CHIRAL ALIPHATIC HYDROXY COMPOUNDS IN NATURE: A REVIEW OF BIOLOGICAL FUNCTIONS AND PRACTICAL APPLICATIONS

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Dedicated to Dr. Alfred Bader[1] on the occasion of his 85th birthday to acknowledge his generous support of Czech chemists.

Chirality is a phenomenon that pervades the life on the Earth and has a tremendous importance for our daily lives. Many pharmaceuticals, agrochemicals, food additives, pheromones, fragrances and cosmetics are chiral. Chiral compounds play an essential role in biological systems, mainly for chemical communication among living organisms, serving as sex pheromones, aggregation pheromones, alarm pheromones, trail pheromones, attractants or repellent agents. This review summarizes our current knowledge of the biologically relevant chiral aliphatic hydroxy compounds, which are divided into eight classes according to their chemical structure: primary alcohols, secondary alcohols, tertiary alcohols, glycols and diols, hydroxy ketones, hydroxy carboxylic acids, hydroxy carboxylic esters and hydroxy amines. Information on biological functions and practical applications is summarized for each class. This information could be of interest to chemists, biochemists, biologists and pharmacists. A review with 475 references.

Keywords: Alcohols; Drugs; Pheromones; Odours; Chiral compounds; Hydroxy compounds; Chemical communication; Enantioselective enzymes; Natural products; Chiral pool.

The year 2009 offers several important anniversaries to remember and celebrate.

160 years ago the French scientist Louis Pasteur demonstrated the existence of chiral molecules for the first time[2]. In his early works, he resolved a problem concerning the nature of tartaric acid. This compound derived from living organisms, especially wine lees, rotated the plane of polarized light passing through it, whereas the same compound obtained by chemi-

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cal synthesis had no such effect. Manual sorting of the crystals gave two forms of tartaric acid: solutions of one form rotated polarized light clockwise, while the other form rotated light counterclockwise. A mixture of equal amounts of the both forms had no polarizing effect on light. Upon examination of the minuscule crystals of tartaric acid, Pasteur correctly deduced that the crystals occur in two asymmetric forms that were mirror images of one another, the same as left- and right-hand gloves, and that the natural form of this compound consisted purely of the one type.

135 years ago Jacobus Henricus van't Hoff and Joseph-Achille Le Bel developed the concepts of asymmetry. They independently recognized that when four different groups are attached to a carbon atom and arrayed at the corners of a tetrahedron, they can be arranged in the two different forms experimentally observed by Pasteur[3,4].

115 years ago, after ten years of intensive work, the German chemist Hermann Emil Fischer[5] finished his monumental work on sugars. In his Nobel prize winning work Fischer explained the stereochemical and isomeric nature of sugars, and described the stereochemical configuration of all sugars known at that time and exactly predicted their possible isomers by an ingenious application of the theory of the asymmetric carbon atom of van't Hoff and Le Bel. Later on, he also studied the synthesis of proteins to find out that only one optically active form of amino acids can be utilized for the polymerization into the proteins.

105 years ago the mathematical physicist Sir William Thomson (Lord Kelvin) published his Baltimore lectures on molecular dynamics and the wave theory of light[6,7]. In the short appendix of his lectures, Lord Kelvin used the terms "chiral" and "chirality" for the first time: *"I call any geometrical figure, or group of points, chiral, and say that it has chirality, if its a plane mirror, ideally realized, cannot be brought to coincide with itself. Two equal and similar right hands are homochirally similar. Equal and similar right and left hands are heterochirally similar or allochirally similar (but heterochirally is better). These are also called enantiomorphs, after a usage introduced, I believe, by German writers. Any chiral object and its image in a plane mirror are heterochirally similar."* The term chiral was derived from the Greek name "kheir" meaning hand.

50 years ago Peter Karlson and Martin Lüscher proposed a new word for the chemicals used for communication between individuals of the same species: "pheromones"[8,9]. Since then, pheromones have been found among bacteria, yeasts, animals and plants, playing a key role for chemical communication within a species.

45 years ago Emanuel Gil-Av[10] and his colleagues at the Weizmann Institute in Israel started the epochal discovery of enantiomeric separation using gas chromatography. After two years, they published the first successful direct enantiomeric separation[11], which astonished the scientific community, since separation of enantiomers had been considered for many years as an untouchable problem. The discovery of a technique for separation of enantiomers laid the foundation for significant advances in life sciences and pharmaceutical industry[12]. In the same year, 1966, Robert Sidney Cahn, Christopher Ingold and Vladimir Prelog published the Cahn–Ingold–Prelog priority rules to distinguish the stereoisomers of molecules[13,14].

40 years ago a boom in application of stereospecific enzymes for asymmetric organic synthesis broke out[15,16]. The enzymes catalyse reactions under mild conditions of temperature, pH and pressure and can be used for production of optically active compounds serving as building blocks for the preparation of homochiral compounds. For these reasons, enzymes are widely used as catalysts in organic synthesis[17–25]. In 1992, the U.S. Food and Drug Administration published the policy statement for the development of new stereoisomeric drugs[26], followed by European guidelines in 1993, which came into force 15 years ago[27]. Many pharmaceuticals, agrochemicals, food additives, pheromones, fragrances and cosmetics are chiral[28–32] and their production is required and rapidly growing-up[33]. Chiral aliphatic hydroxy compounds comprise a very large group of these compounds.

In nature, chiral aliphatic hydroxy compounds play a very important role in chemical communication among living organisms. They act as sex pheromones produced by males or females to attract the opposite sex. Aggregation pheromones attract both sexes at a calling site and increase the density of conspecifics at one place. Some species release volatile chiral hydroxy compounds as alarm pheromones when they are attacked by a predator. Alarm pheromones can trigger fight or aggression in members of the same species. Trail pheromones are common in social insects to mark their paths. Chiral hydroxy compounds can attract predators, parasites, parasitoids, pests, or pollinators and can also act as repellents for other organisms.

This review summarizes our knowledge of the biologically relevant chiral aliphatic hydroxy compounds (Table I). The compounds are divided into eight classes: primary alcohols (IA), secondary alcohols (IB), tertiary alcohols (IC), glycols and diols (II), hydroxy ketones (III), hydroxy carboxylic acids (IV), hydroxy carboxylic esters (V) and hydroxy amines (VI). Information on chemical structure and physico-chemical properties[34,35], natural

TABLE I
Natural producers and applications of chiral aliphatic hydroxy compounds

Class	Compound	Producer species/Application									
		Bacteria	Fungi	Plants	Arthropods	Vertebrates	Drugs	Cosmetics	Food	Pest control	Others
IA. Primary alcohols	2-methylbutan-1-ol		•	•	•			•		•	•
	2-methylbut-3-en-1-ol				•					•	
	3-methyl-pentan-1-ol				•					•	
	3-ethyl-4-methylpentan-1-ol				•						
	2-ethylhexan-1-ol						•	•			
	2,6-dimethylhept-5-en-1-ol				•						
IB. Secondary alcohols	butan-2-ol	•	•	•	•	•	•		•	•	•
	3-methylbutan-2-ol		•	•	•	•				•	•
	3,3-dimethylbutan-2-ol					•					•
	but-3-en-2-ol										•
	4-phenylbut-3-en-2-ol							•			
	pentan-2-ol		•	•	•	•	•	•	•		•
	3-methylpentan-2-ol			•	•						
	4-methylpentan-2-ol				•		•				
	pent-3-en-2-ol	•	•	•	•		•				
	4-methylpent-3-en-2-ol				•		•				
	2-methylpentan-3-ol				•						
	pent-1-en-3-ol			•					•		
	hexan-2-ol			•	•	•	•	•			
	3-methylhexan-2-ol				•						
	5-methylhexan-2-ol				•						
	hexan-3-ol				•						
	4-methylhexan-3-ol				•						
	5-methylhexan-3-ol				•						
	hex-1-en-3-ol			•				•			
	heptan-2-ol		•	•	•	•	•	•	•		
	3-methylheptan-2-ol				•						
	hept-4-en-2-ol			•	•						
	6-methylhept-5-en-2-ol			•	•						
	heptan-3-ol		•		•						•
	4-methylheptan-3-ol				•						
	6-methylheptan-3-ol				•						
	hept-1-en-3-ol							•			

TABLE I
(*Continued*)

Class	Compound	Producer species/Application									
		Bacteria	Fungi	Plants	Arthropods	Vertebrates	Drugs	Cosmetics	Food	Pest control	Others
IB. Secondary alcohols	4-methylhept-4-en-3-ol				•						
	2-methylheptan-4-ol				•						
	6-methylhept-2-en-4-ol				•						
	octan-2-ol				•		•	•			
	octan-3-ol		•	•	•			•		•	•
	oct-1-en-3-ol		•		•	•		•	•		•
	octa-1,5-dien-3-ol		•							•	
	6-methyloctan-3-ol				•						
	2-methyloctan-4-ol				•						
	5-methyloctan-4-ol				•						
	α-ionols		•	•	•		•	•	•	•	
IC. Tertiary alcohols	linalool		•	•	•			•		•	
II. Glycols and diols	butane-2,3-diol	•		•	•				•	•	•
	hexane-1,2-diol							•			
	hexane-2,3-diol				•						
	2-ethylhexane-1,3-diol							•		•	•
	octane-1,2-diol							•			•
	octane-2,3-diol				•						
III. Hydroxy ketones	3-hydroxybutan-2-one			•	•				•	•	
	3-hydroxy-1-phenylbutan-2-one								•		
	3-hydroxy-4-phenylbutan-2-one								•		
	3-hydroxypentan-2-one								•		
	2-hydroxypentan-3-one								•		
	3-hydroxyhexan-2-one				•				•		
	3-hydroxy-5-methylhexan-2-one								•		
	2-hydroxyhexan-3-one				•				•		
	2-hydroxy-5-methylhexan-3-one								•		
	4-hydroxyhexan-3-one								•		
	3-hydroxyheptan-2-one								•		
	3-hydroxy-4-methylheptan-2-one								•		
	3-hydroxyhept-4-en-2-one								•		

TABLE I
(*Continued*)

Class	Compound	Producer species/Application								
		Bacteria	Fungi	Plants	Arthropods	Vertebrates	Drugs	Cosmetics	Food	Pest control	Others
III. Hydroxy ketones	2-hydroxyheptan-3-one								•		
	2-hydroxy-4-methylheptan-3-one								•		
	2-hydroxyhept-4-en-3-one								•		
	5-hydroxy-4-methylheptan-3-one				•				•		
	3-hydroxyoctan-2-one				•				•		
	3-hydroxyoct-4-en-2-one								•		
	2-hydroxyoctan-3-one				•				•		
	2-hydroxyoct-4-en-3-one								•		
	5-hydroxyoctan-4-one								•		
IV. Hydroxy carboxylic acids	lactic acid					•	•				
	2-hydroxybutanoic acid						•				
	2-hydroxy-3-methylbutanoic acid		•		•		•			•	
	3-hydroxybutanoic acid		•		•						
	2-hydroxypentanoic acid						•				
	2-hydroxy-3-methylpentanoic acid		•		•		•				
	2-hydroxy-4-methylpentanoic acid		•				•				
	2-hydroxyheptanoic acid		•							•	
	7-hydroxyoctanoic acid				•						
	mandelic acid						•	•			
V. Hydroxy esters	ethyl lactate				•	•			•		•
	butyl lactate							•			
	ethyl 2-hydroxy-3-methylbutanoate								•		
	ethyl 3-hydroxybutanoate			•							
	ethyl 2-hydroxy-4-methylpentanoate								•		
	1-ethylpropyl 3-hydroxy-2-methylpentanoate				•						
	ethyl 2-hydroxyhexanoate			•					•		
	ethyl 5-hydroxyhexanoate						•				
	isopropyl 5-hydroxyhexanoate				•						
	hex-3-en-1-yl 2-hydroxy-3-methylbutanoate				•						
	hex-3-en-1-yl 3-hydroxybutanoate				•						

TABLE I
(*Continued*)

Class	Compound	Producer species/Application									
		Bacteria	Fungi	Plants	Arthropods	Vertebrates	Drugs	Cosmetics	Food	Pest control	Others
VI. Hydroxy amines	1-aminopropan-2-ol						•				•
	1-(dimethylamino)propan-2-ol										•
	2-aminopropan-1-ol						•				•
	1-aminobutan-2-ol						•				•
	2-amino-1-phenylethan-1-ol					•	•				
	noradrenaline					•	•				
	adrenaline					•	•				
	ephedrine			•			•		•		

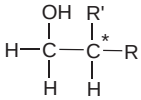
producers, biological functions and practical applications is listed for each class. Detailed information about individual compounds is summarized in the accompanying Tables IA–VI.

CLASS I. CHIRAL ALCOHOLS

Alcohols are common organic compounds which can be structurally viewed as hydroxy derivatives of alkanes or alkyl derivatives of water. The characteristic functional group of this class is the hydroxy group (–OH) attached to an sp^3-hybridized carbon atom. The hydroxy group generally makes the alcohol molecule polar. These groups can form hydrogen bonds among themselves or with other compounds. Due to the hydrogen bonds, alcohols can serve as protic solvents. Two opposing solubility trends in alcohols are the tendency of the polar hydroxy group to promote solubility in water and the tendency of the carbon chain to resist it. The small alcohols containing up to three carbon atoms are miscible in water because the hydroxy group solubilizes the short carbon chain; butanols, with a four-carbon chain, are moderately soluble in water because the two trends are balanced. The alcohols containing five or more carbons are insoluble in water because of the dominant effect of hydrophobic hydrocarbon chains. All simple alcohols are miscible in the organic solvents. Alcohols can be synthesized by a wide variety of methods, and their hydroxy groups can be easily converted to al-

most any other functional groups. Alcohols play a very important role in organic chemistry, serving as reagents, solvents, and synthetic intermediates. Most of the common alcohols are liquids at room temperature and have characteristic odour. Oxidation of alcohols, which is one of the most common organic reactions, leads to aldehydes, ketones and carboxylic acids, while reduction of alcohols leads to alkanes.

CLASS IA. CHIRAL PRIMARY ALCOHOLS



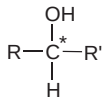
Chiral primary alcohols have the hydroxy group attached to a primary carbon atom, which bears two hydrogen atoms and another chiral carbon atom or the hydrocarbon residue which contains a chiral carbon atom. Primary alcohols can be oxidized, and the aldehydes are formed during oxidation processes.

Biological functions. The simplest chiral primary alcohol 2-methylbutan-1-ol possesses a rich diversity of biological functions. This compound is produced by the fungi of genus *Fusarium* sp. (Hypocreales: Nectriaceae), which causes a widespread disease of maize ears known as "*Fusarium* kernel or ear rot" and also produces fumonisin mycotoxins. Fungal 2-methylbutan-1-ol attracts mold mite *Rhyzoglyphus robini* (Astigmata: Acaridae)[39] or nitidulid sap beetle *Carphophilus davidsoni* (Coleoptera: Nitidulidae)[40]. Sap beetles are involved in the infection process as *Fusarium* vectors. They help with the spreading of the fungus to other host plants. Volatile 2-methylbutan-1-ol of several plant species in the genus *Cocos* sp., *Elaeis* sp. (Arecales: Arecacea) or *Saccharum* sp. (Poales: Poaceae) acts as a synergist to rhynchophorol pheromone and attracts American palm weevil *Rhynchophorus palmarum* and related *Dynamis borassi* (Coleoptera: Curculionidae)[42]. 2-Methylbutan-1-ol is a volatile compound of bread, fruits and other foods which attracts several other animals and pests *Glischrochilus* sp. (Coleoptera: Nitidulidae)[48] or *Vespula* sp. (Hymenoptera: Vespidae)[49,50]. Triatomine bugs *Rhodnius prolixus* and *Triatoma infestans* (Heteroptera: Reduviidae) use 2-methylbutan-1-ol produced by metasternal glands in sexual communication[46,47]. This compound was also found in abdominal defensive secretions of *Proteinus* sp. (Coleoptera: Staphylidae)[45]. Other primary alcohols were detected as (i) attractants for moths *Lacanobia subjuncta*, *Mamestra configurata*, *Xestia c-nigrum* (Lepidoptera: Noctuidae):

3-methylpentan-1-ol[54]; (ii) sex pheromones of *Polyergus* sp. and *Myrmecocystus* sp. (Hymenoptera: Formicidae): 3-ethyl-4-methylpentan-1-ol[56–58], 2,6-dimethylhept-5-en-1-ol[68]; (iii) alarm pheromones of *Ropalidia* sp. (Hymenoptera: Vespidae) and *Acanthomyops claviger* (Hymenoptera: Formicidae): 2-ethylhexan-1-ol[60], 2,6-dimethylhept-5-en-1-ol[65,66].

Applications. 2-Methylbutan-1-ol and 2-methylbut-3-en-1-ol can be used in the control of several important pests. 2-Methylbutan-1-ol is synthesized by microorganisms as new biofuel to solve global energy and environmental problems[51,52]. 2-Ethylhexan-1-ol is a component of several fragrances[59], cosmetics, pharmaceuticals and plasticizers[62–64].

CLASS IB. CHIRAL SECONDARY ALCOHOLS



Chiral secondary alcohols have the hydroxy group attached to a secondary carbon atom, which bears a hydrogen atom and two different alkyl groups R and R′. Secondary alcohols are easily oxidized to give excellent yields of ketones (Class III).

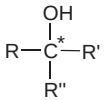
Biological functions. This class of chiral aliphatic hydroxy compounds is the largest in this review and comprises about forty compounds with many different biological functions. Volatile compounds octan-3-ol and oct-1-en-3-ol from fruiting bodies of fungi (Polyporales) strongly attract several species of cucujid grain beetles (Coleoptera: Cucujidae)[224,225,233] and *Onychirus armatus* (Collembola: Onychiuridae)[238]. Flowers emit fragrances such as butan-2-ol, pentan-2-ol, 3-methylpentan-2-ol, hexan-2-ol and heptan-2-ol that mimic the sexual pheromones of insects, mostly Hymenoptera and Coleoptera. Pseudocopulation or sexual mimicry is a remarkable and puzzling pollination strategy within the (Asparagales: Orchidaceae)[105,157], (Alismatales: Araceae)[77], (Cycadales: Cycadaceae)[106]. In this pollination strategy, male insects arrive at flowers and attempt copulation with the median petal. Fruits and leaves volatiles pentan-2-ol, pent-1-en-3-ol, hexan-2-ol, hex-1-en-3-ol, heptan-2-ol, hept-4-en-2-ol, oct-1-en-3-ol are attractive for herbivor or pest insects, mostly Coleoptera[42,107,108,227,228], Diptera[121,240,241,243] or Lepidoptera[151,245]. Also animals emit several long chain secondary alcohols, for example 4-methylheptan-3-ol, octan-3-ol or oct-1-en-3-ol, which attract their parasitoids

(Diptera[194,195,229] and Hymenoptera[193]), haematophagous flies, mosquitos (Diptera)[231,247–270,274] or haematophagous bugs (Heteroptera)[275]. Chiral secondary alcohols (*S*)-butan-2-ol, 3-methylbutan-2-ol, (*S*)-pentan-2-ol and 4-methylpent-3-en-2-ol are known sex pheromones of *Rhodnius prolixus* (Heteroptera: Reduviidae)[46]. Other sex pheromones were found for (i) *Platypus mutatus* (Coleoptera: Platypodidae)[177] (*S*)-6-methylhept-5-en-2-ol; (ii) *Eriocrania cicatricella* (Lepidoptera: Eriocraniidae)[152,153] (*R*)-heptan-2-ol, (*S*)-heptan-2-ol, (2*R*,4*Z*)-hept-4-en-2-ol and (2*S*,4*Z*)-hept-4-en-2-ol; (iii) *Phlogophora meticulosa* (Lepidoptera: Noctuidae)[184,185] 6-methylhept-5-en-2-ol; (iv) *Rhyacophila nubila* (Trichoptera: Rhyacophilidae)[154] (*R*)-heptan-2-ol, (*S*)-heptan-2-ol; (v) *Molanna angustata* (Trichoptera: Molannidae)[155] (*S*)-heptan-2-ol. Beetles *Dynamis borassi*, *Rhabdoscelus obscurus*, *Rhynchophorus* sp., *Scyphophorus acupunctatus*, *Sphenophorus levis* (Coleoptera: Curculionidae)[42,208–214,278–280], *Metamasius* sp. (Coleoptera: Dryophthoridae)[204–207], *Scapanes australis* (Coleoptera: Scarabaeidae)[71,72], *Ahasversus advena* (Coleoptera: Silvanidae)[235], *Gnathotrichus* sp., *Scolytus* sp. (Coleoptera: Scolitidae)[144–146,173–176,186,191,192] use (*R*)-butan-2-ol, (*S*)-butan-2-ol, 4-methylhexan-3-ol, (*R*)-6-methylhept-5-en-2-ol, (*S*)-6-methylhept-5-en-2-ol, 4-methylheptan-3-ol, 2-methylheptan-4-ol, 6-methylhept-2-en-4-ol, (*R*)-oct-1-en-3-ol, 2-methyloctan-4-ol, 3-methyloctan-4-ol, 5-methyloctan-4-ol as aggregation pheromones. Hymenoptera species *Apis* sp., *Melipona* sp., *Trigona* sp. (Apidae)[159,161,163,165–167], *Vespa* sp. (Vespidae)[99], *Atta* sp., *Crematogaster* sp., *Myrmica* sp., *Pseudomyrmex* sp., *Tetramorium* sp., *Trachymyrmex* sp. (Formicidae)[112,120,132–141,169,170,187,196,197,217,218,230] produce a large spectrum of alarm pheromones: (*R*)-pentan-2-ol, (*S*)-pentan-2-ol, 3-methylpentan-2-ol, 2-methylpentan-3-ol, hexan-2-ol, 3-methylhexan-2-ol, 5-methylhexan-2-ol, hexan-3-ol, 4-methylhexan-3-ol, heptan-2-ol, 3-methylheptan-2-ol, heptan-3-ol, 4-methylheptan-3-ol, octan-2-ol, (*R*)-octan-3-ol, (*S*)-octan-3-ol, 6-methyloctan-3-ol.

Applications. The enantiomers of secondary alcohols have generally different odours. For example, (*R*)-pentan-2-ol has light, seedy, and sharp odour, whereas (*S*)-pentan-2-ol has heavy, wild berry, ripe, dusty, and astringent odour; (*R*)-hexan-2-ol can be recognized by mushroom, dusty, and oily odour, the oposite enantiomer (*S*)-hexan-2-ol by mushroom, green, ripe, berry, astringent, and metallic odour[29]. Secondary alcohols can be used for production of cosmetic fragrances[29,88]. Fungi volatile metabolites such as 3-methylbutan-2-ol, pentan-2-ol, heptan-3-ol, octan-3-ol, oct-1-en-3-ol cause the sick building syndrom[38,82,104,221,222]. Butan-2-ol, pent-1-en-3-ol, oct-1-en-3-ol are used for the quality control of food (cheese, fishes, wines, spirits)[81,111,124–126,156]. Other applications of secondary alcohols are in medi-

cine as anesthetics[73,74] butan-2-ol, pentan-2-ol, hexan-2-ol, heptan-2-ol or as intermediates for synthesis of anti-Alzheimer disease drugs[30] (*S*)-pentan-2-ol and (*S*)-heptan-2-ol.

CLASS IC. CHIRAL TERTIARY ALCOHOLS

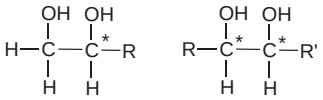


Chiral tertiary alcohols have the hydroxy group attached to a tertiary carbon atom, which bears three different alkyl groups R, R′, and R″. Tertiary alcohols cannot be easily oxidized because there is no hydrogen atom available on the carbon atom bearing the hydroxy group, and any oxidation must take place by breaking carbon–carbon bonds. Tertiary alcohols can be reduced to alkanes by replacement of the hydroxy group by a hydrogen atom.

Biological functions. 3,7-Dimethylocta-1,6-dien-3-ol (linalool) is the most important tertiary alcohol which is very common in many plants. Flowers of *Cirsium arvense* (Asterales: Asteraceae)[296], *Silene otites* (Caryophyllales: Caryophyllaceae)[297], *Cornus florida* (Cornales: Cornaceae)[285], *Glochidion* sp. (Malpighiales: Phyllantaceae)[281], *Salix* sp. (Malpighiales: Salicaceae)[303,304], *Daphne mezereum* (Malvales: Thymelaeaceae)[286], *Ficus hispida* (Rosales: Moraceae)[287] produce linalool to attract pollinators *Andrena* sp., *Lasioglossum* sp., *Colletes* sp., *Ceratosolen* sp. (Hymenoptera) or *Epicephala* sp., *Paralobesia viteana* (Lepidoptera). The production of linalool increases in herbivore-damaged plants. Damaged leaves emit higher concentrations of linalool, which attracts predators *Neoseiulus* sp., *Phytoseiulus* sp. (Prostigmata: Phytoseiidae)[298] or insectivorous birds[312]. Several moths *Scoliopteryx libatrix*, *Cydia pomonella*, *Busseola fusca*, *Spodoptera frugiperda*, *Heliothis* sp., *Helicoverpa* sp. (Lepidoptera: Noctuidae)[288,307,309–311] are sensitive to linalool produced by plant leaves. (*S*)-Linalool was detected in *Colletes cunicularius* (Hymenoptera: Colletidae) as sex pheromone[289–293] and abdominal glands of *Podisus maculiventris* (Hemiptera: Pentatomidae) include linalool as aggregation pheromone[314].

Applications. Linalool shows acaricidal, antigiardial, trypanocidal, antimicrobial activities[282,299–301] and has antinoceptive and antiinflammatory effects[284]. Linalool is the major compound of coriander essential oil, which is used as a flavor ingredient in cooking and in a traditional medicine[294].

CLASS II. CHIRAL GLYCOLS AND DIOLS



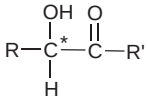
Alcohols with two hydroxy groups are called glycols or diols. The term glycol generally means a 1,2-diol (vicinal diol). In glycols one of the two carbon atoms bearing hydroxy groups is chiral, whereas in diols the both hydroxy groups are attached to two chiral carbon atoms. Thus, the diols exist as stereoisomers [(*R*,*R*), (*R*,*S*), (*S*,*R*), and (*S*,*S*)]. They have two diastereomers [(*R*,*R*)/(*S*,*S*) × (*R*,*S*)/(*S*,*R*)], and two pairs of enantiomers [(*R*,*R*)/(*S*,*S*) and (*R*,*S*)/(*S*,*R*)]. Diols react like alcohols, such as esterification and ether formation. They are used as comonomers in polycondensation reactions forming polyesters and polyurethanes. Diols can be converted to cyclic ethers with acid catalyst (diol cyclization). In glycol cleavage, the C–C bond in a vicinal diol is cleaved with the formation of a ketone or aldehyde.

Biological functions. Diols are mostly sex or aggregation pheromones of beetles *Curius dentatus*, *Hylotrupes bajulus*, *Megacyllene caryae*, *Neoclytus acuminatus*, *Pyrrhidium sanguineum*, *Xylotrechus* sp. (Coleoptera: Cerambycidae)[345–351,358–365], *Amphimallon solstitiale*, *Rhizotrogus majalis*, *Scapanes australis* (Coleoptera: Scarabaeidae)[71,72,326,327]. (2*R*,3*R*)-Butane-2,3-diol, (2*S*,3*S*)-butane-2,3-diol, *meso*-butane-2,3-diol, (2*R*,3*R*)-hexane-2,3-diol, (2*R*,3*S*)-hexane-2,3-diol, (2*S*,3*R*)-hexane-2,3-diol, (2*S*,3*S*)-hexane-2,3-diol, and (2*S*,3*S*)-octane-2,3-diol produced in prothorax glands play a significant role in coleoptera communication. Sex pheromone (2*R*,3*R*)-butane-2,3-diol was detected also in abdominal glands of *Leucophaea madarea* and *Eurycotis florida* (Dictyoptera: Blattidae)[328,329]. Butane-2,3-diol is the only known compound produced by plants: *Cocos* sp., *Elaeis* sp. (Arecales: Arecacea), *Jacaratia* sp. (Brassicales: Caricaceae), *Saccharum* sp. (Poales: Poaceae) which acts as a synergist to rhynchophorol pheromone and attracts American palm weevil *Rhynchophorus palmarum* and related *Dynamis borassi* (Coleoptera: Curculionidae)[42].

Applications. Butane-2,3-diol is discussed in literature as a new marker for ischemia in patients with acute myocardial infarction[338]. Butane-2,3-diol containing mainly the (+) and (–) stereoisomers could be a very useful cryoprotectant for organ cryopreservation. However, it would perhaps be better to use it in combination with other cryoprotectants, since it is a little more toxic than glycerol or propane-1,2-diol at high concentrations[339,240]. Several applications of hexane-1,2-diol, octane-1,2-diol and 2-ethyl-

hexane-1,3-diol in cosmetics, antiperspirants, deodorants, shaving gels or skin desinfections were patented[342–344,356,357]. 2-Ethylhexane-1,3-diol is used in synthesis of insect repellents[352–355].

CLASS III. CHIRAL HYDROXY KETONES



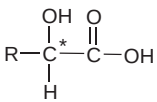
Chiral hydroxy ketones are organic compounds containing hydroxy groups on chiral carbon atom, which is near or adjacent to carbonyl group (>C=O). The carbonyl carbon atom is sp^2-hybridized, with the expected sp^2 geometry. Ketones have a trigonal planar arrangement of groups around the carbonyl carbon atom. Hydroxy ketones are good solvents for polar alcohols and they are also remarkably soluble in water. Ketones are amphoteric, they can react as both acids and bases. Their reactivity arises from the electronegativity of the oxygen atom and the polarization of the carbon–oxygen double bond. Hydroxy ketones can be reduced by hydride reagents to diols (Class II).

Biological functions. 3-Hydroxybutan-2-one, 3-hydroxyhexan-2-one, 2-hydroxyhexan-3-one, 3-hydroxyoctan-2-one and (*S*)-2-hydroxyoctan-3-one as well as similar diols (Class IV) are sex and aggregation pheromones of beetles. These compounds are produced in prothorax glands of *Anaglyptus subfaciatus*, *Brothylus gemmulatus*, *Hylotrupes bajulus*, *Neoclytus acuminatus*, *Phymatodes lecontei*, *Pyrrhidium sanguineum*, *Xylotrechus* sp. (Coleoptera: Cerambycidae)[36,345–351,358–365,381–385], *Amphimallon solstitiale*, *Rhizotrogus majalis*, *Scapanes australis* (Coleoptera: Scarabaeidae)[71,72,326,327]. Sex pheromone 3-hydroxybutan-2-one was detected also in male sternal glands of *Leucophaea madarea*, *Henschoutedenia* sp. and *Nauphoeta cinerea* (Dictyoptera: Blattidae)[328,371–375]. Several plants *Cocos* sp., *Elaeis* sp. (Arecales: Arecacea), *Jacaratia* sp. (Brassicales: Caricaceae), *Sicana odorifera* (Cucurbitales: Cucurbitaceae), *Quercus* sp. (Fagales: Fagaceae), *Clusia* sp. (Malphigiales: Clusiaceae), *Psidium guajava* (Myrtales: Myrtaceae), *Saccharum* sp. (Poales: Poaceae), *Prunus* sp. (Rosales: Rosaceae), *Musa* sp. (Zingiberales: Musaceae) emit from their fruits, flowers, leaves or sack volatile 3-hydroxybutan-2-one, which attracts insects (Coleoptera, Dictyoptera, Lepidoptera)[42,43,83,333,366–368]. (4*S*,5*R*)-5-Hydroxy-4-methyl-heptan-3-one (sitophinone) is a grain-derived volatile attractive for an internal-feeding pest of intact grains *Sitophilus oryzae* (Coleoptera: Curculionidae) and an

external-feeding pest of damaged grains and flour *Tribolium castaneum* (Coleoptera: Tenebrionidae)[386–389].

Applications. Chiral hydroxy ketones can be very well characterized as a class of food volatiles. Each compound has its typical caramel-sweet, buttery, hay-like, floral, earthy, nut-like, mushroom, cheese, sour milk, green, herbaceous, woody or spicy odour. These compounds are volatiles of cheese, durian, tea, coffee, cocoa, honey, butter, wine, sherry, soy sauce, beverages, beef or mutton fat[101,378–380].

CLASS IV. CHIRAL HYDROXY CARBOXYLIC ACIDS

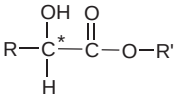


Chiral hydroxy carboxylic acids are organic compounds containing hydroxy groups on chiral carbon atom, which is near or adjacent to carboxyl group (–COOH). These compounds are distinctly acidic due to the presence of the carboxyl group. Carboxylic acids donate protons by heterolytic cleavage of the acidic O–H bond to give a proton and a carboxylate anion. These compounds form hydrogen bonds with water, and the lower-molecular-weight compounds up to four carbon atoms are miscible in water. As the hydrocarbon chain length increases, their water solubility decreases. Acids with more than ten carbon atoms are essentially insoluble in water. Hydroxy carboxylic acids are very soluble in alcohols, because the acids and alcohols form hydrogen bonds. Hydroxy carboxylic acids can be reduced to glycols (Class II), alkylated to hydroxy ketones (Class III) or converted to hydroxy carboxylic esters (Class V) in the acid-catalyzed esterification of carboxylic acids with alcohols.

Biological functions. Lactic acid is attractive for *Aedes* sp. and *Anopheles* sp. (Diptera: Culicidae)[390–392]. (*R*)-3-Hydroxybutanoic acid and its dimer (*R*)-3-{[(*R*)-3-hydroxybutanoyl]oxy}butanoic acid have been identified as sex pheromones of a spider. These compounds elicit web reduction behavior by males of *Linyphia triangularis* (Araneae: Linyphiidae) on the webs of unmated adult females[404]. Defensive osmeterial secretions of the pre-final instar larvae of the citrus swallowtail *Papilio demodocus* (Lepidoptera: Papilionidae) contains 3-hydroxybutanoic acid[405]. Mandibular glands of *Apis mellifera capensis* virgin queens (Hymenoptera: Apidae) produce 7-hydroxyoctanoic acid[412].

Applications. Chiral hydroxy carboxylic acids have a wide range of applications in medicine. Lactic acid, 2-hydroxybutanoic acid, 2-hydroxy-3-methylbutanoic acid, 2-hydroxypentanoic acid, 2-hydroxy-3-methylpentanoic acid, 2-hydroxy-4-methylpentanoic acid, 2-hydroxyheptanoic acid and mandelic acid are mostly used as pharmaceutical intermediates[396,416,417]. They show antiviral[393,394,413–415], antifungal and insecticidal activities and are part of depsipeptide antibiotics (Aureobasidins, Pleofungins)[395,399,409–411]. Mandelic acid is used for production of cosmetic, antiperspirant and dermatological agents[419–421].

CLASS V. CHIRAL HYDROXY CARBOXYLIC ESTERS



Chiral hydroxy carboxylic esters are organic compounds containing hydroxy groups on chiral carbon atom, which is near to alkoxy group (–OR); general formula RCOOR′. These compounds are more volatile than carboxylic acids of similar molecular weight.

Biological functions. Ethyl (*S*)-lactate acts as a synergist to rhynchophorol pheromone of American palm weevil *Rhynchophorus cruentatus* (Coleoptera: Curculionidae)[42,454]. Male volatile 1-ethylpropyl (2*S*,3*R*)-3-hydroxy-2-methylpentanoate or (2*S*,3*R*)-sitophilate of the grain weevil *Sitophilus granarius* (Coleoptera: Curculionidae) is known as aggregation pheromone and may play a significant role in enhancing the trap catch of this economically important pest[431–433]. Defensive osmeterial secretions of pre-final instar larvae of the citrus swallowtail *Papilio demodocus* (Lepidoptera: Papilionidae) contain methyl 3-hydroxybutanoate[405]. Adult males of asparagus flies *Plioreocepta poeciloptera* (Diptera: Tephritidae) exhibit a typical calling behavior during which they emit a single volatile compound, isopropyl (*S*)-5-hydroxyhexanoate[434]. The males of decorator wasps *Eucerceris* sp. (Hymenoptera: Sphecidae) have been observed to display abdomen-dragging behavior on plants surrounding their nest. During this behavior they apply a territorial-marking sex pheromone hex-3-en-1-yl (*R*)-3-hydroxybutanoate which serves to alert females to the male territory for courtship and mating[436].

Applications. Chiral hydroxy carboxylic esters are volatile compounds of wine, sherry, spirits or beverages[111,429]. Ethyl (*S*)-5-hydroxyhexanoate is an intermediate in the synthesis of several pharmaceuticals and anti-Alzheimer disease drugs[30].

TABLE IA
Chiral primary alcohols

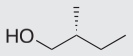
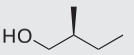
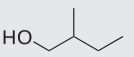
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-2-Methylbutan-1-ol Cas.: 616-16-0						
A	*Phymatodes lecontei*	Coleoptera	prothorax glands	aggregation pheromone, M		36
(*S*)-2-Methylbutan-1-ol Cas.: 1565-80-6						
					attractant for wasps	37
2-Methylbutan-1-ol Cas.: 137-32-6						
F	*Aspergillus* sp.	Eurotiales	fungal metabolism		detection of fungal indoor pollution	38
F	*Fusarium oxysporum*	Hypocreales		attractant for *Rhizoglyphus robini* (Astigmata)		39
F	*Fusarium* sp.	Hypocreales		attractant for *Carpophilus humeralis* (Coleoptera)		40
F	*Rhizopus oligosporus*	Mucorales		volatile metabolite	tempeh fermentation	41
P	*Cocos* sp. *Elaeis* sp. *Saccharum* sp.	Arecales Poales		rhynchophorol pheromone synergist, attractant for *Rhynchophorus palmarum*, *Dynamis borassi* (Coleoptera)		42
P	*Psidium guajava* L.	Myrtales	fruit	fruit flavor		43
A	*Carpophilus davidsoni*	Coleoptera		attractant	pest trap	44
A	*Proteinus* sp.	Coleoptera	abdominal glands	defensive secretions		45
A	*Rhodnius prolixus* *Triatoma infestans*	Heteroptera	metasternal glands	sexual communication, M+F		46,47

TABLE IA
(*Continued*)

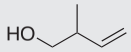
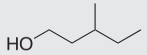
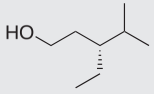
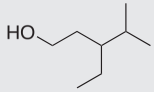
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
	wheat bread			attractant for (Coleoptera) *Glischrochilus* sp.	pest trap	48
	fruits, food			attractant for *Vespula* sp. (Hymenoptera)		49,50
					biofuels	51,52
2-Methylbut-3-en-1-ol Cas.: 4516-90-9						
A	*Monochamus galloprovincialis*	Coleoptera		attractant, kairomone	pest trap	53
3-Methylpentan-1-ol Cas.: 589-35-5						
A	*Lacanobia subjuncta* *Mamestra configurata* *Xestia c-nigrum*	Lepidoptera		attractant	moth attractants (Lepidoptera: Noctuidae)	54,55
(*R*)-3-Ethyl-4-methylpentan-1-ol Cas.: 100431-82-1						
A	*Polyergus breviceps*	Hymenoptera	mandibular glands	queen sex pheromone		57,58
3-Ethyl-4-methylpentan-1-ol Cas.: 38514-13-5						
A	*Polyergus rufescens* *P. breviceps*	Hymenoptera	mandibular glands	queen sex pheromone		56–58

TABLE IA
(*Continued*)

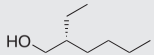
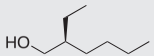
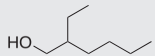
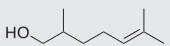
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-2-Ethylhexan-1-ol Cas.: 50373-29-0						
				heavy, earthy, slightly floral odour	synthesis of fragrances	59
(*S*)-2-Ethylhexan-1-ol Cas.: 128821-84-1						
				light, sweet floral odour	synthesis of fragrances	59
2-Ethylhexan-1-ol Cas.: 104-76-7						
A	*Ropalidia* sp.	Hymenoptera	poison glands	alarm pheromone		60
					indoor air pollutant plasticizer metabolite	61–63
					cosmetics, pharmaceuticals	64
2,6-Dimethylhept-5-en-1-ol Cas.: 4234-93-9						
A	*Acanthomyops claviger*	Hymenoptera		alarm pheromone		65,66
A	*Camponotus clarithorax*	Hymenoptera	mandibular glands			67
A	*Myrmecocystus* sp.	Hymenoptera	mandibular glands	sex pheromone		68

TABLE IB
Chiral secondary alcohols

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-Butan-2-ol Cas.: 14898-79-4						
B	*Lactobacillus* sp.	Lactobacillales			bacterial spoilage of distilled spirits, beverages	69,70
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	71,72
A	mammals				anesthetics	73,74
(*S*)-Butan-2-ol Cas.: 4221-99-2						
F	*Saccharomyces* sp.	Saccharomycetales			fermentation of spirits and beverages	69,70
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	71,72
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
A	mammals				anesthetics	73,74
Butan-2-ol Cas.: 78-92-2						
B,F	bacteria, fungi				biofuels	75,76
F	*Rhizopus oligosporus*	Mucorales		volatile metabolite	tempeh fermentatiton	41
P	*Homalomena propinqua*	Alismatales	flowers	attractant for pollinator beetle *Parastasia bimaculata Chaloenus schwalleri*		77
A	*Cochliomyia hominivorax*	Diptera		attractant		78
				inhibitors of HIV protease	substituted butan-2-ols	79
					green olives fermentation	80
				cheese volatiles	cheese quality control	81

TABLE IB
(*Continued*)

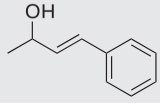
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
3-Methylbutan-2-ol Cas.: 598-75-4						
F	*Strachybotrys chartarum*	Moniliales		volatile metabolite	sick building syndrom indoor fungi fingerprint	82
P	*Sicana odorifera*	Cucurbitales	fruit	fruit aroma		83
P	*Gossypium* sp.	Malvales	leaves	cotton leaf-derived volatiles	growth inhibition of *Aspergillus flavus*	84
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
					moth attractants (Lepidoptera: Noctuidae)	55
3,3-Dimethylbutan-2-ol Cas.: 464-07-3						
A	guinean pig	Artodactyla	liver	activity of liver microsomal enzymes	Soman degradation pathway	85
				precursor to a nerve agent Soman	preparation of cataluminescence sensor	86
But-3-en-2-ol Cas.: 598-32-3						
					synthesis of polyketides	87
4-Phenylbut-3-en-2-ol Cas.: 17488-65-2						
					cosmetic fragrance	88

TABLE IB
(*Continued*)

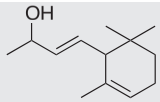
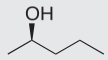
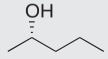
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
α-Ionol (4-(2,6,6-trimethylcyclohex-2-en-1-yl)-but-3-en-2-ol) Cas.: 25312-34-9						
F	*Saccharomyces cerevisiae*	Saccharomycetales			plant aromas production	89
P	*Laurus nobilis* L.	Laurales	leaves		food, drugs, cosmetics	90
P	*Zea mays*	Poales	roots	growth inhibitor of *Fusarium*	antifungal compound	91
P	*Rubus laciniata* L. *Prunus persica* L.	Rosales	leaves fruits	aroma		92,93
A	*Bactrocera latifrons*	Diptera	rectal gland	M attractant; phagostimulant		94–97
					cosmetic fragrance	29,88
(*R*)-Pentan-2-ol Cas.: 31087-44-2						
P	*Passiflora edulis*	Violales	fruits			98
A	*Vespa mandariana*	Hymenoptera	poison glands	alarm pheromone		99
A	mammals				anesthetics	73,74
				light, seedy, sharp odour	odorant	29
(*S*)-Pentan-2-ol Cas.: 26184-62-3						
P	*Passiflora edulis*	Violales	fruits			98
P	*Musa* sp.	Zingiberales	fruits			29,100,101
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
A	*Vespa mandariana*	Hymenoptera	poison glands	alarm pheromone		99
A	mammals				anesthetics	73,74

TABLE IB
(*Continued*)

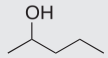
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
					intermediate in the synthesis of anti-Alzheimer drugs	30,102,103
				heavy, wild berry, ripe, dusty, astringent odour	odorant	29
Pentan-2-ol Cas.: 6032-29-7						
F	*Penicillium* sp. *Aspergillus* sp. *Cladosporium* sp.	Eurotiales Eurotiales Moniliales			microbial volatile organic compounds - the sick building syndrome	104
P	*Orphys* sp.	Asparagales	flowers	insect pollination		105
P	*Cycas* sp.	Cycadales	flowers	insect pollination		106
P	*Cocos* sp. *Zea* sp. *Rubus* sp. *Musa* sp.	Arecales Poales Rosales Zingiberales	fruit	flavor		29,100
P	*Musa* sp.	Zingiberales	dried-fruit	attractant for coleopterans *Carpophilius hemipterus*		107
P	*Prunus* sp.	Rosales	fruit	attractant for coleopterans *Conotrachelus nenuphar*		108
A	*Rhyzopertha dominica*	Coleoptera		metabolites		109
A	*Platyzosteria armata*	Dictyoptera		defensive secretions		110
				cheese volatiles	cheese quality control	81
					spirits, beverages aroma	111

TABLE IB
(*Continued*)

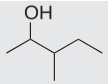
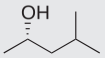
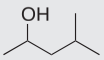
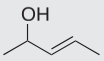
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
3-Methylpentan-2-ol Cas.: 565-60-6						
P	*Cycas* sp.	Cycadales	flowers	insect pollination		106
A	*Rhyzopertha dominica*	Coleoptera		metabolites		109
A	*Crematogaster nigriceps*	Hymenoptera	mandibular glands	alarm pheromone		112
(*S*)-4-Methylpentan-2-ol Cas.: 14898-80-7						
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
4-Methylpentan-2-ol Cas.: 108-11-2						
A	*Anastrepha ludens*, *A. obliqua*	Diptera		kairomon		113
A	mammals				anesthetics	73
Pent-3-en-2-ol Cas.: 1569-50-2						
B F	*Methylobacterium* sp. *Penicillium viridicatum*	Rhizobiales Eurotiales		volatile organic compounds human allergic reactions		114
P	*Actinidia deliciosa*	Ericales	fruit	kiwi fruit flavor		115
P	*Psidium guajava* L.	Myrtales	fruit	fruit flavor		43
A	*Dendroctonus pseudotsugae*	Coleoptera				116,117
					synthesis of cryptophycin	118

TABLE IB
(*Continued*)

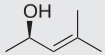
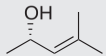
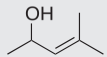
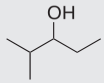
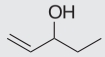
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-4-Methylpent-3-en-2-ol Cas.: 74112-34-8						
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
(*S*)-4-Methylpent-3-en-2-ol Cas.: 50373-46-1						
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
4-Methylpent-3-en-2-ol Cas.: 4325-82-0						
					synthesis of antimalarial 1,2,4-trioxanes	119
2-Methylpentan-3-ol Cas.: 565-67-3						
A	*Rhyzopertha dominica*	Coleoptera		metabolites		109
A	*Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm and defence		120
Pent-1-en-3-ol Cas.: 616-25-1						
P	*Momordica charantia*	Cucurbitales	fruit	*Dacus cucurbitae* attractant		121
P	*Camellia* sp.	Ericales	leaves	aroma	green tea aroma	122
P	*Olea* sp.	Lamiales	fruit		olive oil discrimination	123
P	*Psidium guajava* L.	Myrtales	fruit	fruit flavor		43

TABLE IB
(*Continued*)

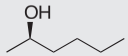
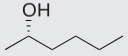
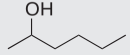
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
	fishes (*Sparus aurata, Clupea harengus, Salmo salar, Oncorhynchus* ...)			lipid oxidation off-flavor	indicator of frozen fish quality	124–126
(*R*)-Hexan-2-ol Cas.: 26549-24-6						
A	mammals				anesthetics	73,74
				mushroom, dusty, oily odour	odorant	29
(*S*)-Hexan-2-ol Cas.: 26549-24-6						
P	*Musa* sp.	Zingiberales	fruits			29,100,101
A	mammals				anesthetics	73,74
				mushroom, green, ripe, berry, astringent, metallic odour		29
Hexan-2-ol Cas.: 626-93-7						
P	*Dianthus caryophyllus*	Caryophyllales	flower petals	fragrance volatiles		127,128
P	*Cocos* sp. *Zea* sp. *Rubus* sp. *Musa* sp.	Arecales Poales Rosales Zingiberales	fruit	flavor		29,100
P	*Cycas* sp.	Cycadales	flowers	insect pollination		106
P	*Prunus* sp.	Rosales	fruit	attractant for coleopterans *Conotrachelus nenuphar*		108

TABLE IB
(*Continued*)

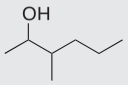
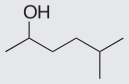
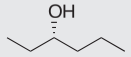
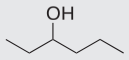
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
P	*Nicotiana* sp.	Solanales	flowers			129
A	*Periplaneta americana*	Blattaria		olfactory information		130
A	*Rhyzopertha dominica*	Coleoptera		metabolites		109
A	*Apis mellifera*	Hymenoptera		olfactory information		131
A	*Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm and defence		120
3-Methylhexan-2-ol Cas.: 2313-65-7						
A	*Crematogaster nigriceps* *Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm pheromone alarm and defence		112,120
5-Methylhexan-2-ol Cas.: 627-59-8						
A	*Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm and defence		120
(S)-Hexan-3-ol Cas.: 6210-51-1						
A	*Rhodnius prolixus*	Heteroptera	metasternal glands	sexual communication, M+F		46
Hexan-3-ol Cas.: 623-37-0						
A	*Crematogaster nigriceps* *Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm pheromone alarm and defence		112,120
A	*Myrmica* sp.	Hymenoptera	mandibular glands	workers attractant		132–134
A	*Tetraponera penzigi*	Hymenoptera	mandibular glands			142

TABLE IB
(*Continued*)

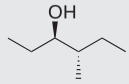
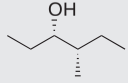
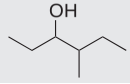
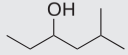
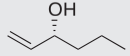
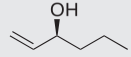
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(3*R*,4*S*)-4-Methylhexan-3-ol Cas.: 73176-99-5						
A	*Tetramorium impurum*	Hymenoptera	mandibular glands	M		143
(3*S*,4*S*)-4-Methylhexan-3-ol Cas.: 99602-93-4						
A	*Scolytus amygdali*	Coleoptera		aggregation pheromone, F		144–146
4-Methylhexan-3-ol Cas.: 615-29-2						
A	*Tetramorium caespitum*	Hymenoptera	mandibular glands			147,148
A	*Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm and defence		120
A	*Leiobunum nigripalpi*	Opoliones		defensive secreations		149
5-Methylhexan-3-ol Cas.: 623-55-2						
A	*Staphylinus dimidiaticornis*	Coleoptera	abdominal glands			150
(*R*)-Hex-1-en-3-ol Cas.: 139164-92-4						
				top impact, acid, meat odour	odorant	29
(*S*)-Hex-1-en-3-ol Cas.: 139164-93-5						
				metallic, green, earthy odour	odorant	29

TABLE IB
(*Continued*)

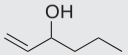
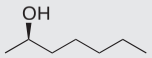
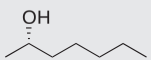
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Hex-1-en-3-ol Cas.: 4798-44-1						
P	*Brassica oleracea*	Brassicales	leaves	host-plant attractant (*Plutella xylostella*)		151
(*R*)-Heptan-2-ol Cas.: 6033-24-5						
P	*Passiflora edulis*	Violales	fruits			98
A	*Eriocrania cicatricella*	Lepidoptera		sex pheromone, F		152,153
A	*Rhyacophila nubila*	Trichoptera	F abdominal gland	sex pheromone, F		154
A	mammals				anesthetics	73
				fruity, sweet, oily, fatty odour	odorant	29
(*S*)-Heptan-2-ol Cas.: 6033-23-4						
P	*Rubus laciniata* L.	Rosales	fruits, leaves	aroma		29,92
P	*Passiflora edulis*	Violales	fruits			98
P	*Musa* sp.	Zingiberales	fruits			29,100,101
A	*Eriocrania sparrmannella*	Lepidoptera		sex pheromone, F		152,153
A	*Molanna angustata*	Trichoptera	F sternal glands	sex pheromone, F		155
A	*Rhyacophila nubila*	Trichoptera	F abdominal gland	sex pheromone, F		154
A	mammals				anesthetics	73
					intermediate in the synthesis of several anti-Alzheimer's drugs	30,102,103
				mushroom, oily, fatty, blue cheese, mouldy odour	odorant	29

TABLE IB
(*Continued*)

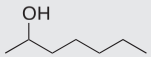
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Heptan-2-ol Cas.: 543-49-7						
	Botrytis cinerea	Helotiales		grapes and musts damage	wine quality	156
F	*Aspergillus nigri* *Penicillium* sp.	Eurotiales				
P	*Mormolyca ringens*	Asparagales	flowers	sexual mimicry, pollination by *Scaptotrigona* males		157
P	*Myrcianthes* sp.	Myrtales	leaves	leaf essential oil	odour	158
P	*Saccharum* sp.	Poaceae		rhynchophorol synergist, attractant for *Rhynchophorus palmarum*, *Dynamis borassi* (Coleoptera)		42
A	*Platyzosteria armata*	Dictyoptera		defensive secretions		110
A	*Apis mellifera*	Hymenoptera	sting extracts	alarm pheromone		159
A	*Frieseomelitta varia* *F. xanthopleura*	Hymenoptera	cephalic secretions			160–162
A	*Melipona fasciata* *M. interrupta*	Hymenoptera	mandibular glands	alarm and defence		163
A	*Scaptotrigona mexicana*	Hymenoptera	cephalic glands	chemical communication		164
A	*Trigona hypogea*, *T. mexicana*, *T.pectoralis*, *T. silvestriana*, *T. truculenta*	Hymenoptera	cephalic secretions	alarm and trail pheromone		161, 165–167
A	*Tetragona clavipes*	Hymenoptera	cephalic secretions			161
A	*Hypoclinea bidens*	Hymenoptera	pygidial glands			168
A	*Atta texana* *Atta opaciceps*	Hymenoptera	mandibular glands	alarm pheromone		169,170

TABLE IB
(*Continued*)

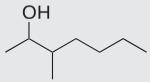
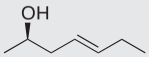
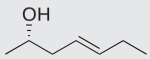
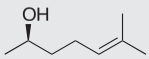
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
A	*Rhyacophila fasciata* *R. nubila*	Trichoptera	abdominal sternites	sex pheromone, F		171
					spirits, beverages aroma	111
				cheese volatiles	cheese quality control	81
					Gorgonzola cheese odour	172
3-Methylheptan-2-ol Cas.: 597-96-6						
A	*Crematogaster nigriceps* *Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm pheromone alarm and defence		112,120
(2*R*,4*Z*)-Hept-4-en-2-ol Cas.: 124753-74-8						
A	*Eriocrania cicatricella*	Lepidoptera		sex pheromone, F		152,153
(2*S*,4*Z*)-Hept-4-en-2-ol Cas.: 124753-75-9						
P	*Musa* sp.	Zingiberales	fruits			29,100,101
A	*Eriocrania sparrmannella*	Lepidoptera		sex pheromone, F		152,153
(*R*)-6-Methylhept-5-en-2-ol ((*R*)-sulcatol) Cas.: 58917-27-4						
P	*Rubus laciniata* L.	Rosales	leaves	aroma		29,92
A	*Gnathotrichus sulcatus* *G. materiarius*	Coleoptera		aggregation pheromone, M		173–176

TABLE IB
(*Continued*)

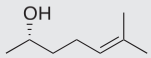
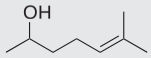
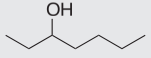
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-6-Methylhept-5-en-2-ol ((*S*)-sulcatol) Cas.: 58917-26-3						
P	*Rubus laciniata* L.	Rosales	leaves	aroma		29,92
A	*Gnathotrichus sulcatus* *G. retusus*	Coleoptera		aggregation pheromone, M		173–175
A	*Platypus mutatus*	Coleoptera		sex pheromone, M		177
6-Methylhept-5-en-2-ol (sulcatol) Cas.: 1569-60-4						
P	*Triticum aestivum*	Poales		infestation by aphids *Rhopalosiphum padi*, ants *Linepithema humile* repellent		178–180
A	*Iridomyrmex purpureus*	Hymenoptera	mandibular glands			181
A	*Polyrhachis simplex*	Hymenoptera	mandibular glands			182
A	*Agraulis vanillae*	Lepidoptera	defensive glands	repellent of avian predators		183
A	*Phlogophora meticulosa*	Lepidoptera	glands	sex pheromone, M		184,185
Heptan-3-ol Cas.: 589-82-2						
F	*Aspergillus* sp.	Eurotiales	fungal metabolism		detection of fungal indoor pollution	38
A	*Atta texana* *Atta opaciceps*	Hymenoptera	mandibular glands	alarm pheromone		169,170
A	*Crematogaster nigriceps* *Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm pheromone alarm and defence		112,120

TABLE IB
(*Continued*)

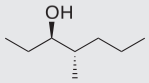
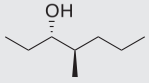
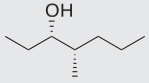
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
A	*Myrmica rubra*, *M. ruginodis*, *M. sabuleti*, *M. scabrinodis*	Hymenoptera	mandibular glands			132–134
(3*R*,4*S*)-4-Methylheptan-3-ol Cas.: 68509-47-7						
A	*Scolytus intricatus*	Coleoptera		aggregation pheromone, F		186
A	*Atta sexdes*	Hymenoptera	mandibular glands	alarm pheromone, M		187
A	*Leptogenys diminuta*	Hymenoptera	mandibular glands	trail pheromone		188,189
A	*Cerapachys* sp.	Hymenoptera	mandibular glands			190
(3*S*,4*R*)-4-Methylheptan-3-ol Cas.: 63782-91-2						
A	*Cerapachys* sp.	Hymenoptera	mandibular glands			190
(3*S*,4*S*)-4-Methylheptan-3-ol Cas.: 68509-48-8						
A	*Scolytus amygdali* *S. multistriatus* *S. pygmaeus*, *S. scolytus*	Coleoptera		aggregation pheromone, F		144–146 191,192
A	*Atta sexdes*	Hymenoptera	mandibular glands	alarm pheromone, M		187

TABLE IB
(*Continued*)

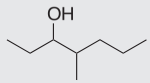
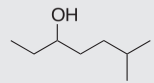
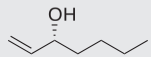
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(3*S*,4*S*)-4-Methylheptan-3-ol Cas.: 68509-48-8						
A	*Scolytus multistriatus*	Coleoptera		attractant for parasitoids *Cheiropachus colon, Entedon leucogramma, Dendrosoter protuberans, Spathius benefactor,* Cerocephala eccoptogastri (Hymenoptera)		193
A	*Paraponera clavata*	Hymenoptera	mandibular glands	attractant for F parasitoids Apocephalus paraponerae (Diptera)		194,195
A	*Atta cephalotes* *A. sexdes, A. texana* *Trachymyrmex* sp.	Hymenoptera	mandibular glands, M+F	alarm pheromone		169,187 196,197
A	*Leptogenys diminuta*	Hymenoptera	poison glands	trail pheromone		198,199
A	*Odontoponera transversa*	Hymenoptera	mandibular glands			200
A	*Pogonomyrmex badius*	Hymenoptera	mandibular glands	alarm pheromone		201
A	*Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm and defence		120
A	*Leiobunum townsendi*	Opiliones				202
6-Methylheptan-3-ol Cas.: 18720-66-6						
A	*Hesperophylax occidentalis*	Trichoptera				203
(*R*)-Hept-1-en-3-ol Cas.: 87247-56-1						
				chemical, diffusible, green odour	odorant	29

TABLE IB
(*Continued*)

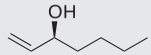
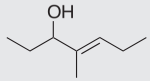
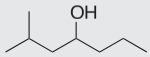
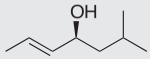
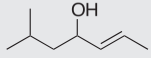
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-Hept-1-en-3-ol Cas.: 87247-44-7						
				fruity, earthy odour	odorant	29
(4*E*)-4-Methylhept-4-en-3-ol Cas.: 81280-12-8						
A	*Leiobunum townsendi*	Opiliones				202
2-Methylheptan-4-ol Cas.: 21570-35-4						
A	*Metamasius hemipterus sericeus, M.* sp.	Coleoptera		aggregation pheromone, F+M		204–207
A	*Rhabdoscelus obscurus*	Coleoptera		aggregation pheromone, F+M		208
A	*Scyphophorus acupunctatus*	Coleoptera		aggregation pheromone, F+M		209,210
(2*E*,4*S*)-6-Methylhept-2-en-4-ol ((*S*)-rhynchophorol) Cas.: 59983-76-5						
A	*Rhynchophorus palmarum*	Coleoptera		aggregation pheromone, M		211
(2*E*)-6-Methylhept-2-en-4-ol (rhynchophorol) Cas.: 4798-62-3						
A	*Rhabdoscelus obscurus*	Coleoptera		aggregation pheromone, F+M		208
A	*Rhynchophorus palmarum*	Coleoptera		aggregation pheromone, M		211–214
A	*Dynamis borassi*	Coleoptera		aggregation pheromone, M		42

TABLE IB
(*Continued*)

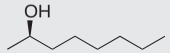
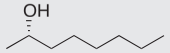
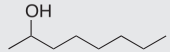
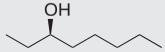
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-Octan-2-ol Cas.: 5978-70-1						
				creamy, cucumber, fatty, sour odour	odorant	29
(*S*)-Octan-2-ol Cas.: 6169-06-8						
				mushroom, oily, fatty, creamy, grape odour	odorant	29
					enantioseparation of drugs	215
					identification of D-2-hydroxyglutaric acid in glutaric aciduria type II	216
Octan-2-ol Cas.: 123-96-6						
A	*Frieseomelitta xanthopleura, Trigona* sp.	Hymenoptera	cephalic secretions	alarm and trail pheromone		161
(*R*)-Octan-3-ol Cas.: 20296-29-1						
A	*Myrmica scabrinodis*	Hymenoptera	mandibular gland	alarm pheromone		217

TABLE IB
(*Continued*)

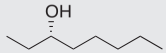
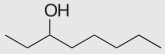
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-Octan-3-ol Cas.: 22658-92-0						
A	*Crematogaster nigriceps*, *C. castanea*, *C. liengmei*	Hymenoptera	mandibular glands	alarm pheromone		112,218
Octan-3-ol Cas.: 20296-29-1						
F	*Tricholoma* sp., *Suillus* sp., *Amanita* sp.	Agaricales				219,220
F	*Boletus* sp.	Boletales				220
F	*Penicillium* sp. *Aspergillus* sp. *Cladosporium* sp.	Eurotiales Eurotiales Moniliales			microbial volatile organic compounds – the sick building syndrome	104, 221,222
F	*Trichoderma* sp.	Hypocreales		induction of conidiation		223
F				attractant for cucujid beetles *Cryptolestes ferrugineus*, *Ahasversus advena*, *Oryzaephilus mercator*, *O. surinamensis* (Coleoptera)		224
F	*Fomitopsis pinicola*, *Fomes fomentarius*	Polyporales	fruiting bodies	attractant for beetles *Anaspis rufilabris*, *Athous subfuscus*, *Atheta* sp., *Dendrophagus crenatus*, *Enicmus rugosus*, *Malthius* sp., *Rhagonycha* sp., *Salpingus ruficollis*, *Xylita laevigata* (Coleoptera)		225
P	*Medicago sativa*	Fabales		attractant for parasitoids *Bruchophagus roddi* (Hymenoptera)		226

TABLE IB
(*Continued*)

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
P	*Betula* sp. *Populus* sp.	Fagales Malphighiales	leaves, bark	attractant for *Ips duplicatus* (Coleoptera)		227,228
A	*Cerapachys jacobsoni*	Hymenoptera	mandibular glands			190
A	*Crematogaster ashmeadi, C. castanea, C. liengmei, C. mimosae, C. nigriceps, C. peringueyi, C. rochai, C. scutellaris, C. sjostedti*	Hymenoptera	mandibular glands	alarm pheromone		112,120 138–141
A	*Myrmica brevinodis, M. lobicornis, M. rubra, M. ruginodis, M. sabuleti, M. scabrinodis, M. sulcinodis*	Hymenoptera	mandibular glands	alarm pheromone		132–137
A	*Myrmica scabrinodis*	Hymenoptera	mandibular glands	attractant for parasitoids *Microdon mutabilis* (Diptera)		229
A	*Lasius flavus*	Hymenoptera	mandibular glands	alarm pheromone		136
A	*Pseudomyrmex* sp.	Hymenoptera	mandibular glands	alarm and defence		120
A	*Tetraponera penzigi*	Hymenoptera	mandibular glands			142
A	*Trachymyrmex seminole, T. septentrionalis, Cyphomyrmex rimosus, Acromyrmex landolti*	Hymenoptera	mandibular glands	alarm pheromone		197
A	*Decamorium uelense, Tetramorium* sp.	Hymenoptera	mandibular glands			230
A	*Bos* sp.	Artiodactyla		attractant for cattle flies (Diptera) *Musca autumnalis, Haematobia irritans, Stomoxys calcitrans, Wohlfahrtia magnifica*		231

TABLE IB
(*Continued*)

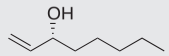
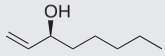
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
					cosmetic fragrance	88
					ant insecticide	232
(*R*)-Oct-1-en-3-ol Cas.: 3687-48-7						
F	*Trametes gibbosa* *Spongiporus* sp.	Polyporales	fruiting body	attractant for *Cis boleti* (Coleoptera)		233,234
F				attractant for cucujid beetles *Cryptolestes ferrugineus*, *Ahasversus advena*, *Oryzaephilus mercator*, *O. surinamensis* (Coleoptera)		224
A	*Ahasversus advena*	Coleoptera		aggregation pheromone		235
				mushroom, fruity odour	odorant	29,70,236
(*S*)-Oct-1-en-3-ol Cas.: 24587-53-9						
F	*Trametes gibbosa*	Polyporales	fruiting body	attractant for *Cis boleti* (Coleoptera)		233
F				attractant for cucujid beetles *Cryptolestes ferrugineus*, *Ahasversus advena*, *Oryzaephilus mercator*, *O. surinamensis* (Coleoptera)		224
				herbaceous, musty odour	odorant	29,236

TABLE IB
(*Continued*)

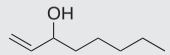
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Oct-1-en-3-ol Cas.: 3391-86-4						
F	*Tricholoma* sp., *Suillus* sp., *Amanita* sp.	Agaricales				219,220
F	*Tricholoma matsutake*	Agaricales		repellent of *Proisotoma minuta* (Collembola)		237
F	*Boletus* sp.	Boletales				220
F	*Botrytis cinerea* *Aspergillus nigri* *Penicillium* sp.	Helotiales Eurotiales		grapes and musts damage	wine quality	156
F	*Penicillium* sp. *Aspergillus* sp. *Cladosporium* sp.	Eurotiales Eurotiales Moniliales			microbial volatile organic compounds – the sick building syndrome	104 221,222
F	*Trichoderma* sp.	Hypocreales		induction of conidiation		223
F	*Verticillium bulbillosum*	Hypocreales		attractant for *Onychiurus armatus* (Collembola)		238
F	*Rhizopus oligosporus*	Mucorales		volatile metabolite	tempeh fermentatiton	41
F	*Fomitopsis pinicola*, *Fomes fomentarius*	Polyporales	fruiting bodies	attractant for *Anaspis* sp., *Agathidium seminulum*, *Athous subfuscus*, *Atheta* sp., *Atomaria* sp., *Bibloporus bicolor*, *Cerylon* sp., *Cryptophagus* sp., *Cychramus variegatus*, *Crypturgus* sp., *Dalopius* sp., *Dasytes plumpeus*, *Dendrophagus crenatus*, *Enicmus rugosus*, *Euplectus* sp., *Lordithon lunulatus*, *Malthius* sp., *Mathodes* sp., *Philonthus succiola*, *Rhagonycha* sp., *Salpingus ruficollis*, *Xylita laevigata* (Coleoptera), *Epinotia tedella* (Lepidoptera)		225

TABLE IB
(*Continued*)

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
F	*Trametes gibbosa*	Polyporales		attractant for *Cis boleti* (Coleoptera)		233
P	*Foeniculum vulgare*	Apiales	seeds	odour		239
P	*Cornus florida*	Cornales	fruits	attractant for *Rhagoletis pomonella* (Diptera)		240
P	*Phaseolus vulgaris*	Fabales	beans	attractant *for Delia platura* (Diptera), oviposition		241
P	*Medicago sativa*	Fabales		attractant for parasitoids *Bruchophagus roddi* (Hymenoptera)		226,242
P	*Betula* sp. *Populus* sp.	Fagales Malphighiales	leaves, bark	attractant for *Ips duplicatus* (Coleoptera)		227
P	*Lantana camara*	Lamiales	leaves, flowers	attractant and cover for *Glossina* sp. (Diptera)		243
P	*Plantago lanceolata*	Lamiales	leaves, fruits			244
P	*Vitis vinifera*	Vitales		attractant for *Lobesia botrana* (Lepidoptera)		245
A	*Sitophilus granarius*	Coleoptera	larval feces	repellent of *Lariophagus distinguendus* (Hymenoptera)		246
A	*Aedes* sp., *Anopheles* sp., *Atylotus* sp., *Chrysops* sp., *Culicoides* sp., *Cydistomyia* sp., *Dasybasis* sp., *Diachlorus* sp., *Glossina* sp., *Heamatopota* sp., *Hybomitra* sp., *Lilaea* sp., *Lucilia* sp., *Lutzomyia* sp., *Mansonia titillans, Morellia* sp., *Ochlerotatus* sp., *Phlebotomus* sp., *Pseudotabanus* sp., *Sergentomyia* sp., *Tabanus* sp., *Wyeomyia* sp.	Diptera		kairomone used by haematophagous insects to locate their vertebrate hosts	attractant	231 247–270

TABLE IB
(*Continued*)

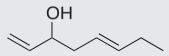
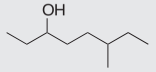
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
A	*Amblyomma variegatum*	Ixodida		aggregation pheromone, vertebrate host finding		271,272
A	*Niponia nodulosa*	Polydesmida		ant repellent		273
A	*Bos* sp.	Artiodactyla		attractant for cattle flies (Diptera) *Musca autumnalis, Haematobia irritans, Stomoxys calcitrans, Wohlfahrtia magnifica*		231
A	Vertebrata	Artiodactyla		attractant for *Cephenemyia* sp. (Diptera)		274
A	Vertebrata			attractant for bug *Triatoma infestans* (Heteroptera)		275
					Gorgonzola cheese odour	172
	fishes (*Clupea harengus*)			lipid oxidation, off-flavor	indicator of frozen fish quality	126
Octa-1,5-dien-3-ol Cas.: 83861-74-9						
F	homobasisiomycetes			attractant for *Tyrophagus putrescentiae* (Astigmata)		276
					attractant for biting insect	277
6-Methyloctan-3-ol Cas.: 40225-75-0						
A	*Crematogaster sjostedti*	Hymenoptera	mandibular glands	alarm pheromone		112
A	*Myrmica* sp.	Hymenoptera	mandibular glands	alarm pheromone		134
A	*Tetramorium* sp.	Hymenoptera	mandibular glands	alarm pheromone		230

TABLE IB
(*Continued*)

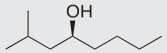
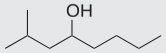
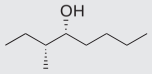
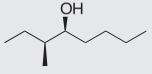
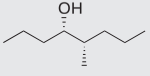
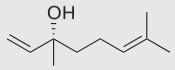
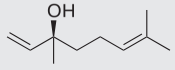
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-2-Methyloctan-4-ol Cas.: 93031-26-6						
A	*Sphenophorus levis*	Coleoptera		aggregation pheromone, F+M		278
2-Methyloctan-4-ol Cas.: 40575-41-5						
A	*Metamasius hemipterus sericeus*, *M.* sp.	Coleoptera		aggregation pheromone, F+M		204–206
A	*Rhabdoscelus obscurus*	Coleoptera		aggregation pheromone, F+M		209
A	*Scyphophorus acupunctatus*	Coleoptera		aggregation pheromone, F+M		209,210
(3*R*,4*R*)-3-Methyloctan-4-ol ((*R*,*R*)-phoenicol) Cas.: 151765-86-5						
A	*Rhynchophorus cruentatus*	Coleoptera		aggregation pheromone M		279
(3*S*,4*S*)-3-Methyloctan-4-ol ((*S*,*S*)-phoenicol) Cas.: 151765-88-7						
A	*Rhynchophorus cruentatus*, *R. phoenicis*	Coleoptera		aggregation pheromone M		279
(4*S*,5*S*)-5-Methyloctan-4-ol ((*S*,*S*)-cruentol) Cas.: 154802-25-2						
A	*Rhynchophorus cruentatus*	Coleoptera		aggregation pheromone M		279,280

TABLE IC
Chiral tertiary alcohols

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-3,7-Dimethylocta-1,6-dien-3-ol ((*R*)-linalool, licareol) Cas.: 126-90-9						
F	*Spongiporus* sp.	Polyporales	fruiting body			234
P	*Glochidion* sp.	Malpighiales	flowers	attractant for pollinators *Epicephala* sp. (Lepidoptera)		281
P	*Paeonia suffruticosa*	Saxifragales	root bark	acaricidal activities	fumigant	282
	jasmine tea			sedative effects		283
				stimulation of opioidergic, cholinergic, dopaminergic systems	antiinflammatory, antihyperalgestic, antinoceptive effects	284
(*S*)-3,7-Dimethylocta-1,6-dien-3-ol ((*S*)-linalool, coriandrol) Cas.: 126-91-0						
P	*Cornus florida*	Cornales	flowers	attractant for pollinators *Andrena* sp., *Lasioglossum* sp. (Hymenoptera)		285
P	*Glochidion* sp.	Malpighiales	flowers	attractant for pollinators *Epicephala* sp. (Lepidoptera)		281
P	*Daphne mezereum*	Malvales	flowers	attractant for pollinators *Colletes* sp. (Hymenoptera)		286
P	*Ficus hispida*	Rosales	flowers	attractant for pollinator wasps *Ceratosolen* sp. (Hymenoptera)		287
P	plants		leaves	attractant for *Heliothis* sp., *Helicoverpa* sp. (Lepidoptera)		288
A	*Colletes cunicularius*	Hymenoptera	mandibular glands	mate attraction pheromone sex pheromone		289–293

Collect. Czech. Chem. Commun. 2009, Vol. 74, Nos. 7–8, pp. 1195–1278

TABLE IC
(*Continued*)

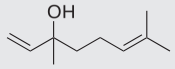
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
3,7-Dimethylocta-1,6-dien-3-ol (linalool) Cas.: 126-91-0 						
P	*Coriandrum sativum*	Apiales	seeds		cooking, medicine	294
P	*Blumea* sp.	Asterales	leaves		larvicidal effect against *Culex* sp. (Diptera)	295
P	*Cirsium arvense*	Asterales		attractant for herbivores and pollinators		296
P	*Silene otites*	Caryophyllales		attractant for pollinator *Culex* sp. (Diptera)		297
P	*Camellia* sp.	Ericales	leaves	aroma	green tea aroma	122
P	*Phaseolus lunatus*	Fabales	leaves	herbivore-induced volatiles attractant for predators *Neoseiulus* sp., *Phytoseiulus* sp. (Prostigmata)		298
P	*Ocimum basilicum* *Lippia alba, Mentha* sp.	Lamiales			antigiardial, trypanocidal, antimicrobial activity	299–301
P	*Origanum majorana*	Lamiales			fumigants, toxic for *Blattella germanica* (Orthoptera)	302
P	*Salix* sp.	Malpighiales		attractant for pollinators		303,304
P	*Myrcianthes* sp.	Myrtales	leaves	leaf essential oil	odour	158
P	*Pinus* sp.	Pinales	needles	herbivore-induced volatiles, damage by *Dendrolimus* sp. (Lepidoptera)		305
P	*Prunus persica* L.	Rosales	fruits	aroma		93

TABLE IC
(*Continued*)

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
P	*Ficus hispida*	Rosales	flowers	attractant for pollinator wasps *Ceratosolen* sp. (Hymenoptera)		287
P	*Nicotiana* sp.	Solanales	flowers			129
P	*Vitis riparia*	Vitales	shoots	attractant for (Lepidoptera) *Paralobesia viteana*		306
P	plants		leaves	attractant for (Lepidoptera) *Scoliopteryx libatrix, Cydia pomonella, Busseola fusca, Chilo partellus, Spodoptera frugiperda, Heliothis* sp., *Helicoverpa*		307–311
P	plants		leaves	herbivore-damaged trees attract insectivorous birds		312
A	*Carabus lefebvrei*	Coleoptera	abdominal glands	prophylaxis function against pathogens		313
A	*Podisus maculiventris*	Hemiptera	abdominal glands	aggregation pheromone		314
A	*Bombyx mori*	Lepidoptera	antennae	genes for odorant receptors		315
					killing parasitic *Varroa jacobsoni* (Acari)	316
				attractant for *Leptinotarsa decemlineata* (Coleoptera)		317
				attractant for moth (Lepidoptera)		318,319
				attractant for wasps		320
					pest controlling soap based pesticides	321,322

TABLE IC
(*Continued*)

Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
				antimicrobial packaging material	323
				cosmetic substances	324
				sila-linalool, silicon based odorants	325

TABLE II
Chiral glycols and diols

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(2*R*,3*R*)-Butane-2,3-diol Cas.: 24347-58-8						
A	*Amphimallon solstitiale*	Coleoptera		sex pheromone, M		326
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	70,71
A	*Rhizotrogus majalis*	Coleoptera	balloon-like organs	sex pheromone, F		327
A	*Leucophaea madarea*	Dictyoptera	abdominal glands	sex pheromone, M		328
A	*Eurycotis florida*	Dictyoptera	epidermal glands	sex pheromone, M		329

TABLE II
(*Continued*)

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(2*S*,3*S*)-Butane-2,3-diol Cas.: 19132-06-0						
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	70,71
***meso*-Butane-2,3-diol** Cas.: 1029272-42-1						
A	*Amphimallon solstitiale*	Coleoptera		sex pheromone, M		326
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	70,71
A	*Rhizotrogus majalis*	Coleoptera	balloon-like organs	sex pheromone, F		327
Butane-2,3-diol Cas.: 513-85-9						
B	*Aeromonas* sp., *Bacillus* sp., *Serratia* sp., *Enterobacter* sp., *Klebsiella* sp., *Erwinia* sp.	Aeromonadales Bacillales Enterobacte-riales			acute lung injury	330
B	*Bacillus* sp., *Serratia* sp., *Enterobacter* sp., *Erwinia* sp., *Pseudomonadales* sp.	Bacillales Enterobacteriales Pseudomonadales		plant growth-promoting rhizobacteria, plant protection to pathogen infection		331,332
P	*Cocos* sp., *Elaeis* sp., *Saccharum* sp., *Jacaratia* sp.	Arecales Poaceae Brassicales		rhynchophorol pheromone synergist, attractant for *Rhynchophorus palmarum*, *Dynamis borassi* (Coleoptera)		42
P	*Psidium guajava* L.	Myrtales	fruit	fruit flavor		43
P	*Quercus* sp.	Fagales	sak	attractant for *Kaniska canae*, *Vanessa indica* (Lepidoptera)		333
A	*Pteropus* sp.	Chiroptera	shoulder glands, M			334

TABLE II
(*Continued*)

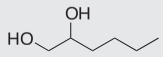
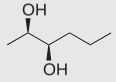
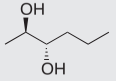
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
					balsamic vinegars, wines etc. aging	335–337
					marker for ischaemia	338
					anti-freeze agents liver transplantation	339,340
					synthesis of quassinoids	341
Hexane-1,2-diol Cas.: 6920-22-5						
					cosmetics	342
					antiperspirant, deodorant	343,344
(2*R*,3*R*)-Hexane-2,3-diol Cas.: 159407-05-3						
A	*Hylotrupes bajulus* *Pyrrhidium sanguineum*	Coleoptera	prothorax glands	sex pheromone, M		345–349
A	*Curius dentatus* *Neoclytus acuminatus*	Coleoptera		sex pheromone, M		350
(2*R*,3*S*)-Hexane-2,3-diol Cas.: 209917-89-5						
A	*Curius dentatus*	Coleoptera		sex pheromone, M		350
A	*Megacyllene caryae*	Coleoptera	prothorax glands	aggregation pheromone, M		351

TABLE II
(*Continued*)

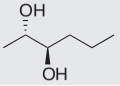
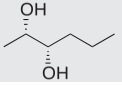
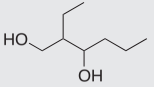
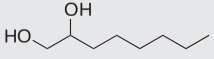
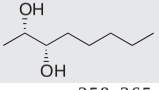
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(2*S*,3*R*)-Hexane-2,3-diol Cas.: 160549-93-9						
A	*Curius dentatus*	Coleoptera	prothorax glands	sex pheromone, M		350
A	*Hylotrupes bajulus* *Pyrrhidium sanguineum*	Coleoptera	prothorax glands	sex pheromone, M		345–349
A	*Megacyllene caryae*	Coleoptera	prothorax glands	aggregation pheromone, M		351
(2*S*,3*S*)-Hexane-2,3-diol Cas.: 187328-66-1						
A	*Curius dentatus* *Neoclytus acuminatus*	Coleoptera		sex pheromone, M		350
2-Ethyl-hexane-1,3-diol Cas.: 94-96-2						
					insect repellent	352–355
					shaving gels	356
Octane-1,2-diol Cas.: 1117-86-8						
					cosmetics	342
					skin disinfectant	357
(2*S*,3*S*)-Octane-2,3-diol Cas.: 84518-30-9						
A	*Xylotrechus* sp.	Coleoptera		sex pheromone, M		358–365

TABLE III
Chiral hydroxy ketones

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*R*)-3-Hydroxybutan-2-one ((*R*)-acetoin) Cas.: 53584-56-8						
A	*Amphimallon solstitiale*	Coleoptera		sex pheromone, M		326
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	70,71
A	*Rhizotrogus majalis*	Coleoptera	balloon-like organs	sex pheromone, F		327
A	*Leucophaea madarea*	Dictyoptera	sternal glands, M	sex pheromone, M		328
					fermented food, beverages, honey	101
(*S*)-3-Hydroxybutan-2-one ((*S*)-acetoin) Cas.: 78183-56-9						
A	*Scapanes australis*	Coleoptera	abdomen tip	aggregation pheromone, M	pest trap	70,71
					fermented food, beverages, honey	101
3-Hydroxybutan-2-one (acetoin) Cas.: 513-86-0						
P	*Cocos* sp. *Elaeis* sp. *Saccharum* sp. *Jacaratia* sp.	Arecales Poaceae Brassicales		rhynchophorol pheromone synergist, attractant for *Rhynchophorus palmarum*, *Dynamis borassi* (Coleoptera)		42
P	*Prunus* sp.	Rosales	fruits	attractant for *Conotrachelus nenuphar* (Coleoptera)		366
P	*Musa* sp., citruses	Zingiberales	fruits, flowers	attractant for *Pachnoda marginata* (Coleoptera)		367
P	*Clusia* sp.	Malpighiales	flowers	attractant for cockroaches as pollinators (Dictyoptera)		368

TABLE III
(*Continued*)

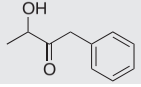
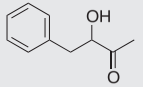
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
P	*Quercus* sp.	Fagales	sak	attractant for *Kaniska canae*, *Vanessa indica* (Lepidoptera)		333
P	plants infested with herbivours hosts *Mythimna separata*			attractant for parasitoid *Exorista japonica* (Diptera)		369
P	*Sicana odorifera*	Cucurbitales	fruit	fruit aroma		83
P	*Psidium guajava* L.	Myrtales	fruit	fruit flavor		43
A	*Rhynchophorus palmarum*	Coleoptera		synergist for pheromone		214,370
A	*Henschoutedenia* sp. *Nauphoeta cinerea*	Dictyoptera	sternal glands, M	sex pheromone		371–376
A	*Leucophaea madarea*	Dictyoptera	sternal glands, M	sex pheromone		328,371
A	vertebrata		sweat	attactant for *Anopheles gambie* (Diptera)		377
					balsamic vinegars, wines aging	335–337
3-Hydroxy-1-phenylbutan-2-one Cas.: 62763-33-1						
					food volatiles (sherry)	378,379
3-Hydroxy-4-phenylbutan-2-one Cas.: 5355-63-5						
				floral-sweet odour	food volatiles (wine, sherry, honey)	378,379

TABLE III
(*Continued*)

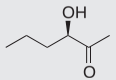
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
3-Hydroxypentan-2-one Cas.: 3142-66-3						
				caramel-sweet, buttery odour	food volatiles (cheese, durian, coffee, wine, honey, tea, butter, sherry, soy sauce, beverages)	101, 378,379
3-Hydroxypentan-3-one Cas.: 5704-20-1						
				buttery, hay-like odour	food volatiles (cheese, durian, wine, honey, butter, sherry, soy sauce, beverages)	101, 378–380
(*R*)-3-Hydroxyhexan-2-one Cas.: 152212-60-7						
A	*Anaglyptus subfaciatus*	Coleoptera		sex pheromone, M		381,382
A	*Hylotrupes bajulus* *Pyrrhidium sanguineum*	Coleoptera	prothorax glands	sex pheromone, M		345–349
A	*Brothylus gemmulatus* *Neoclytus* sp. *Phymatodes lecontei* *Xylotrechus nauticus*	Coleoptera	prothorax glands	aggregation pheromone, M		36 383–385

TABLE III
(*Continued*)

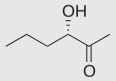
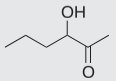
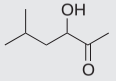
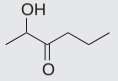
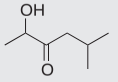
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-3-Hydroxyhexan-2-one Cas.: 152212-36-7						
A	*Phymatodes lecontei* *Xylotrechus nauticus*	Coleoptera	prothorax glands	aggregation pheromone, M		36
3-Hydroxyhexan-2-one Cas.: 54073-43-7						
				earthy, mushroom-like odour	food volatiles	378,379
3-Hydroxy-5-methylhexan-2-one Cas.: 163038-04-8						
				cheese, sour milk odour	food volatiles (mozzarella cheese)	378,379
2-Hydroxyhexan-3-one Cas.: 54073-43-7						
A	*Hylotrupes bajulus*	Coleoptera	prothorax glands	sex pheromone, M		346
				green, hay-like, sour milk odour	food volatiles (wine)	378,379
2-Hydroxy-5-methylhexan-3-one Cas.: 246511-74-0						
				cheese, sour milk odour	food volatiles (sherry)	378,379

TABLE III
(*Continued*)

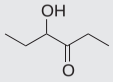
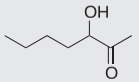
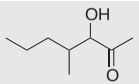
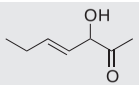
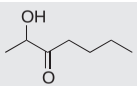
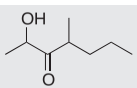
Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
4-Hydroxyhexan-3-one Cas.: 4984-85-4					
				food volatiles (durian, tea)	378,379
3-Hydroxyheptan-2-one Cas.: 68113-60-0					
			earthy, hay-like, herbaceous odour	food volatiles	378,379
3-Hydroxy-4-methylheptan-2-one Cas.: 309972-33-6					
			floral-earthy, hay-like odour	food volatiles	378,379
3-Hydroxyhept-4-en-2-one Cas.: 309972-37-0					
			earthy, mushroom-like odour	food volatiles	378,379
2-Hydroxyheptan-3-one Cas.: 71467-29-3					
			floral, buttery, mushroom-like odour	food volatiles	378,379
2-Hydroxy-4-methylheptan-3-one Cas.: 309972-34-7					
			floral-green, hay-like odour	food volatiles	378,379

TABLE III
(*Continued*)

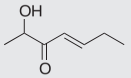
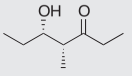
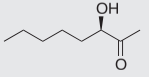
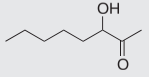
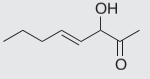
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
2-Hydroxyhept-4-en-3-one Cas.: 309972-38-1						
				floral, spicy, earthy odour	food volatiles	378,379
(4*S*,5*R*)-5-Hydroxy-4-methylheptan-3-one (sitophinone) Cas.: 115014-45-4						
P	*Oryza* sp. *Zea* sp.	Poales	grains	attractant for *Sitophilus oryzae*, *Tribolium castaneum* (Coleoptera)		386–389
(*R*)-3-Hydroxyoctan-2-one Cas.: 146329-67-1						
A	*Anaglyptus subfaciatus*	Coleoptera		sex pheromone, M		381,382
3-Hydroxyoctan-2-one Cas.: 37160-77-3						
A	*Xylotrechus* sp.	Coleoptera		sex pheromone, M		364
				earthy, mushroom-like, herbaceous odour	food volatiles (beeef and mutton fat)	378,379
3-Hydroxyoct-4-en-2-one Cas.: 309972-39-2						
				earthy, floral, mushroom-like odour	food volatiles	378,379

TABLE III
(*Continued*)

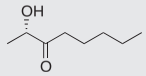
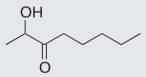
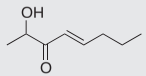
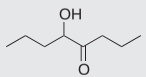
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-2-Hydroxyoctan-3-one Cas.: 84435-13-2						
A	*Xylotrechus* sp.	Coleoptera		sex pheromone, M		358–365
2-Hydroxyoctan-3-one Cas.: 52279-26-2						
				floral-sweet, buttery odour	food volatiles	378,379
2-Hydroxyoct-4-en-3-one Cas.: 309972-40-5						
				floral, green, woody odour	food volatiles	378,379
5-Hydroxyoctan-4-one Cas.: 496-77-5						
				sweet, buttery, nut-like, floral odour	food volatiles (cocoa)	378,379

TABLE IV
Chiral hydroxy carboxylic acids

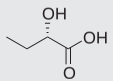
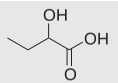
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
(*S*)-Lactic acid Cas.: 79-33-4						
A	mammals			attractant for *Aedes* sp., (Diptera)		390,391
Lactic acid Cas.: 50-21-5						
A	mammals			synergist for attraction of *Anopheles* sp. (Diptera)		392
					poly(lactic acid), antiviral drugs	393,394
					intermediates for synthesis of pharmaceuticals	395
(*S*)-2-Hydroxybutanoic acid Cas.: 3347-90-8						
					pharmaceutical intermediates	396
2-Hydroxybutanoic acid Cas.: 600-15-7						
					urine marker for lactic and keto acidosis	397,398

TABLE IV
(*Continued*)

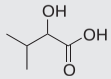
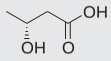
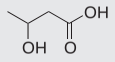
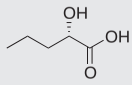
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
2-Hydroxy-3-methylbutanoic acid (2-hydroxyisovaleric acid) Cas.: 4026-18-0						
F	*Phoma* sp.	Pleosporales			Pleofungins, depsipeptide antifungal antibiotics	399
A	*Creatonotos transiens* *Estigmene acrea* *Grammia geneura*	Lepidoptera		insect pyrrolizidine alkaloids, necic acids in creatonotines		400–402
(*R*)-3-Hydroxybutanoic acid Cas.: 625-72-9						
F	*Hypoxylon truncatum*	Xylariales				403
A	*Linyphia triangularis*	Araneae	web	sex pheromone, F		404
3-Hydroxybutanoic acid Cas.: 300-85-6						
A	*Papilio demodocus*	Lepidoptera	osmeterium	defensive secretions		405
					ophthalmic operation	406–408
(*S*)-2-Hydroxypentanoic acid Cas.: 41014-93-1						
					pharmaceutical intermediates	396

TABLE IV
(*Continued*)

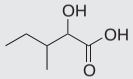
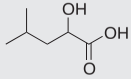
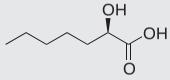
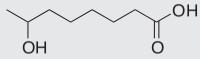
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
2-Hydroxy-3-methylpentanoic acid Cas.: 488-15-3						
F	*Aureobasidium pullulans*	Dothideales			Aureobasidins, cyclic depsipeptides with antifungal activity	409
A	*Creatonotos transiens* *Estigmene acrea* *Grammia geneura*	Lepidoptera		insect pyrrolizidine alkaloids, necic acids in creatonotines		400–402
					bogorol peptide antibiotics	410
2-Hydroxy-4-methylpentanoic acid (2-hydroxyisocaproic acid) Cas.: 498-36-2						
F	*Phoma* sp.	Pleosporales			Pleofungins, depsipeptide antifungal antibiotics	399
(*R*)-2-Hydroxyheptanoic acid Cas.: 52437-20-4						
F	*Verticillium* sp.	Hypocreales			Verticilide, 24-membered cyclic depsipeptide, insecticidal activity	411
7-Hydroxyoctanoic acid Cas.: 17173-14-7						
A	*Apis mellifera*	Hymenoptera	mandibular glands	queen signals		412

TABLE IV
(*Continued*)

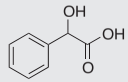
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
2-Hydroxy-2-phenylacetic acid (mandelic acid) Cas.: 90-64-2						
					poly(mandelic acid) anti-HIV aictivity	413–415
					intermediates for synthesis of pharmaceuticals	416,417
					antifungal activity	418
					antiperspirant agents, cosmetic, dermatological formulation	419–421
					synthesis of pregabalin	422
					synthesis of derivatives, thrombin inhibitors	423,424

TABLE V
Chiral hydroxy carboxylic esters

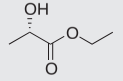
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Ethyl (*S*)-2-hydroxypropanoate (ethyl (*S*)-lactate) Cas.: 687-47-8						
A	*Rhynchophorus cruentatus*	Coleoptera		synergist for pheromone		42,454

TABLE V
(*Continued*)

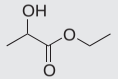
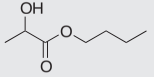
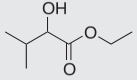
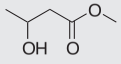
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Ethyl 2-hydroxypropanoate (ethyl lactate) Cas.: 97-64-3						
A	mammals			down-regulation of the production of proinflammatory cytokines		425
					spirits, beverages aroma	111
					treatment of acne	426
					photosensitive resin composition	427
Butyl 2-hydroxypropanoate (butyl lactate) Cas.: 138-22-7						
					denaturating agent for cosmetic and oral hygienic products	428
Ethyl 2-hydroxy-3-methylbutanoate Cas.: 2441-06-7						
					spirits, beverages aroma (wine, sherry)	111,429
Methyl 3-hydroxybutanoate Cas.: 1487-49-6						
A	*Papilio demodocus*	Lepidoptera	osmeterium	defensive secretions		405
					synthesis of macrosphelides	430

TABLE V
(*Continued*)

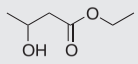
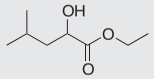
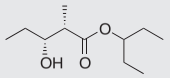
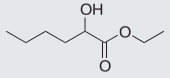
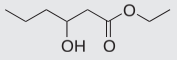
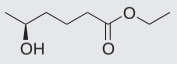
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Ethyl 3-hydroxybutanoate Cas.: 5405-41-4						
P	*Sicana odorifera*	Cucurbitales	fruit	fruit aroma		83
Ethyl 2-hydroxy-4-methylpentanoate Cas.: 10348-47-7						
					food volatiles (wine, sherry)	429
1-Ethylpropyl (2*S*,3*R*)-3-hydroxy-2-methylpentanoate Cas.: 114715-56-9						
A	*Sitophilus granarius*	Coleoptera		aggregation pheromone		431–433
Ethyl 2-hydroxyhexanoate Cas.: 52089-55-1						
					spirits, beverages aroma	111
Ethyl 3-hydroxyhexanoate Cas.: 2305-25-1						
P	*Sicana odorifera*	Cucurbitales	fruit	fruit aroma		83
Ethyl (*S*)-5-hydroxyhexanoate Cas.: 118627-53-5						
					intermediate in the synthesis of several pharmaceuticals	30,102

TABLE V
(*Continued*)

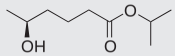
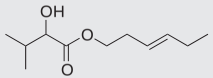
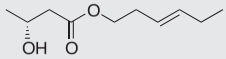
	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Isopropyl (*S*)-5-hydroxyhexanoate Cas.: 861695-45-6						
A	*Plioreocepta poeciloptera*	Diptera		sex pheromone, M		434
Hex-3-en-1-yl (*R*)-2-hydroxy-3-methylbutanoate						
A	*Pristhesancus plagipennis*	Hemiptera	abdominal glands	aggregation pheromone		435
Hex-3-en-1-yl (*R*)-3-hydroxybutanoate Cas.: 363184-83-2						
A	*Eucerceris* sp.	Hymenoptera	mandibular glands	sex pharomone, M		436

TABLE VI
Chiral hydroxy amines

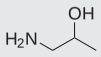
Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
1-Aminopropan-2-ol Cas.: 78-96-6					
				thermal study for cryopreservation	437
				polymer hydrogel films: drug release, biosensors, tissue engineering, pH sensors	438
				derivatives active in antiviral therapy (HIV)	439,440
				synthesis of xanthone derivatives, anticonvulsant activity	441

TABLE VI
(*Continued*)

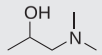
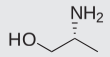
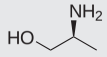
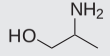
Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
1-(Dimethylamino)propan-2-ol Cas.: 108-16-7					
				reactive amine catalysts	442
				synthesis of silicoaluminophosphate	443
(*R*)-2-Aminopropan-1-ol Cas.: 35320-23-1					
				synthesis of antitumour, antimelanoma agents	444
(*S*)-2-Aminopropan-1-ol Cas.: 2749-11-3					
				synthesis of antitumour, antimelanoma agents	444
2-Aminopropan-1-ol Cas.: 6168-72-5					
				thermal study for cryopreservation	437
				synthesis of xanthone derivatives, anticonvulsant activity	441
				flavours modulation	445

TABLE VI
(*Continued*)

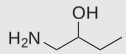
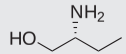
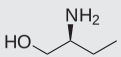
Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
1-Aminobutan-2-ol Cas.: 13552-21-1					
				synthesis of xanthone derivatives, anticonvulsant activity	441
(*R*)-2-Aminobutan-1-ol Cas.: 5856-63-3					
			β1-blocker used to reduce arterial blood pressure	synthesis of metoprolol analogues	446
				synthesis of antitumour, antimelanoma agents	444
				synthesis of prodrugs of some 2-arylpropanoic acids: ibuprofen, naproxen, diclofenac, ketorolac	447
(*S*)-2-Aminobutan-1-ol Cas.: 5856-63-3					
			β1-blocker used to reduce arterial blood pressure	synthesis of metoprolol analogues	446
				synthesis of antitumour, antimelanoma agents	444
				synthesis of derivatives, anticonvulsant activity	448
				inhibitor of ethanolamine kinase (*Plasmodium falciparum*) inhibitor of multiplication	449,450

TABLE VI
(*Continued*)

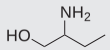
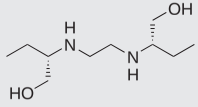
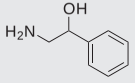
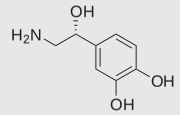
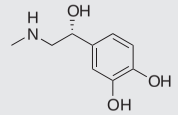
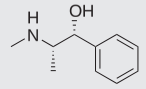
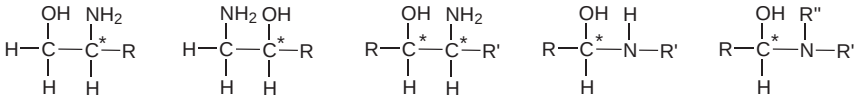
Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
2-Aminobutan-1-ol Cas.: 96-20-8					
				synthesisn of xanthone derivatives as potential antiarrhythmic and hypotensive agents	451
				synthesis of polyurethanes for implants	452
				ophthalmic compositions	453
(2*S*,2′*S*)-2,2′-(Ethane-1,2-diyldiimino)dibutan-1-ol Cas.: 74-55-5					
				treatment of tuberculosis, synthesis of analogues antitubercular drugs	455–468
2-Amino-1-phenylethan-1-ol Cas.: 7568-93-6					
mammals			neurotransmitter	noradrenaline analogue, pharmaceuticals	469
				pharmaceuticals, gastrointestinal tract	470

TABLE VI
(*Continued*)

	Producer species	Order	Organ/Tissue	Biological function	Application	Ref.
Noradrenaline (norepinephrine) Cas.: 138-65-8						
	mammals			stress hormone, neurotransmitter	pharmaceuticals, increases blood pressure	
Adrenaline (epinephrine) Cas.: 329-65-7						
	mammals			stress hormone, neurotransmitter	pharmaceuticals, immunosuppressant	
Ephedrine Cas.: 53214-57-6						
P	*Ephedra* sp.	Ephedrales			bronchodilator, asthma treatment, pharmaceuticals	
					chewing gums	471
					pharmaceuticals	472–474

B – bacteria, F – fungi, P – plants, A – animals; M – male, F – female.

CLASS VI. CHIRAL HYDROXY AMINES



Chiral hydroxy amines are organic compounds containing hydroxy groups on or next to the chiral carbon atom, which is near or adjacent to amino group ($–NH_2$). Amines are derivatives of ammonia with one or more alkyl groups bonded to the nitrogen atom. They are classified according to the number of alkyl groups bonded to the nitrogen atom into three classes: primary amines ($–NH_2$), secondary amines (–NHR′), and tertiary amines (–NR′R″). For all practical purposes, the nitrogen atom of an amine can be considered to be sp^3-hybridized with the unshared electron pair occupying one orbital. This means that the unshared pair is relatively exposed and is involved in almost all of the reactions of amines. Hydroxy amines are highly polar organic compounds because the large dipole moment of the lone pair of electrons adds to the dipole moments of the C–N and H–N bonds.

Biological functions. Neurotrasmitters 2-amino-1-phenylethan-1-ol, noradrenaline, adrenaline and their derivatives form one of the most important classes of pharmaceutical compounds. Also other chiral hydroxy amines 1-aminopropan-2-ol, 2-aminopropan-1-ol, 1-aminobutan-2-ol, 2-aminobutan-1-ol and ethambutol are widely used in pharmaceutical industry.

Applications. Derivatives of 1-aminopropan-2-ol are active in antiviral therapy[439,440]. 2-Aminopropan-1-ol and 2-aminobutan-1-ol can be used in the synthesis of antitumour and antimelanoma agents[444]. Ethambutol, (2*S*,2*S*′)-2,2′-(ethane-1,2-diyldiimino)dibutan-1-ol is a mainstay of contemporary chemotherapy in the treatment of tuberculosis, which causes the highest mortality attributable to a single etiologic agent. Nearly three million people infected with the tuberculosis bacillus perish every year[455,475].

CONCLUSIONS

Chiral aliphatic hydroxy compounds play an important role in biological systems. They are employed in chemical communication among living organisms where they serve as sex pheromones, aggregation pheromones, alarm pheromones, trail pheromones, attractants or repellents. Chiral hydroxy compounds are important also for medical, industrial and agricul-

tural applications. Many pharmaceuticals, agrochemicals, food additives, fragrances and cosmetics used in daily lives are based on chiral aliphatic hydroxy compounds, e.g., pentan-2-ol, oct-1-en-3-ol, linalool, butane-2,3-diol, hexane-1,2-diol, lactic acid, mandelic acid, ethyl lactate, ethyl 5-hydroxyhexanoate, 1-aminopropan-2-ol or ethambutol.

The chirality of organic compounds is an important topic in the design, development and marketing of new products. It is expected that the 21st century will bring an additional knowledge of the structure–function relationships in recognition of chiral organic compounds by biomolecules and of the role of this recognition in the chemical communication among organisms. We also expect development of new methods for separation of optically pure compounds and their production using chemical synthesis and biocatalysis. The integration of collected information about the physico-chemical properties, biological functions and practical applications of chiral hydroxy compounds into a publically accessible knowledgebase, work on which is underway in our laboratory, may assist these efforts.

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