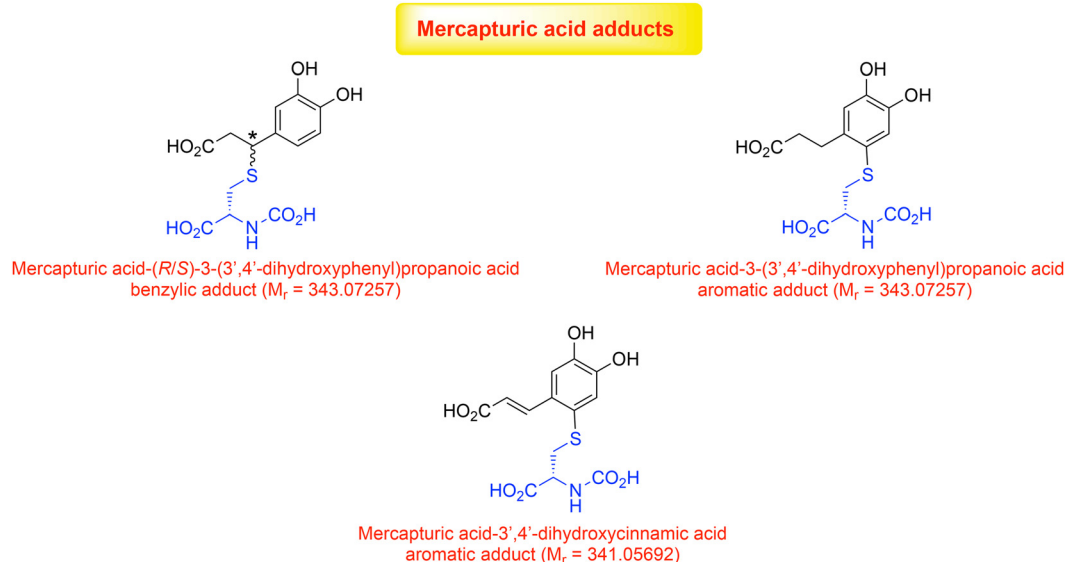


Fig. 22 Benzylic (black) and aromatic mercapturic acid (blue) adducts. The asterisk "*" represents the presence of a chiral centre of unknown absolute configuration (*R* or *S*).



Lignans and enterolignans: Stereochemical issues

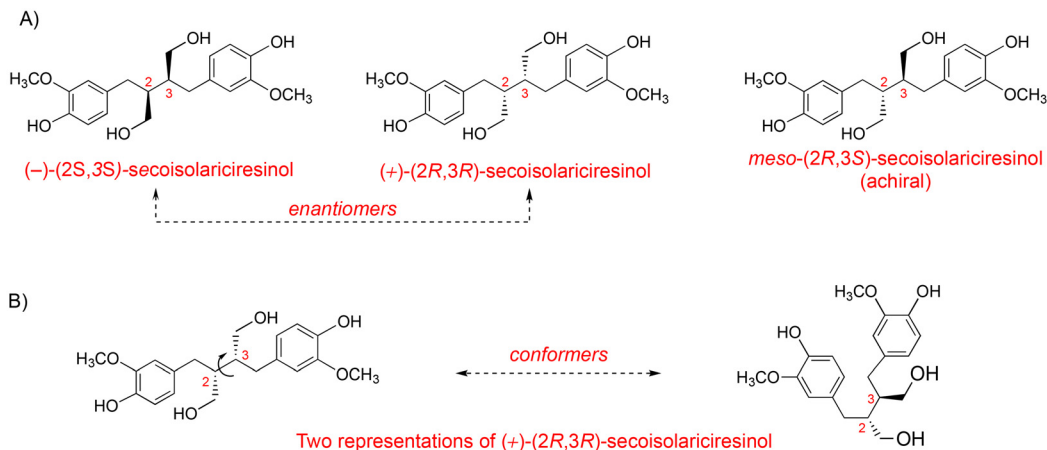


Fig. 23 (A) The structure of lignan diastereomers illustrated using secoisolariciresinol as an example. (B) Representation of two conformations of *(+)-(2R,3R)-secoisolariciresinol* unveiling its C_2 -symmetry pattern.

Lignan chemotypes metabolized by gut microbiota

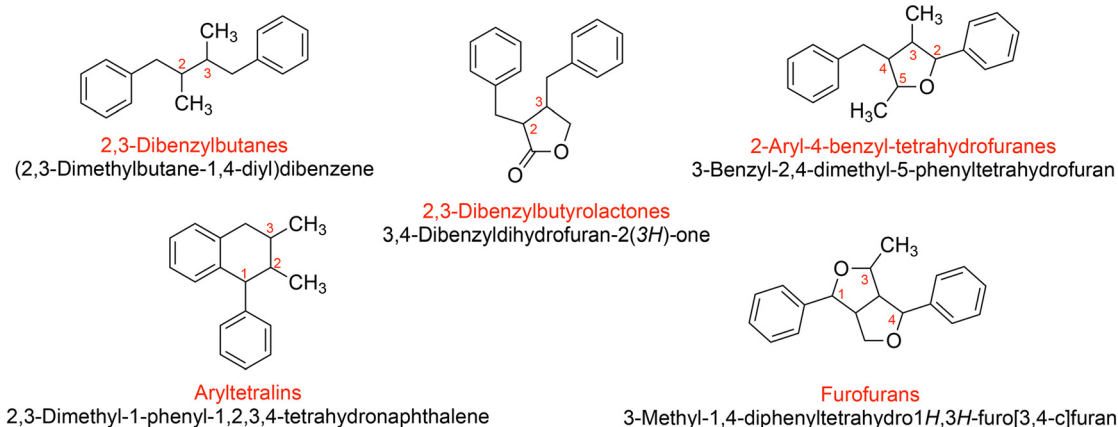


Fig. 24 Skeleton structures of the five classes of lignans of which the gut microbiota catabolism has been investigated. Red names – synonyms; black – IUPAC nomenclature.

with foods has been investigated: namely the 2,3-dibenzylbutanes, 2,3-dibenzylbutyrolactones, 2-aryl-4-benzyl-tetrahydrofurans, aryltetralins, and furofurans (Fig. 24). Sugars, if present, are removed by the gut microbiota and the aglycones are further transformed.

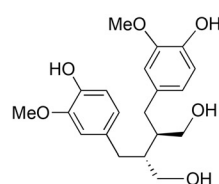
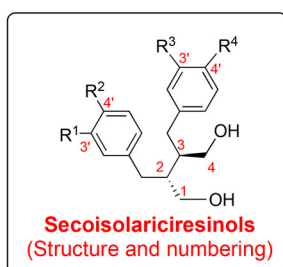
These aglycone transformation products are commonly referred to as enterolignans and include 2,3-dibenzylbutane-1,4-diols, 2,3-dibenzylbutyrolactones and 1,2-dibenzylcyclopentanes (for specimen structures see Fig. 25–27). The known substitution patterns of the aromatic moieties are 4'-hydroxy-3',5'-dimethoxy-, 3',4'-dimethoxy-, 4'-hydroxy-3'-methoxy-, 3',4'-dihydroxy-, 3',4'-methylenedioxy-, and 3'-hydroxy-(either benzyl or phenyl depending on the enterolignan class), and these occur in several combinations.^{66–70} Structures are shown in Fig. 25–27 for

the unconjugated metabolites. Note that for matairesinols, which do not possess C_2 -symmetry, two regioisomers are possible if the aromatic substituents are different (Fig. 26).

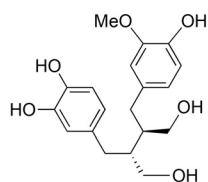
Quartieri *et al.*⁷⁰ reported 25 enterolignan sulfate, glucuronide, and sulfo-glucuronide conjugates in human urine after volunteers consumed secoisolariciresinol-diglucoside and this is almost certainly an under-estimate because there was no allowance made for regioisomerism of either the aromatic moieties or for the phase-II conjugating moiety attached thereto. For example, it has previously been reported that human urine may contain two mono-glucuronides and two mono-sulfates of both enterodiols and enterolactone^{71–73} but note that human phase-II metabolism of enterodiols and enterolactone is predominantly mono-glu-



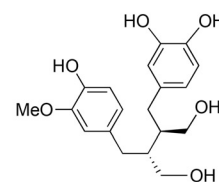
2,3-Dibenzyl-butan-1,4-diols - Secoisolariciresinols



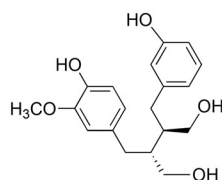
(2*R*,3*R*)-bis(4'-Hydroxy-3'-methoxybenzyl)butane-1,4-diol
(2*R*,3*R*)-2,3-bis(4-Hydroxy-3-methoxyphenyl)butane-1,4-diol



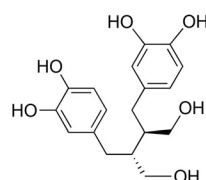
Two representations
of the same molecule



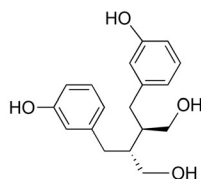
(2*R*,3*R*)-2-(3',4'-Dihydroxybenzyl)-3-(4'-hydroxy-3'-methoxybenzyl)butane-1,4-diol
4-[(2*R*,3*R*)-4-Hydroxy-3-(4-hydroxy-3-methoxybenzyl)-2-(hydroxymethyl)butyl]benzene-1,2-diol



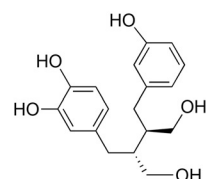
(2*R*,3*R*)-2-(4'-Hydroxy-3'-methoxybenzyl)-3-(3'-hydroxybenzyl)butane-1,4-diol
(2*R*,3*R*)-2-(4-Hydroxy-3-methoxybenzyl)-3-(3-hydroxybenzyl)butane-1,4-diol



(2*R*,3*R*)-bis(3',4'-Dihydroxybenzyl)butane-1,4-diol
4,4'-[(2*R*,3*R*)-2,3-Bis(hydroxymethyl)butane-1,4-diyl]bis(benzene-1,2-diol)



(Di-demethyl-di-dehydroxy-secoisolariciresinol)
(2*R*,3*R*)-bis(3'-Hydroxybenzyl)-butane-1,4-diol
(2*R*,3*R*)-2,3-bis(3-Hydroxybenzyl)butane-1,4-diol



(2*R*,3*R*)-2-(3',4'-Dihydroxybenzyl)-3-(3'-hydroxybenzyl)butane-1,4-diol
4-[(2*R*,3*R*)-4-hydroxy-3-(3-hydroxybenzyl)-2-(hydroxymethyl)butyl]benzene-1,2 diol

Fig. 25 Secoisolariciresinol and its associated gut microbiota catabolites. Red names – synonyms, blue – recommended nomenclature, black – IUPAC nomenclature.

curonidation with only a small contribution from mono-sulfates.

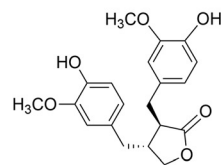
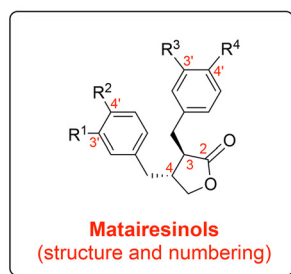
The IUPAC rules for naming these unconjugated enterolignans are complex and clumsy, and the approach adopted varies significantly depending on the class of metabolite (see names in black in Fig. 24–26). The literature contains numerous approaches, which do not allow easy comparison and meta-analysis, so we propose a system which is more uniform across the

main classes of metabolites and consistent with our previous recommendations.²⁹ These proposals are straightforward for metabolites where both aromatic moieties are identical, less so for matairesinols when they are different, because there is no easy method for distinguishing the regioisomers.

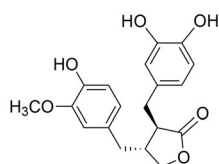
As stated earlier, once the structure of a catabolite has been defined using the recommended nomenclature, it is acceptable to associate it with a trivial name, which is subsequently used in



2,3-Dibenzylbutyrolactones: Matairesinols

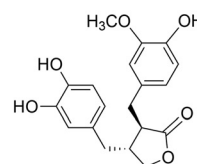


Matairesinol
(3*R*,4*R*)-bis(4'-Hydroxy-3'-methoxybenzyl) dihydrofuran-2-one
(3*R*,4*R*)-3,4-bis[(4-Hydroxy-3-methoxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-3,4-bis(4-Hydroxy-3-methoxybenzyl)dihydrofuran-2(3*H*)-one

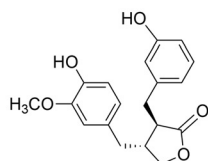


Demethyl-matairesinol (regioisomer I)
(3*R*,4*R*)-3-(3',4'-Dihydroxybenzyl)-4-(4'-hydroxy-3'-methoxybenzyl)dihydrofuran-2-one
(3*R*,4*R*)-3-[(3',4'-Dihydroxyphenyl)methyl]-4-[(4-hydroxy-3-methoxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-3-(3,4-Dihydroxybenzyl)-4-(4-hydroxy-3-methoxybenzyl)dihydrofuran-2(3*H*)-one

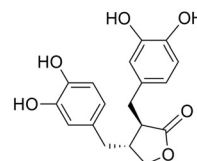
regioisomers



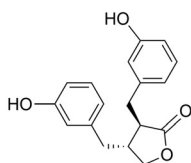
Demethyl-matairesinol (regioisomer II)
(3*R*,4*R*)-4-(3',4'-Dihydroxybenzyl)-3-(4'-hydroxy-3'-methoxybenzyl)dihydrofuran-2-one
(3*R*,4*R*)-3-[(4-Hydroxy-3-methoxyphenyl)methyl]-4-[(3,4-dihydroxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-4-(3,4-Dihydroxybenzyl)-3-(4-hydroxy-3-methoxybenzyl)dihydrofuran-2(3*H*)-one



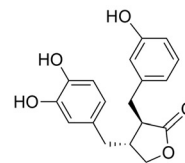
Demethyl-dehydroxy-matairesinol*
(3*R*,4*R*)-3-(3'-Hydroxybenzyl)-4-(4'-hydroxy-3'-methoxybenzyl)dihydrofuran-2-one
(3*R*,4*R*)-4-[(4-Hydroxy-3-methoxyphenyl)methyl]-3-[(3-hydroxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-4-(4-Hydroxy-3-methoxybenzyl)-3-(3-hydroxybenzyl)dihydrofuran-2(3*H*)-one



Demethyl-matairesinol
(3*R*,4*R*)-bis(3',4'-Dihydroxybenzyl)dihydrofuran-2-one
(3*R*,4*R*)-3-[(3,4-Dihydroxyphenyl)methyl]-4-[(3,4-dihydroxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-3,4-bis(3,4-Dihydroxybenzyl)dihydrofuran-2(3*H*)-one



Enterolactone
Di-demethyl-di-dehydroxymatairesinol
(3*R*,4*R*)-bis(3'-hydroxybenzyl)dihydrofuran-2-one
(3*R*,4*R*)-3,4-bis[3-hydroxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-3,4-bis(3-hydroxybenzyl)dihydrofuran-2(3*H*)-one



Di-demethyl-dehydroxy-matairesinol
(3*R*,4*R*)-3-(3'-hydroxybenzyl)-4-(3',4'-dihydroxybenzyl)-dihydrofuran-2-one
(3*R*,4*R*)-3,4-[3-Hydroxyphenyl)methyl]-4-[(3,4-dihydroxyphenyl)methyl]oxolan-2-one
(3*R*,4*R*)-3-(3-Hydroxybenzyl)-4-(3,4-dihydroxybenzyl)-dihydrofuran-2(3*H*)-one

Fig. 26 Matairesinol and its associated gut microbiota catabolites. Red names – synonyms; blue – recommended nomenclature, black – IUPAC traditional, green – IUPAC nomenclature via Chemdraw. * – two possible regioisomers, only one shown.

the text. Relatively few of the enterolignans, however, have trivial names, but the approach used by Quartieri *et al.*⁷⁰ is convenient. This system of nomenclature utilizes the trivial name of the sub-

strate and records how many demethylations and/or dehydroxylations have produced the metabolite. For example, the plant lignan secoisolariciresinol, for which we recommend (2*R*,3*R*)-bis



2,3-Dibenzylcyclopentanes: *anhydro-secoisolariciresinols*

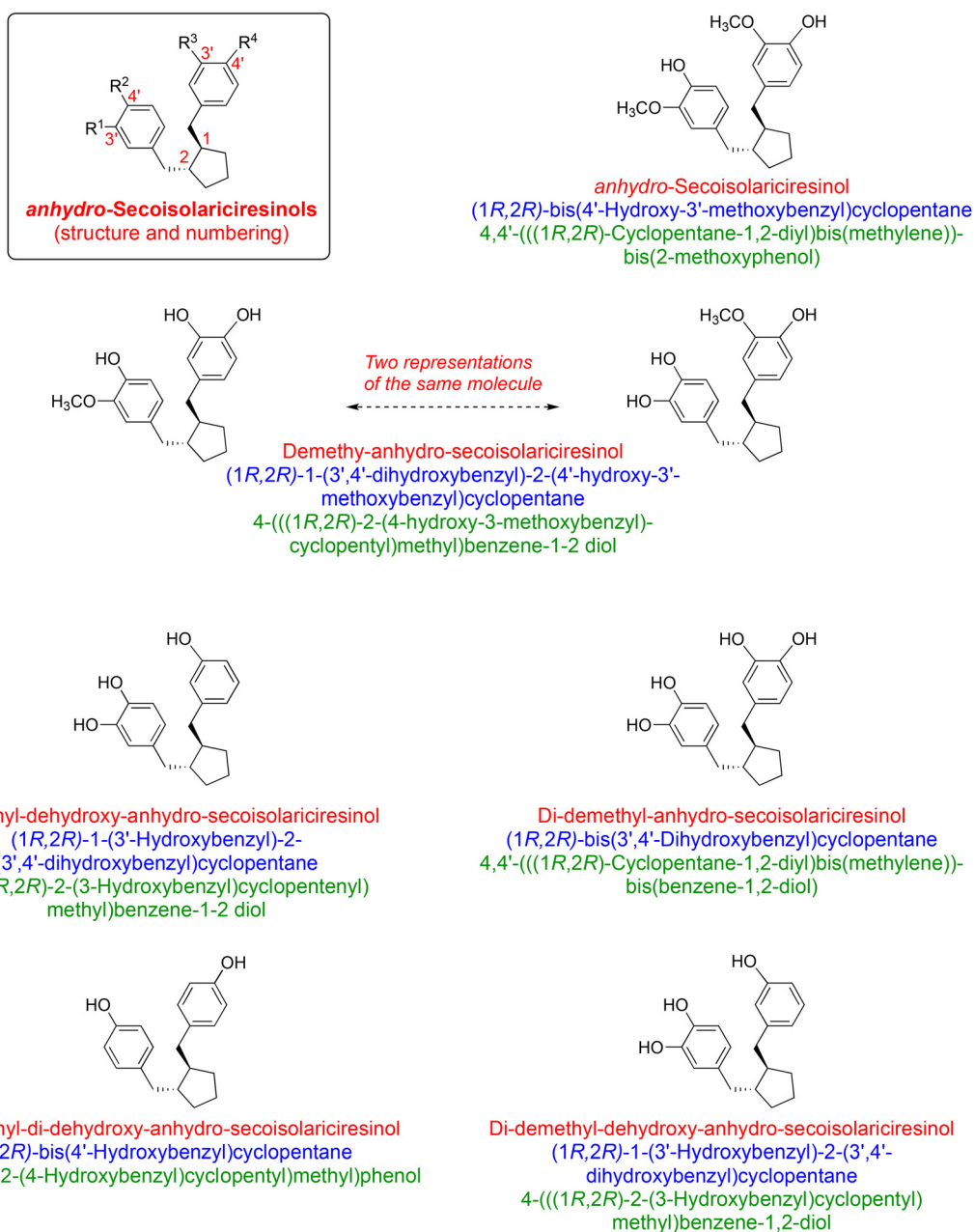


Fig. 27 Anhydro-secoisolariciresinol and its associated gut microbiota catabolites. Red names – synonym, blue – adjusted to simplify with inconsistencies removed to correspond as closely as possible to our existing recommendations, green – IUPAC nomenclature via Chemdraw.

(4'-hydroxy-3'-methoxybenzyl)butane-1,4-diol, is transformed by the gut microbiota yielding demethyl-, di-demethyl-, demethyl-dehydroxy-, di-demethyl-dehydroxy- and di-demethyl-di-dehydroxy-secoisolariciresinol as illustrated in Fig. 24. Fig. 26 and 27 provide the corresponding information for 2,3-dibenzyl-butylactones and 1,2-dibenzyl-cyclopentanes. This simplified nomenclature is particularly of interest when the positions where the demethylations and/or dehydroxylations take place are unknown.

Until such time as the phase-II conjugates are fully characterized and authentic standards are available, such conjugates should be described as “a sulfate/glucuronide/sulfo-glucuronide conjugate of secoisolariciresinol”, *etc.* This does not help to improve the accuracy of databases like PhytoHub and HMDB, but it represents a conservative approach that may avoid further mistakes.

As discussed for other classes of metabolites, the vendors' literature is inconsistent. Some of the vendors listed on



Pubchem^{¶¶} and Chemspider^{|||} show an undefined enterolignan structure, and others show one enantiomer, but these structures are presented from a variety of perspectives. The naturally occurring C_2 -symmetrical (-)-(2*R*,3*R*)-enantiomer of secoisolariciresinol, its antipode the (+)-(2*S*,3*S*)-enantiomer, and the racemic mixture are commercially available. The *meso*-form has been synthesized, and *in vitro* studies indicate that biological activity varies with the isomer tested.^{74,75} Similarly, racemic and optically pure (2*R*,3*R*)-matairesinol are to be found in vendors' listings, but prospective purchasers should obtain written confirmation regarding enantiomeric purity if a specific isomer is required.

4. Conclusions

The relentless advances of metabolomic research continue to increase the number of metabolites reported, particularly those produced from dietary (poly)phenols by the microbiota, and which are thought to be responsible for some of the beneficial effects of a plant-based diet. These microbial metabolites constitute an extremely diverse set of polyfunctionalized chemical structures many of which have regioisomeric and stereoisomeric forms. Such isomers are likely to differ in their biological activity.

Recognition that such metabolites are inconsistently described in the literature and sometimes even overlooked, persuaded us to focus upon the stereoisomeric forms of chiral metabolites (enantiomers and diastereomers) and expand the proposals for the nomenclature of (poly)phenol metabolites made by Kay *et al.*²⁹ Our intention is to establish a convenient, clear, and unambiguous nomenclature in a modality to be read and understood also by non-chemists who often have difficulty in 'reading' 3-dimensional structures expressed in 2-dimensions. We believe that the use of this consistent and unambiguous nomenclature will facilitate data retrieval for meta-analysis and the preparation of critical systematic reviews, which ultimately will improve our understanding of the biological effects of these metabolites.

We also recommend that identifications and tentative identifications are categorized as Metabolomics Standards Initiative levels 1 or 2 according to Sumner *et al.*⁷⁶ Tentative level 2 identifications are made in the absence of authentic reference compounds and, consequently, quantitative data so obtained should be treated with caution and viewed only as estimates.

Abbreviations

CAS	Chemical Abstracts Service Registry Number (also referred to as CASRN)
C_{\max}	Peak plasma concentration

¶¶ <https://pubchem.ncbi.nlm.nih.gov/compound/65373#section=Chemical-Vendors>

||| https://www.chemspider.com/Chemical-Structure.58845.html?rid=3fab6e1e-69d3-4563-99b4-c7cc30aeb390&page_num=0

InChIKey IUPAC International Chemical Identifier
 IUPAC International Union of Pure and Applied Chemistry
 L-DOPA L-3',4'-Dihydroxyphenylalanine

Author contributions

C. C., M. N. C., C. D. K. and A. C. conceived the study, and wrote the first version of the manuscript, edited drafts and had responsibility for the final content. P. M., A. R.-M., D. D. R., G. W. and G. J. M. helped edit drafts of the manuscript. D. M. assisted with some of the figures. All authors: contributed to various versions the text and read and approved the final version of the manuscript.

Data availability

Data files are available on requested from Alan Crozier at alan.cozier44@gmail.com.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

C. C. received financial support from the University of Parma. C. D. K. was funded by USDA-ARS project 6026-10700-001-000D. P. M. and D. D. R. were supported by the National Recovery and Resilience Plan of the Italian Ministry of University and Research funded by the European Union-NextGenerationEU; Award Number: PE00000003 "ON Foods – Research and innovation network on Food and Nutrition, Sustainability, Safety and Security – Working ON Foods". G. M. D. was supported by the Rural & Environment Science & Analytical Services Division of the Scottish Government" A. C., G. P.-C. and C. I. R. G. were funded by the Distinguished Scientist Fellowship Program (DSFP) of King Saud University, Riyadh, Saudi Arabia.

References

- 1 A. Cassidy, K. J. Mukamai, L. Liu, M. Franz, A. H. Eliassen and E. B. Rimm, High anthocyanin intake is associated with a reduced risk of myocardial infarction in young and middle-aged women, *Circulation*, 2014, **127**, 188–196, DOI: [10.1161/CIRCULATIONAHA.112.122408](https://doi.org/10.1161/CIRCULATIONAHA.112.122408).
- 2 D. Del Rio, A. Rodriguez-Mateos, J. P. E. Spencer, M. Tognolini, G. Borges and A. Crozier, Dietary (poly)phenolics in human health: structures, bioavailability, and evidence of protective effects against chronic diseases, *Antioxid. Redox Signaling*, 2013, **18**, 1818–1892, DOI: [10.1089/ars.2012.4581](https://doi.org/10.1089/ars.2012.4581).



- 3 A. M. Brickman, U. A. Khan, F. A. Provenzano, L. K. Yeung, W. Suzuki, H. Schroeter, M. Wall, R. P. Sloan and S. A. Small, Enhancing dentate gyrus function with dietary flavanols improves cognition in old adults, *Nat. Neurosci.*, 2014, **17**, 1798e17803, DOI: [10.1038/nn.3850](https://doi.org/10.1038/nn.3850).
- 4 A. M. Rodriguez-Mateos, D. Vauzour, C. G. Krueger, D. Shanmuganayagam, J. Reed, L. Calani, P. Mena, D. Del Rio and A. Crozier, Bioavailability, bioactivity and impact on health of dietary flavonoids and related compounds: an update, *Arch. Toxicol.*, 2014, **88**, 1803, DOI: [10.1007/s00204-014-1330-7](https://doi.org/10.1007/s00204-014-1330-7).
- 5 R. P. Sloan, M. Wall, L.-K. Yeung, T. Feng, X. Feng, F. Provenzano, H. Schroeter, V. Lauriola, A. M. Brinkman and S. A. Small, Insights into the role of diet and dietary flavanols in cognitive ageing: results of a randomised controlled trial, *Sci. Rep.*, 2021, **1**, 3837, DOI: [10.1038/s41598-021-83370-2](https://doi.org/10.1038/s41598-021-83370-2).
- 6 H. D. Sesso, P. M. Rist, A. K. Aragaki, S. Rautiainen, L. G. Johnson, G. Friedenberg, T. Copeland, A. Clar, S. Mora, M. V. Moorthy, A. Sarkissian, J. Wactawski-Wende, L. F. Tiner, W. R. Carrick, G. L. Andeson, J. E. Manson and COSMOS Research Group, Multivitamins in the prevention of cancer and cardiovascular disease: The COSMOS randomized clinical trial, *Am. J. Clin. Nutr.*, 2022, **115**, 1501–1510, DOI: [10.1093/ajcn/nqac056](https://doi.org/10.1093/ajcn/nqac056).
- 7 G. Williamson, C. D. Kay and A. Crozier, The bioavailability, transport and bioactivity of dietary flavonoids: A review from a historical perspective, *Compr. Rev. Food Sci. Food Saf.*, 2018, **17**, 1054–1112, DOI: [10.1111/1541-4337.12351](https://doi.org/10.1111/1541-4337.12351).
- 8 M. N. Clifford, I. A. Ludwig, G. Pereira-Caro, L. Zeraik, G. Borges, T. M. Almutairi, S. Dobani, L. Bresciani, P. Mena, C. I. R. Gill and A. Crozier, Exploring and disentangling the production of potentially bioactive phenolic catabolites from dietary (poly)phenols, phenylalanine, tyrosine and catecholamines, *Redox Biol.*, 2024, **71**, 103068, DOI: [10.1016/j.redox.2024.103068](https://doi.org/10.1016/j.redox.2024.103068).
- 9 M. Hidalgo, S. Martin-Santamaria, I. Recio, C. Sanchez-Moreno, B. de Pascual, G. Rimbach and S. de Pascual-Teresa, Potential anti-inflammatory, anti-adhesive, anti-estrogenic, and angiotensin-converting enzyme inhibitory activities of anthocyanins and their gut metabolites, *Genes Nutr.*, 2012, **7**, 295–306, DOI: [10.1007/s12263-011-0263-5](https://doi.org/10.1007/s12263-011-0263-5).
- 10 H. P. Amin, C. Czank, S. Raheem, O. Zhang, N. P. Botting, A. Cassidy and C. D. Kay, Anthocyanins and their physiologically relevant metabolites alter the expression of IL-6 and VCAM-1 in CD40L and oxidized LDL challenged vascular endothelial cells, *Mol. Nutr. Food Res.*, 2015, **59**, 1095–1106, DOI: [10.1002/mnfr.201400803](https://doi.org/10.1002/mnfr.201400803).
- 11 E. F. Warner, Q. Zhang, K. S. Raheem, D. O'Hagan, M. A. O'Connell and C. D. Kay, Common phenolic metabolites of flavonoids, but not their unmetabolized precursors, reduce the secretion of vascular cellular adhesion molecules by human endothelial cells, *J. Nutr.*, 2016, **14**, 465–473, DOI: [10.3945/jn.115.217943](https://doi.org/10.3945/jn.115.217943).
- 12 E. F. Warner, M. J. Smith, Q. Zhang, K. S. Raheem, D. O'Hagan, M. A. O'Connell and C. D. Kay, Signatures of anthocyanin metabolites identified in humans inhibit biomarkers of vascular inflammation in human endothelial cells, *Mol. Nutr. Food Res.*, 2017, **61**, 1700053, DOI: [10.1002/mnfr.201700053](https://doi.org/10.1002/mnfr.201700053).
- 13 E. Van Rymenant, C. Grootaert, K. Beerens, P. W. Need, P. A. Kroon, A. Kerimi, G. Williamson, R. García-Villalba, A. González-Sarriás, F. Tomás Barberán, J. C. Van Camp and J. Van de Voorde, Vasorelaxant activity of twenty-one physiologically relevant (poly)phenolic metabolites on isolated mouse arteries, *Food Funct.*, 2017, **8**, 4331–4335, DOI: [10.1039/c7fo01273j](https://doi.org/10.1039/c7fo01273j).
- 14 X. Han, M. Li, L. Sun, X. Liu, Y. Yin, J. Hao and W. Zhang, *p*-Hydroxybenzoic acid ameliorates colitis by improving the mucosal barrier in a gut microbiota-dependent manner, *Nutrients*, 2022, **14**, 5383, DOI: [10.3390/nu14245383](https://doi.org/10.3390/nu14245383).
- 15 X. Xu, A. Luo, X. Lu, M. Liu, H. Wang, H. Song, C. Wei, Y. Wang and X. Duan, *p*-Hydroxybenzoic acid alleviates inflammatory responses and intestinal mucosal damage in DSS-induced colitis by activating ER β signaling, *J. Funct. Foods*, 2021, **87**, 104835, DOI: [10.1016/j.jff.2021.104835](https://doi.org/10.1016/j.jff.2021.104835).
- 16 Z. Y. Wang, Y. Yin, D. N. Li, D. Y. Zhao and J. Q. Huang, Biological activities of *p*-hydroxycinnamic acids in maintaining gut barrier integrity and function, *Foods*, 2023, **12**, 26236, DOI: [10.3390/foods12132636](https://doi.org/10.3390/foods12132636).
- 17 X. Yang, X. Sun, F. Zhou, S. Xiao, L. Zhong, S. Hu, Z. Zhou, L. Li and Y. Tan, Protocatechuic acid alleviates dextran-sulfate-sodium-induced ulcerative colitis in mice via the regulation of intestinal flora and ferroptosis, *Molecules*, 2023, **28**, 3775, DOI: [10.3390/molecules28093775](https://doi.org/10.3390/molecules28093775).
- 18 S. Dobani, C. Latimer, G. J. McDougall, J. W. Allwood, G. Pereira-Caro, J. M. Moreno-Rojas, N. G. Ternan, L. K. Pourshahahidi, R. Lawther, K. M. Tuohi, D. Del Rio, G. O'Connor, I. Rowland, T. M. Almutairi, A. Crozier and C. I. R. Gill, *Ex vivo* fecal fermentation of human ileal fluid collected after raspberry consumption modifies (poly)phenolics and modulates genoprotective effects in colonic epithelial cells, *Redox Biol.*, 2021, **40**, 101862, DOI: [10.1016/j.redox.2021.101862](https://doi.org/10.1016/j.redox.2021.101862).
- 19 J. Rubert, P. Gatto, M. Pancher, V. Sidarovich, C. Curti, P. Mena, D. del Rio, A. Quattrone and F. Mattivi, A screening of native (poly)phenols and gut-related metabolites on 3D HCT116 spheroids reveals gut health benefits of a flavan-3-ol metabolite, *Mol. Nutr. Food Res.*, 2022, **66**, 2101043, DOI: [10.1002/mnfr.202101043](https://doi.org/10.1002/mnfr.202101043).
- 20 I. Figueira, G. Garcia, R. C. Pimpão, A. P. Terrasso, I. Costa, A. F. Almeida, L. Tavares, T. F. Pais, P. Pinto, M. R. Ventura, A. Filipe, G. J. McDougall, D. Stewart, K. S. Kim, I. Palmela, D. Brites, A. M. Brito, C. Brito and C. Nunes Santos, Polyphenols journey through blood-brain barrier towards neuronal protection, *Sci. Rep.*, 2017, **7**, 11456, DOI: [10.1038/s41598-017-11512-6](https://doi.org/10.1038/s41598-017-11512-6).
- 21 E. Cremonini, E. Daveri, D. E. Iglesias, J. Kang, Z. Wang, R. Gray, A. Mastaloudis, C. D. Kay, S. N. Hester,



- S. M. Wood, C. G. Fraga and P. I. Oteiza, A randomized placebo-controlled cross-over study on the effects of anthocyanins on inflammatory and metabolic responses to a high-fat meal in healthy subjects, *Redox Biol.*, 2022, **51**, 102273, DOI: [10.1016/j.redox.2022.102273](https://doi.org/10.1016/j.redox.2022.102273).
- 22 D. Carregosa, C. Pinto, M. A. Ávila-Gálvez, P. Bastos, D. Berry and C. Nunes Santos, A look beyond dietary (poly) phenols: The low molecular weight phenolic metabolites and their concentrations in human circulation, *Compr. Rev. Food Sci. Food Saf.*, 2022, **21**, 3931–3962, DOI: [10.1111/1541-4337.13006](https://doi.org/10.1111/1541-4337.13006).
- 23 G. Williamson and M. N. Clifford, A critical examination of human data for the biological activity of phenolic acids and their phase-2 conjugates derived from dietary (poly) phenols, phenylalanine, tyrosine and catecholamines, *Crit. Rev. Food Sci. Nutr.*, 2024, DOI: [10.1080/10408398.2024.2410874](https://doi.org/10.1080/10408398.2024.2410874).
- 24 J. I. Ottaviani, A. Britten, D. Lucarelli, R. Luben, A. A. Mulligan, M. A. Lentjes, R. Fong, N. Gray, P. B. Grace, D. H. Mawson, A. Tym, A. Wierzbicki, N. G. Forouhi, K.-T. Khaw, H. Schroeter and G. G. C. Kuhnle, Biomarker-estimated flavan-3-ol intake is associated with lower blood pressure in cross-sectional analysis in EPIC Norfolk, *Sci. Rep.*, 2020, **10**, 7964, DOI: [10.1038/s41598-020-74863-7](https://doi.org/10.1038/s41598-020-74863-7).
- 25 E. D. Clarke, M. E. Rollo, C. E. Collins, L. Wood, R. Callister, M. Philo, P. A. Kroon and R. L. Haslam, The relationship between dietary polyphenol intakes and urinary polyphenol concentrations in adults prescribed a high vegetable and fruit diet, *Nutrients*, 2020, **12**, 3431, DOI: [10.3390/nu12113431](https://doi.org/10.3390/nu12113431).
- 26 D. Angelino, A. Caffrey, H. McNulty, C. I. R. Gill, P. Mena, A. Rosi, K. Moore, L. Hoey, M. Clements, E. Laird, K. Boyd, B. Mullen, B. Pucci, H. Jarrett, C. Cunningham, M. Ward, J. J. Strain, K. McCarroll, A. J. Moore, A. M. Molloy and D. Del Rio, Association of dietary flavan-3-ol intakes with plasma phenyl- γ -valerolactones: analysis from the TUDA cohort of healthy older adults, *Am. J. Clin. Nutr.*, 2023, **118**, 476–484, DOI: [10.1016/j.ajcnut.2023.06.006](https://doi.org/10.1016/j.ajcnut.2023.06.006).
- 27 B. H. Parmenter, S. Shinde, K. Croft, K. Murphy, C. P. Bondonno, A. Genoni, C. T. Christopherson, K. Bindon, C. Kay, P. Mena, D. Del Rio, J. M. Hodgson and N. P. Bondonno, Performance of urinary phenyl- γ -valerolactones as biomarkers of dietary flavan-3-ol exposure, *J. Nutr.*, 2023, **153**, 2193–2204, DOI: [10.1016/j.tjn.2023.06.035](https://doi.org/10.1016/j.tjn.2023.06.035).
- 28 Y. Xu, Y. Li, X. Ma, W. Alotaibi, M. Le Sayec, A. Cheik, E. Wood, S. Hein, P. Yang, W. L. Hall, C. Nosarti, P. Dazzan, R. Gison and A. Rodriguez-Mateos, Comparison between dietary assessment methods and biomarkers in estimating dietary (poly)phenol intake, *Food Funct.*, 2023, **14**, 1369–1386, DOI: [10.1039/D2FO02755K](https://doi.org/10.1039/D2FO02755K).
- 29 C. D. Kay, M. N. Clifford, P. Mena, G. J. McDougall, A. Cassidy, D. Del Rio, C. Andres-Lacueva, N. Kuhnert, C. Manach, G. Pereira-Caro, A. Rodriguez-Mateos, A. Scalbert, F. Tomás Barberán, G. Williamson, D. S. Wishart and A. Crozier, Recommendations for standardizing nomenclature for dietary (poly)phenol catabolites, *Am. J. Clin. Nutr.*, 2020, **112**, 1051–1068, DOI: [10.1093/ajcn/nqaa204](https://doi.org/10.1093/ajcn/nqaa204).
- 30 L. M. Bode, D. Bunzel, M. Huch, G.-S. Cho, D. Ruhland, M. Bunzel, A. Bub, C. Map Franz and S. E. Kulling, In vivo and in vitro metabolism of *trans*-resveratrol by human gut microbiota, *Am. J. Clin. Nutr.*, 2013, **97**, 295–309, DOI: [10.3945/ajcn.112.049379](https://doi.org/10.3945/ajcn.112.049379).
- 31 C. E. Iglesias-Aguirre, F. Vallejo, D. D. Beltrána, J. Berná, J. Puigcerver, M. Alajarín, M. V. Selma and J. C. Espín, 4-Hydroxydibenzyl: a novel metabolite from the human gut microbiota after consuming resveratrol, *Food Funct.*, 2022, **13**, 7487–7493, DOI: [10.1039/d2fo01475k](https://doi.org/10.1039/d2fo01475k).
- 32 P. Wang, H. Chen, Y. Zhu, J. McBride, J. Fu and S. M. Sang, Oat avenanthramide-C (2c) is biotransformed by mice and the human microbiota into bioactive metabolites, *J. Nutr.*, 2015, **145**, 239–245, DOI: [10.3945/jn.114.206508](https://doi.org/10.3945/jn.114.206508).
- 33 P. Wang, S. W. Zhang, A. Yerke, C. L. Ohland, R. Z. Gharaibeh, F. Fouladi, A. A. Fodor, C. Jobin and S. M. Sang, Avenanthramide metabolite from whole-grain oat intake is influenced by *Faecalibacterium prausnitzii* in healthy adults, *J. Nutr.*, 2012, **151**, 1426–1443, DOI: [10.1093/jn/nxab006](https://doi.org/10.1093/jn/nxab006).
- 34 G. Corona, X. Tzounis, D. M. Assunta, M. Deiana, E. S. Debnam, F. Visioli and J. P. E. Spencer, The fate of olive oil polyphenols in the gastrointestinal tract: implications of gastric and colonic microflora-dependent biotransformation, *Free Radic. Res.*, 2006, **40**, 647–658, DOI: [10.1080/10715760500373000](https://doi.org/10.1080/10715760500373000).
- 35 R. Jaiswal and N. Kuhnert, Identification and characterization of the phenolic glycosides of *Lagenaria siceraria* Stand. (Bottle Gourd) fruit by liquid chromatography tandem mass spectrometry, *J. Agric. Food Chem.*, 2014, **62**, 1261–1271, DOI: [10.1021/jf4053989](https://doi.org/10.1021/jf4053989).
- 36 W. Neupert, R. Brugger, C. K. Euchenhofer, K. Brune and G. Geisslinger, Effects of ibuprofen enantiomers and its coenzyme A thioesters on human prostaglandin endoperoxide synthases, *Br. J. Pharmacol.*, 2009, **122**, 487–492, DOI: [10.1038/sj.bjp.0701415](https://doi.org/10.1038/sj.bjp.0701415).
- 37 H. P. Hao, G. J. Wang and J. G. Sun, Enantioselective pharmacokinetics of ibuprofen and involved mechanisms, *Drug Metab. Rev.*, 2005, **37**, 215–234, DOI: [10.1081/dmr-200047999](https://doi.org/10.1081/dmr-200047999).
- 38 Q. E. Che, P. Quan, M. Mu, X. F. Zhang, H. Q. Zhao, Y. Zhang, S. You, Y. Xiao and L. Fang, Enantioselective skin permeation of ibuprofen enantiomers: mechanistic insights from ATR-FTIR and CLSM studies based on synthetic enantiomers as naphthalimide fluorescent probes, *Expert Opin. Drug Delivery*, 2004, **11**, 1513–1523, DOI: [10.1517/17425247.2014.929661](https://doi.org/10.1517/17425247.2014.929661).
- 39 I. Tamai, H. Takanaga, T. Ogihara, H. Higashida, H. Maeda, H. Sai and A. Tsuji, Participation of a proton-cotransporter, MCT1, in the intestinal transport of monocarboxylic acids, *Biochem. Biophys. Res. Commun.*, 1995, **214**, 482–489, DOI: [10.1006/bbrc.1995.2312](https://doi.org/10.1006/bbrc.1995.2312).



- 40 J. Z. Wang, X. Y. Lu, N. P. Zhao, Y. Y. Cheng and S. Zeng, Simultaneous determination of phenylglyoxylic acid, mandelic acid, styrene glycol and hippuric acid in primary culture of rat hepatocytes incubate by high-performance liquid chromatography, *Biomed. Chromatogr.*, 2007, **21**, 497–501, DOI: [10.1002/bmc.783](https://doi.org/10.1002/bmc.783).
- 41 H. S. Kim, S. Chung, M.-Y. Song, C. Lim, H. Shin, J. Hur, H. Kwon, Y.-G. Suh, E.-H. Kim, D. Shin and S.-H. Kim, Efficient and divergent enantioselective syntheses of DHPVs and anti-inflammatory effect on IEC-6 cells, *Molecules*, 2020, **25**, 2215, DOI: [10.3390/molecules25092215](https://doi.org/10.3390/molecules25092215).
- 42 J. Hur, A.-R. Kim, H. S. Kim, C. Lim, T. Kim, T.-A. Kim, J. Sim and Y.-G. Suh, Concise synthesis of catechin metabolites 5-(3',4'-dihydroxyphenyl)- γ -valerolactones (DHPV) in optically pure form and their stereochemical effects on skin wrinkle-reducing activities, *Molecules*, 2020, **25**, 1970, DOI: [10.3390/molecules25081970](https://doi.org/10.3390/molecules25081970).
- 43 P. Mena, L. Bresciani, N. Brindani, I. A. Ludwig, G. Pereira-Caro, D. Angelino, R. Llorach, L. Calani, F. Brighenti, M. N. Clifford, C. I. R. Gill, A. Crozier, C. Curti and D. Del Rio, Phenyl- γ -valerolactones and phenylvaleric acids, the main colonic metabolites of flavan-3-ols: synthesis, analysis, bioavailability, and bioactivity, *Nat. Prod. Rep.*, 2019, **36**, 714–752, DOI: [10.1039/C8NP00062J](https://doi.org/10.1039/C8NP00062J).
- 44 G. Pereira-Caro, M. N. Clifford, T. Polyviou, I. Ludwig, H. Alfheaid, J. Moreno-Rojas, A. L. Garcia, D. Malkova and A. Crozier, Plasma pharmacokinetics of (poly)phenol metabolites and catabolites after ingestion of orange juice by endurance trained men, *Free Radicals Biol. Med.*, 2020, **160**, 784–795, DOI: [10.1016/j.freeradbiomed.2020.09.007](https://doi.org/10.1016/j.freeradbiomed.2020.09.007).
- 45 M. F. Matei, R. Jaiswal and N. Kuhnert, Investigating the chemical changes of chlorogenic acids during coffee brewing - conjugate addition of water to the olefinic moiety of chlorogenic acids and their quinides, *J. Agric. Food Chem.*, 2012, **60**, 12105–12115.
- 46 M. Yevglevskis, C. R. Bowskill, C. C. Y. Chan, J. H.-J. Heng, M. D. Threadgill, T. J. Woodman and M. D. Lloyd, A study on the chiral inversion of mandelic acid in humans, *Org. Biomol. Chem.*, 2014, **12**, 6737–6744, DOI: [10.1039/C3OB42515K](https://doi.org/10.1039/C3OB42515K).
- 47 M. D. Armstrong and K. F. Shaw, The occurrence of (-)- β -*m*-hydroxyphenylhydracrylic acid in human urine, *J. Biol. Chem.*, 1957, **225**, 269–278 <https://www.jbc.org/content/225/1/269.citation>.
- 48 M. N. Clifford, L. J. King, A. Kerimi, G. Pereira-Caro and G. Williamson, Metabolism of phenolics in coffee and plant-based foods by canonical pathways: an assessment of the role of fatty acid β -oxidation to generate biologically-active and -inactive intermediates, *Crit. Rev. Food Sci. Nutr.*, 2022, **64**, 3326–3383, DOI: [10.1080/10408398.2022.2131730](https://doi.org/10.1080/10408398.2022.2131730).
- 49 S. A. Dickert, D. Pierik, D. Linder and W. Buckel, The involvement of coenzyme A esters in the dehydration of (*R*)-phenyllactate to (*E*)-cinnamate by *Clostridium sporogenes*, *Eur. J. Biochem.*, 2000, **267**, 3874–3884, DOI: [10.1046/j.1432-1327.2000.01427](https://doi.org/10.1046/j.1432-1327.2000.01427).
- 50 M. Heil, F. Podebrad, T. Beck, A. Mosandl, A. C. Sewell and H. Böhles, Enantioselective multidimensional gas chromatography mass spectrometry in the analysis of urinary organic acids, *J. Chromatogr. B: Biomed. Sci. Appl.*, 1998, **714**, 119–126, DOI: [10.1016/s0378-4347\(98\)00233-3](https://doi.org/10.1016/s0378-4347(98)00233-3).
- 51 M. Kim and J. Han, Absolute configuration of (-)-2-(4-hydroxyphenyl)propionic acid: Stereochemistry of soy isoflavone metabolism, *Bull. Korean Chem. Soc.*, 2014, **35**, 1883–1886, DOI: [10.5012/bkcs.2014.35.6.1883](https://doi.org/10.5012/bkcs.2014.35.6.1883).
- 52 M. N. Clifford, J. Kirkpatrick, N. Kuhnert, H. Roozendaal and P. R. Salgado, LC-MSⁿ analysis of the *cis* isomers of chlorogenic acids, *Food Chem.*, 2008, **106**, 379–385, DOI: [10.1016/j.foodchem.2007.05.081](https://doi.org/10.1016/j.foodchem.2007.05.081).
- 53 U. Knust, G. Erben, B. Spiegelhalder, H. Bartsch and R. W. Owen, Identification and quantitation of phenolic compounds in faecal matrix by capillary gas chromatography and nano-electrospray mass spectrometry, *Rapid Commun. Mass Spectrom.*, 2006, **20**, 3119–3129, DOI: [10.1016/j.fct.2005.12.008](https://doi.org/10.1016/j.fct.2005.12.008).
- 54 O. Lagatie, E. N. Ediage, D. Van Roosbroeck, S. Van Asten, A. Verheyen, L. B. Debrah, M. F. Odiere, R. T'Kindt, E. Dumont, K. Sandra, L. Dillen, T. Verhaeghe, R. Vreeken, F. Cuyckens and L. J. Stuyver, Multimodal biomarker discovery for active *Onchocerca volvulus*, infection, *PLoS Neglected Trop. Dis.*, 2021, **15**, DOI: [10.1371/journal.pntd.0009999](https://doi.org/10.1371/journal.pntd.0009999).
- 55 V. Wewer, H. Peisker, K. Gutbrod, M. Al-Bahra, D. Menche, N. G. Amambo, F. F. Fombad, A. J. Njouendou, S. Wanji, A. Hoeruaf and P. Dörmann, Urine metabolites for the identification of *Onchocerca volvulus*, infections in patients from Cameroon, *Parasites Vectors*, 2021, **14**, 397, DOI: [10.1186/s13071-021-04893-1](https://doi.org/10.1186/s13071-021-04893-1).
- 56 G. Balaj, Z. Tamanai-Shacoori, D. Olivier-Jimenez, A. Sauvager, M. Faustin, L. Bousarghin, S. David-Le Gall, S. Guyot, D. Nebija, S. Tomasi and L. M. Abasq, An insight into an intriguing oxidative biotransformation pathway of 5-*O*-caffeoylquinic acid by a gut bacterium, *Food Funct.*, 2022, **13**, 6195–6204, DOI: [10.1039/d1fo04304h](https://doi.org/10.1039/d1fo04304h).
- 57 M. H. Omar, W. Mullen, A. Stalmach, C. Auger, J. M. Rouanet, P.-L. Teissedre, S. T. Caldwell, R. C. Hartley and A. Crozier, Absorption, disposition, metabolism, and excretion of [³⁻¹⁴C]caffeic acid in rats, *J. Agric. Food Chem.*, 2012, **60**, 5205–5214, DOI: [10.1021/jf3001185](https://doi.org/10.1021/jf3001185).
- 58 L. Poquet, M. N. Clifford and G. Williamson, Transport and metabolism of ferulic acid through the colonic epithelium, *Drug Metab. Dispos.*, 2008, **36**, 190–197, DOI: [10.1124/dmd.107.017558](https://doi.org/10.1124/dmd.107.017558).
- 59 A. Vorster, Comparing predefined derivatisation parameters for GC-MS analysis of selected organic acids, (M.Sc. Biochemistry), North West University, Potchefstroom Campus, South Africa, (2019), <https://repository.nwu.ac.za/handle/10394/34135?show=full>.
- 60 X. M. Liu, H. Lv, Y. Q. Guo, T. Teka, X. M. Wang, Y. H. Huang, L. Han and X. G. Pan, Structure-based reactivity profiles of reactive metabolites with glutathione, *Chem. Res. Toxicol.*, 2020, **33**, 1579–1593, DOI: [10.1021/acs.chemrestox.0c00081](https://doi.org/10.1021/acs.chemrestox.0c00081).



- 61 Y. J. Hong and A. E. Mitchell, Identification of glutathione-related quercetin metabolites in humans, *Chem. Res. Toxicol.*, 2006, **19**, 1525–1532, DOI: [10.1021/tx0601758](https://doi.org/10.1021/tx0601758).
- 62 C. Xie, D. Zhong and X. Chen, Identification of the ortho-benzoquinone intermediate of 5-O-caffeoylquinic acid *in vitro* and *in vivo*: comparison of bioactivation under normal and pathological situations, *Drug Metab. Dispos.*, 2012, **40**, 1628–1640, DOI: [10.1124/dmd.112.045641](https://doi.org/10.1124/dmd.112.045641).
- 63 V. Cheynier, E. K. Trousdale, V. L. Singleton, M. J. Salgues and R. Wylde, Characterization of 2-S-glutathionylcaftaric acid and its hydrolysis in relation to grape wines, *J. Agric. Food Chem.*, 1986, **34**, 217–221, DOI: [10.1021/jf00068a016](https://doi.org/10.1021/jf00068a016).
- 64 G. J. McDougall, A. Foito, G. Dobson, C. Austin, J. Sungurtas, S. Su, L. Wang, C. Feng, S. Li, L. Wang, W. Wei, J. W. Allwood and D. Stewart, Glutathionyl-S-chlorogenic acid is present in fruit of *Vaccinium* species, potato tubers and apple juice, *Food Chem.*, 2020, **330**, 127227, DOI: [10.1016/j.foodchem.2020.127227](https://doi.org/10.1016/j.foodchem.2020.127227).
- 65 C. Xie, D. Zhong and X. Chen, A fragmentation-based method for the differentiation of glutathione conjugates by high-resolution mass spectrometry with electrospray ionization, *Anal. Chim. Acta*, 2013, **788**, 89–98, DOI: [10.1016/j.aca.2013.06.022](https://doi.org/10.1016/j.aca.2013.06.022).
- 66 F. Zálešák, D. Bon and J. Pospisil, Lignans and neolignans: Plant secondary metabolites as a reservoir of biologically active substances, *Pharmacol. Res.*, 2019, **146**, 104284, DOI: [10.1016/j.phrs.2019.104284](https://doi.org/10.1016/j.phrs.2019.104284).
- 67 T. Clavel, D. Borrmann, A. Braune, J. Dore and M. Blaut, Occurrence and activity of human intestinal bacteria involved in the conversion of dietary lignans, *Anaerobe*, 2006, **12**, 140–147, DOI: [10.1016/j.anaerobe.2005.11.002](https://doi.org/10.1016/j.anaerobe.2005.11.002).
- 68 S. Heinonen, T. Nurmi, K. Liukkonen, K. Poutanen, K. Wahala, T. Deyama, S. Nishibe and H. Adlercreutz, *In vitro* metabolism of plant lignans: new precursors of mammalian lignans enterolactone and enterodiol, *J. Agric. Food Chem.*, 2001, **49**, 3178–3186, DOI: [10.1021/jf010038a](https://doi.org/10.1021/jf010038a).
- 69 B. Michalak, A. Filipek, P. Chomicki, M. Pyza, M. Wozniak, B. Zyzynska-Granica, J. P. Piwowarski, A. Kicel, M. A. Olszewska and A. K. Kiss, Lignans from *Forsythia x Intermedia* leaves and flowers attenuate the pro-inflammatory function of leukocytes and their interaction with endothelial cells, *Front. Pharmacol.*, 2018, **9**, DOI: [10.3389/fphar.2018.00401](https://doi.org/10.3389/fphar.2018.00401).
- 70 A. Quartieri, R. Garcia-Villalba, A. Amaretti, S. Raimondi, A. Leonardi, M. Rossi and F. Tomás Barberán, Detection of novel metabolites of flaxseed lignans *in vitro* and *in vivo*, *Mol. Nutr. Food Res.*, 2016, **60**, 1590–1601, DOI: [10.1002/mnfr.201500773](https://doi.org/10.1002/mnfr.201500773).
- 71 B. Dean, S. Chang, G. A. Doss, C. King and P. E. Thomas, Glucuronidation, oxidative metabolism, and bioactivation of enterolactone in rhesus monkeys, *Arch. Biochem. Biophys.*, 2004, **429**, 244–251, DOI: [10.1016/j.abb.2004.06.023](https://doi.org/10.1016/j.abb.2004.06.023).
- 72 U. Knust, W. E. Hull, B. Spiegelhalter, H. Bartsch, T. Strowitzki and R. W. Owen, Analysis of enterolignan glucuronides in serum and urine by HPLC-ESI-MS, *Food Chem. Toxicol.*, 2006, **44**, 1038–1049, DOI: [10.1016/j.fct.2005.12.008](https://doi.org/10.1016/j.fct.2005.12.008).
- 73 N. P. Norskov, C. Kyro, A. Olsen, A. Tjonneland and K. E. B. Knudsen, High-throughput LC-MS/MS method for direct quantification of glucuronidated, sulfated, and free enterolactone in human plasma, *J. Proteome Res.*, 2016, **15**, 1051–1058, DOI: [10.1021/acs.jproteome.5b01117](https://doi.org/10.1021/acs.jproteome.5b01117).
- 74 S. Yamauchi, T. Sugahara, Y. Nakashima, K. Abe, Y. Hayashi, K. Akiyama, T. Kishida and M. Maruyama, Effect of benzylic oxygen on the cytotoxic activity for colon 26 cell line of phenolic lignans, *Biosci. Biotechnol. Biochem.*, 2006, **70**, 2942–2947, DOI: [10.1271/bbb.60353](https://doi.org/10.1271/bbb.60353).
- 75 T. Sugahara, S. Yamauchi, A. Kondo, F. Ohno, S. Tominaga, Y. Nakashima, T. Kishida, K. Akiyama and M. Maruyama, First stereoselective synthesis of *meso*-secoisolariciresinol and comparison of its biological activity with (+)- and (–)-secoisolariciresinol, *Biosci. Biotechnol. Biochem.*, 2007, **71**, 2962–2968, DOI: [10.1271/bbb.70358](https://doi.org/10.1271/bbb.70358).
- 76 L. W. Sumner, A. Amberg, D. Barrett, M. H. Beale, R. Beger, C. A. Daykin, T. W. M. Fan, O. Fiehn, R. Goodacre, J. L. Griffin, T. Hankemeier, N. Hardy, J. Harnly, R. Higashi, J. Kopka, A. N. Lane, J. C. Lindon, P. Marriott, A. W. Nicholls, M. D. Reily, J. J. Thaden and M. R. Viant, Proposed minimum reporting standards for chemical analysis: chemical analysis working group (CAWG) Metabolomics Standards Initiative (MSI), *Metabolomics*, 2007, **3**, 211–221, DOI: [10.1007/s11306-007-0082-2](https://doi.org/10.1007/s11306-007-0082-2).

