The Enzyme List
Class 5 — Isomerases

Nomenclature Committee
of the
International Union of Biochemistry and Molecular Biology
(NC-IUBMB)

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Contents

EC 5.1 Racemases and epimerases

This subclass contains enzymes that catalyse either racemization or epimerization of a centre of chirality. Sub-subclasses are based on the substrate: amino acids and derivatives (EC 5.1.1), hydroxy acids and derivatives (EC 5.1.2), carbohydrates and derivatives (EC 5.1.3), or other compounds (EC 5.1.99).

EC 5.1.1 Acting on amino acids and derivatives

EC 5.1.1.1
Accepted name: alanine racemase
Reaction: L-alanine = D-alanine
Other name(s): L-alanine racemase
Systematic name: alanine racemase
Comments: A pyridoxal-phosphate protein.
References: [176, 323, 324]

[EC 5.1.1.1 created 1961]

EC 5.1.1.2
Accepted name: methionine racemase
Reaction: L-methionine = D-methionine
Systematic name: methionine racemase
Comments: A pyridoxal-phosphate protein.
References: [131]

[EC 5.1.1.2 created 1961]

EC 5.1.1.3
Accepted name: glutamate racemase
Reaction: L-glutamate = D-glutamate
Systematic name: glutamate racemase
Comments: A pyridoxal-phosphate protein.
References: [94]

[EC 5.1.1.3 created 1961]

EC 5.1.1.4
Accepted name: proline racemase
Reaction: L-proline = D-proline
Systematic name: proline racemase
References: [269]

[EC 5.1.1.4 created 1961]

EC 5.1.1.5
Accepted name: lysine racemase
Reaction: L-lysine = D-lysine
Systematic name: lysine racemase
References: [118]

[EC 5.1.1.5 created 1961]

EC 5.1.1.6
Accepted name: threonine racemase
Reaction: L-threonine = D-threonine
Systematic name: threonine racemase
Comments: Inverts both chiral centres.
References: [9]

[EC 5.1.1.6 created 1961, modified 1981]

EC 5.1.1.7

Accepted name: diaminopimelate epimerase
Reaction: LL-2,6-diaminoheptanedioate = *meso*-diaminoheptanedioate
Systematic name: LL-2,6-diaminoheptanedioate 2-epimerase
References: [14]

[EC 5.1.1.7 created 1961]

EC 5.1.1.8

Accepted name: 4-hydroxyproline epimerase
Reaction: *trans*-4-hydroxy-L-proline = *cis*-4-hydroxy-D-proline
Other name(s): hydroxyproline epimerase; hydroxyproline 2-epimerase; L-hydroxyproline epimerase
Systematic name: 4-hydroxyproline 2-epimerase
Comments: Also interconverts *trans*-4-hydroxy-D-proline and *cis*-4-hydroxy-L-proline.
References: [2]

[EC 5.1.1.8 created 1965, modified 1983]

EC 5.1.1.9

Accepted name: arginine racemase
Reaction: L-arginine = D-arginine
Systematic name: arginine racemase
Comments: A pyridoxal-phosphate protein.
References: [335]

[EC 5.1.1.9 created 1972]

EC 5.1.1.10

Accepted name: amino-acid racemase
Reaction: an L-amino acid = a D-amino acid
Other name(s): L-amino acid racemase
Systematic name: amino-acid racemase
Comments: A pyridoxal-phosphate protein.
References: [265]

[EC 5.1.1.10 created 1972]

EC 5.1.1.11

Accepted name: phenylalanine racemase (ATP-hydrolysing)
Reaction: ATP + L-phenylalanine + H_2O = AMP + diphosphate + D-phenylalanine
Other name(s): phenylalanine racemase; phenylalanine racemase (adenosine triphosphate-hydrolysing); gramicidin S synthetase I
Systematic name: phenylalanine racemase (ATP-hydrolysing)
References: [329]

[EC 5.1.1.11 created 1972]

EC 5.1.1.12

Accepted name: ornithine racemase
Reaction: L-ornithine = D-ornithine

Systematic name: ornithine racemase
References: [47]

[EC 5.1.1.12 created 1972 as EC 5.4.3.1, transferred 1976 to EC 5.1.1.12]

EC 5.1.1.13
Accepted name: aspartate racemase
Reaction: L-aspartate = D-aspartate
Other name(s): D-aspartate racemase; McyF
Systematic name: aspartate racemase
Comments: Also acts, at half the rate, on L-alanine.
References: [160, 332, 168, 259, 331]

[EC 5.1.1.13 created 1976]

EC 5.1.1.14
Accepted name: nocardicin-A epimerase
Reaction: isonocardicin A = nocardicin A
Other name(s): isonocardicin A epimerase
Systematic name: nocardicin-A epimerase
Comments: The (9′*S*) configuration of isonocardicin A is converted into the (9′*R*) configuration.
References: [313]

[EC 5.1.1.14 created 1992]

EC 5.1.1.15
Accepted name: 2-aminohexano-6-lactam racemase
Reaction: L-2-aminohexano-6-lactam = D-2-aminohexano-6-lactam
Other name(s): α-amino-ε-caprolactam racemase
Systematic name: 2-aminohexano-6-lactam racemase
Comments: Contains pyridoxal 5′-phosphate. Also racemises 2-aminopentano-5-lactam (α-amino-δ-valerolactam) and 2-amino-4-thiahexano-6-lactam (where S replaces CH_2 of C-4). It does not catalyse the racemisation of α-amino acids but has some transaminase activity with them.
References: [4, 5]

[EC 5.1.1.15 created 1999]

EC 5.1.1.16
Accepted name: protein-serine epimerase
Reaction: [protein]-L-serine = [protein]-D-serine
Other name(s): protein-serine racemase
Systematic name: [protein]-serine epimerase
Comments: The enzyme specifically interconverts the configuration of Ser-46 of the peptide ω-agatoxin-KT, found in the venom of the funnel web spider, *Agelenopsis aperta*, but not that of the other serine residue, Ser-28.
References: [256]

[EC 5.1.1.16 created 1999]

EC 5.1.1.17
Accepted name: isopenicillin-N epimerase
Reaction: isopenicillin N = penicillin N

Systematic name: penicillin-N 5-amino-5-carboxypentanoyl-epimerase
Comments: This enzyme contains pyridoxal phosphate. Epimerization at C-5 of the 5-amino-5-carboxypentanoyl group to form penicillin N is required to make a substrate for EC 1.14.20.1, deactoxycephalosporin-C synthase, to produce cephalosporins. Forms part of the penicillin biosynthesis pathway (for pathway, click here).
References: [299, 159, 43, 333]

[EC 5.1.1.17 created 2002]

EC 5.1.1.18
Accepted name: serine racemase
Reaction: L-serine = D-serine
Other name(s): SRR
Systematic name: serine racemase
Comments: A pyridoxal-phosphate protein that is highly selective for L-serine as substrate. D-Serine is found in type-II astrocytes in mammalian brain, where it appears to be an endogenous ligand of the glycine site of *N*-methyl-D-aspartate (NMDA) receptors [321, 322]. The reaction can also occur in the reverse direction but does so more slowly at physiological serine concentrations [82].
References: [321, 322, 196, 82]

[EC 5.1.1.18 created 2007]

EC 5.1.2 Acting on hydroxy acids and derivatives

EC 5.1.2.1
Accepted name: lactate racemase
Reaction: (*S*)-lactate = (*R*)-lactate
Other name(s): lacticoracemase; hydroxyacid racemase; lactic acid racemase
Systematic name: lactate racemase
References: [120, 145]

[EC 5.1.2.1 created 1961]

EC 5.1.2.2
Accepted name: mandelate racemase
Reaction: (*S*)-mandelate = (*R*)-mandelate
Systematic name: mandelate racemase
References: [101]

[EC 5.1.2.2 created 1961]

EC 5.1.2.3
Accepted name: 3-hydroxybutyryl-CoA epimerase
Reaction: (*S*)-3-hydroxybutanoyl-CoA = (*R*)-3-hydroxybutanoyl-CoA
Other name(s): 3-hydroxybutyryl coenzyme A epimerase; 3-hydroxyacyl-CoA epimerase
Systematic name: 3-hydroxybutanoyl-CoA 3-epimerase
References: [272, 307]

[EC 5.1.2.3 created 1961]

EC 5.1.2.4

Accepted name: acetoin racemase
Reaction: (*S*)-acetoin = (*R*)-acetoin
Other name(s): acetylmethylcarbinol racemase
Systematic name: acetoin racemase
References: [284]

[EC 5.1.2.4 created 1972]

EC 5.1.2.5
Accepted name: tartrate epimerase
Reaction: (*R*,*R*)-tartrate = *meso*-tartrate
Other name(s): tartaric racemase
Systematic name: tartrate epimerase
References: [232]

[EC 5.1.2.5 created 1972]

EC 5.1.2.6
Accepted name: isocitrate epimerase
Reaction: (1*R*,2*S*)-1-hydroxypropane-1,2,3-tricarboxylate = (1*S*,2*S*)-1-hydroxypropane-1,2,3-tricarboxylate
Systematic name: (1*R*,2*S*)-1-hydroxypropane-1,2,3-tricarboxylate 1-epimerase
Comments: (1*R*,2*S*)-1-hydroxypropane-1,2,3-tricarboxylate is the commonly occurring isomer of isocitrate.
References: [116]

[EC 5.1.2.6 created 1984]

EC 5.1.3 Acting on carbohydrates and derivatives

EC 5.1.3.1
Accepted name: ribulose-phosphate 3-epimerase
Reaction: D-ribulose 5-phosphate = D-xylulose 5-phosphate
Other name(s): phosphoribulose epimerase; erythrose-4-phosphate isomerase; phosphoketopentose 3-epimerase; xylulose phosphate 3-epimerase; phosphoketopentose epimerase; ribulose 5-phosphate 3-epimerase; D-ribulose phosphate-3-epimerase; D-ribulose 5-phosphate epimerase; D-ribulose-5-P 3-epimerase; D-xylulose-5-phosphate 3-epimerase; pentose-5-phosphate 3-epimerase
Systematic name: D-ribulose-5-phosphate 3-epimerase
Comments: The enzyme also converts D-erythrose 4-phosphate into D-erythrulose 4-phosphate and D-threose 4-phosphate.
References: [16, 64, 121, 276, 286]

[EC 5.1.3.1 created 1961, modified 1989]

EC 5.1.3.2
Accepted name: UDP-glucose 4-epimerase
Reaction: UDP-glucose = UDP-galactose
Other name(s): UDP-galactose 4-epimerase; uridine diphosphoglucose epimerase; galactowaldenase; UDPG-4-epimerase; uridine diphosphate galactose 4-epimerase; uridine diphospho-galactose-4-epimerase; UDP-glucose epimerase; UDP-galactose 4-epimerase; 4-epimerase; UDPG-4-epimerase; uridine diphosphoglucose 4-epimerase; uridine diphosphate glucose 4-epimerase; UDP-D-galactose 4-epimerase
Systematic name: UDP-glucose 4-epimerase
Comments: Requires NAD^+. Also acts on UDP-2-deoxyglucose.
References: [164, 186, 314]

[EC 5.1.3.2 created 1961]

EC 5.1.3.3

Accepted name: aldose 1-epimerase

Reaction: α-D-glucose = β-D-glucose

Other name(s): mutarotase; aldose mutarotase; galactose mutarotase; galactose 1-epimerase; D-galactose 1-epimerase

Systematic name: aldose 1-epimerase

Comments: Also acts on L-arabinose, D-xylose, D-galactose, maltose and lactose. This enzyme catalyses the first step in galactose metabolism by converting β-D-glucose into α-D-glucose, which is the substrate for EC 2.7.1.6, galactokinase [24, 289].

References: [27, 28, 140, 166, 24, 289, 288]

[EC 5.1.3.3 created 1961]

EC 5.1.3.4

Accepted name: L-ribulose-5-phosphate 4-epimerase

Reaction: L-ribulose 5-phosphate = D-xylulose 5-phosphate

Other name(s): phosphoribulose isomerase; ribulose phosphate 4-epimerase; L-ribulose-phosphate 4-epimerase; L-ribulose 5-phosphate 4-epimerase; AraD; L-Ru5P

Systematic name: L-ribulose-5-phosphate 4-epimerase

Comments: Requires a divalent cation for activity.

References: [42, 62, 162, 320, 12, 161, 245]

[EC 5.1.3.4 created 1965, modified 2005]

EC 5.1.3.5

Accepted name: UDP-arabinose 4-epimerase

Reaction: UDP-L-arabinose = UDP-D-xylose

Other name(s): uridine diphosphoarabinose epimerase; UDP arabinose epimerase; uridine 5′-diphosphate-D-xylose 4-epimerase; UDP-D-xylose 4-epimerase

Systematic name: UDP-L-arabinose 4-epimerase

References: [74]

[EC 5.1.3.5 created 1965]

EC 5.1.3.6

Accepted name: UDP-glucuronate 4-epimerase

Reaction: UDP-glucuronate = UDP-D-galacturonate

Other name(s): uridine diphospho-D-galacturonic acid; UDP glucuronic epimerase; uridine diphosphoglucuronic epimerase; UDP-galacturonate 4-epimerase; uridine diphosphoglucuronate epimerase; UDP-D-galacturonic acid 4-epimerase

Systematic name: UDP-glucuronate 4-epimerase

References: [74]

[EC 5.1.3.6 created 1965]

EC 5.1.3.7

Accepted name: UDP-*N*-acetylglucosamine 4-epimerase

Reaction: UDP-*N*-acetyl-D-glucosamine = UDP-*N*-acetyl-D-galactosamine

Other name(s): UDP acetylglucosamine epimerase; uridine diphosphoacetylglucosamine epimerase; uridine diphosphate *N*-acetylglucosamine-4-epimerase; uridine 5′-diphospho-*N*-acetylglucosamine-4-epimerase

Systematic name: UDP-*N*-acetyl-D-glucosamine 4-epimerase

References: [93, 153]

[EC 5.1.3.7 created 1965]

EC 5.1.3.8

Accepted name: *N*-acylglucosamine 2-epimerase
Reaction: *N*-acyl-D-glucosamine = *N*-acyl-D-mannosamine
Other name(s): acylglucosamine 2-epimerase; *N*-acetylglucosamine 2-epimerase
Systematic name: *N*-acyl-D-glucosamine 2-epimerase
Comments: Requires catalytic amounts of ATP.
References: [92]

[EC 5.1.3.8 created 1972]

EC 5.1.3.9

Accepted name: *N*-acylglucosamine-6-phosphate 2-epimerase
Reaction: *N*-acyl-D-glucosamine 6-phosphate = *N*-acyl-D-mannosamine 6-phosphate
Other name(s): acylglucosamine-6-phosphate 2-epimerase; acylglucosamine phosphate 2-epimerase
Systematic name: *N*-acyl-D-glucosamine-6-phosphate 2-epimerase
References: [91]

[EC 5.1.3.9 created 1972]

EC 5.1.3.10

Accepted name: CDP-paratose 2-epimerase
Reaction: CDP-3,6-dideoxy-D-glucose = CDP-3,6-dideoxy-D-mannose
Other name(s): CDP-paratose epimerase; cytidine diphosphoabequose epimerase; cytidine diphosphodideoxyglucose epimerase; cytidine diphosphoparatose epimerase; cytidine diphosphate paratose-2-epimerase; CDP-abequose epimerase (incorrect); CDP-D-abequose 2-epimerase (incorrect)
Systematic name: CDP-3,6-dideoxy-D-glucose 2-epimerase
Comments: Requires NAD^+. CDP-paratose (CDP-3,6-dideoxy-D-glucose), is more systematically called CDP-α-3,6-dideoxy-D-*ribo*-hexose. CDP-tyvelose (CDP-3,6-dideoxy-D-mannose) is systematically called CDP-3,6-dideoxy-D-*arabino*-hexose.
References: [185, 167]

[EC 5.1.3.10 created 1972, modified 2005]

EC 5.1.3.11

Accepted name: cellobiose epimerase
Reaction: cellobiose = D-glucosyl-D-mannose
Systematic name: cellobiose 2-epimerase
References: [296]

[EC 5.1.3.11 created 1972]

EC 5.1.3.12

Accepted name: UDP-glucuronate 5′-epimerase
Reaction: UDP-glucuronate = UDP-L-iduronate
Other name(s): uridine diphosphoglucuronate 5′-epimerase; UDP-glucuronic acid 5′-epimerase; C-5-uronosyl epimerase
Systematic name: UDP-glucuronate 5′-epimerase
Comments: Requires NAD^+.
References: [125]

[EC 5.1.3.12 created 1972]

EC 5.1.3.13

Accepted name: dTDP-4-dehydrorhamnose 3,5-epimerase

Reaction: dTDP-4-dehydro-6-deoxy-D-glucose = dTDP-4-dehydro-6-deoxy-L-mannose

Other name(s): dTDP-L-rhamnose synthetase; dTDP-L-rhamnose synthetase; thymidine diphospho-4-ketorhamnose 3,5-epimerase; TDP-4-ketorhamnose 3,5-epimerase; dTDP-4-dehydro-6-deoxy-D-glucose 3,5-epimerase; TDP-4-keto-L-rhamnose-3,5-epimerase

Systematic name: dTDP-4-dehydro-6-deoxy-D-glucose 3,5-epimerase

Comments: The enzyme occurs in a complex with EC 1.1.1.133 dTDP-4-dehydrorhamnose reductase.

References: [88, 189]

[EC 5.1.3.13 created 1972]

EC 5.1.3.14

Accepted name: UDP-*N*-acetylglucosamine 2-epimerase

Reaction: UDP-*N*-acetyl-D-glucosamine = UDP-*N*-acetyl-D-mannosamine

Other name(s): UDP-*N*-acetylglucosamine 2′-epimerase; uridine diphosphoacetylglucosamine 2′-epimerase; uridine diphospho-*N*-acetylglucosamine 2′-epimerase; uridine diphosphate-*N*-acetylglucosamine-2′-epimerase

Systematic name: UDP-*N*-acetyl-D-glucosamine 2-epimerase

Comments: The enzyme hydrolyses the product to UDP and *N*-acetyl-D-mannosamine.

References: [142]

[EC 5.1.3.14 created 1976]

EC 5.1.3.15

Accepted name: glucose-6-phosphate 1-epimerase

Reaction: α-D-glucose 6-phosphate = β-D-glucose 6-phosphate

Systematic name: D-glucose-6-phosphate 1-epimerase

References: [326]

[EC 5.1.3.15 created 1976]

EC 5.1.3.16

Accepted name: UDP-glucosamine 4-epimerase

Reaction: UDP-glucosamine = UDP-galactosamine

Systematic name: UDP-glucosamine 4-epimerase

References: [173, 260]

[EC 5.1.3.16 created 1984]

EC 5.1.3.17

Accepted name: heparosan-*N*-sulfate-glucuronate 5-epimerase

Reaction: heparosan-*N*-sulfate D-glucuronate = heparosan-*N*-sulfate L-iduronate

Other name(s): heparosan epimerase; heparosan-*N*-sulfate-D-glucuronosyl 5-epimerase; C-5 uronosyl epimerase; polyglucuronate epimerase; D-glucuronyl C-5 epimerase; poly[(1,4)-β-D-glucuronosyl-(1,4)-*N*-sulfo-α-D-glucosaminyl] glucurono-5-epimerase

Systematic name: poly[(1→4)-β-D-glucuronosyl-(1→4)-*N*-sulfo-α-D-glucosaminyl] glucurono-5-epimerase

Comments: Acts on D-glucuronosyl residues adjacent to sulfated D-glucosamine units in the heparin precursor. Not identical with EC 5.1.3.19 chondroitin-glucuronate 5-epimerase.

References: [126]

[EC 5.1.3.17 created 1984]

EC 5.1.3.18

Accepted name: GDP-mannose 3,5-epimerase

Reaction: GDP-mannose = GDP-L-galactose

Other name(s): GDP-D-mannose:GDP-L-galactose epimerase; guanosine 5′-diphosphate D-mannose:guanosine 5′-diphosphate L-galactose epimerase

Systematic name: GDP-mannose 3,5-epimerase

References: [19, 110]

[EC 5.1.3.18 created 1986]

EC 5.1.3.19

Accepted name: chondroitin-glucuronate 5-epimerase

Reaction: chondroitin D-glucuronate = dermatan L-iduronate

Other name(s): polyglucuronate 5-epimerase; dermatan-sulfate 5-epimerase; urunosyl C-5 epimerase; chondroitin D-glucuronosyl 5-epimerase

Systematic name: chondroitin-D-glucuronate 5-epimerase

Comments: Not identical with EC 5.1.3.17 heparosan-*N*-sulfate-glucuronate 5-epimerase.

References: [174]

[EC 5.1.3.19 created 1986]

EC 5.1.3.20

Accepted name: ADP-*glyceromanno*-heptose 6-epimerase

Reaction: ADP-D-*glycero*-D-*manno*-heptose = ADP-L-*glycero*-D-*manno*-heptose

Systematic name: ADP-L-*glycero*-D-*manno*-heptose 6-epimerase

Comments: Requires NAD^+.

References: [65, 229]

[EC 5.1.3.20 created 1999]

EC 5.1.3.21

Accepted name: maltose epimerase

Reaction: α-maltose = β-maltose

Systematic name: maltose 1-epimerase

Comments: The enzyme catalyses the interconversion of α and β anomers of maltose more effectively than those of disaccharides such as lactose and cellobiose.

References: [258]

[EC 5.1.3.21 created 2002]

EC 5.1.3.22

Accepted name: L-ribulose-5-phosphate 3-epimerase

Reaction: L-ribulose 5-phosphate = L-xylulose 5-phosphate

Other name(s): L-xylulose 5-phosphate 3-epimerase; UlaE; SgaU

Systematic name: L-ribulose-5-phosphate 3-epimerase

Comments: Along with EC 4.1.1.85, 3-dehydro-L-gulonate-6-phosphate decarboxylase, this enzyme is involved in a pathway for the utilization of L-ascorbate by *Escherichia coli*.

References: [334]

[EC 5.1.3.22 created 2005]

EC 5.1.3.23

Accepted name: UDP-2,3-diacetamido-2,3-dideoxyglucuronic acid 2-epimerase

Reaction: UDP-2,3-diacetamido-2,3-dideoxy-α-D-glucuronate = UDP-2,3-diacetamido-2,3-dideoxy-α-D-mannuronate

Other name(s): UDP-GlcNAc3NAcA 2-epimerase; UDP-α-D-GlcNAc3NAcA 2-epimerase; 2,3-diacetamido-2,3-dideoxy-α-D-glucuronic acid 2-epimerase; WbpI; WlbD

Systematic name: 2,3-diacetamido-2,3-dideoxy-α-D-glucuronate 2-epimerase

Comments: This enzyme participates in the biosynthetic pathway for UDP-α-D-ManNAc3NAcA (UDP-2,3-diacetamido-2,3-dideoxy-α-D-mannuronic acid), an important precursor of the B-band lipopolysaccharide of *Pseudomonas aeroginosa* serotype O5 and of the band-A trisaccharide of *Bordetella pertussis*, both important respiratory pathogens [311]. The enzyme is highly specific as UDP-α-D-GlcNAc, UDP-α-D-GlcNAcA (UDP-2-acetamido-2-deoxy-α-D-glucuronic acid) and UDP-α-D-GlcNAc3NAc (UDP-2,3-diacetamido-2,3-dideoxy-α-D-glucose) cannot act as substrates [311].

References: [311, 310, 135]

[EC 5.1.3.23 created 2007]

EC 5.1.99 Acting on other compounds

EC 5.1.99.1

Accepted name: methylmalonyl-CoA epimerase

Reaction: (*R*)-methylmalonyl-CoA = (*S*)-methylmalonyl-CoA

Other name(s): methylmalonyl-CoA racemase; methylmalonyl coenzyme A racemase; DL-methylmalonyl-CoA racemase; 2-methyl-3-oxopropanoyl-CoA 2-epimerase [incorrect]

Systematic name: methylmalonyl-CoA 2-epimerase

References: [187, 218]

[EC 5.1.99.1 created 1965, modified 1981]

EC 5.1.99.2

Accepted name: 16-hydroxysteroid epimerase

Reaction: 16α-hydroxysteroid = 16β-hydroxysteroid

Systematic name: 16-hydroxysteroid 16-epimerase

References: [56]

[EC 5.1.99.2 created 1972]

EC 5.1.99.3

Accepted name: allantoin racemase

Reaction: (*S*)(+)-allantoin = (*R*)(-)-allantoin

Systematic name: allantoin racemase

References: [302]

[EC 5.1.99.3 created 1976]

EC 5.1.99.4

Accepted name: α-methylacyl-CoA racemase

Reaction: (2*S*)-2-methylacyl-CoA = (2*R*)-2-methylacyl-CoA

Systematic name: 2-methylacyl-CoA 2-epimerase

Comments: α-methyl-branched acyl-CoA derivatives with chain lengths of more than C10 are substrates. Also active towards some aromatic compounds (e.g. ibuprofen) and bile acid intermediates, such as trihydroxycoprostanoyl-CoA. Not active towards free acids

References: [248]

[EC 5.1.99.4 created 1999]

EC 5.1.99.5

Accepted name: hydantoin racemase

Reaction: D-5-monosubstituted hydantoin = L-5-monosubstituted hydantoin

Other name(s): 5′-monosubstituted-hydantoin racemase; HyuA; HyuE

Systematic name: D-5-monosubstituted-hydantoin racemase

Comments: This enzyme, along with *N*-carbamoylase (EC 3.5.1.77 and EC 3.5.1.87) and hydantoinase, forms part of the reaction cascade known as the "hydantoinase process", which allows the total conversion of D,L-5-monosubstituted hydantoins into optically pure D- or L-amino acids [8]. The enzyme from *Pseudomonas* sp. (HyuE) has a preference for hydantoins with aliphatic substituents, e.g. D- and L-5-(2-methylthioethyl)hydantoin, whereas that from *Arthrobacter aurescens* shows highest activity with arylalkyl substituents, especially 5-benzylhydantoin, at the 5-position [312]. In the enzyme from *Sinorhizobium meliloti*, Cys^{76} is responsible for recognition and proton retrieval of D-isomers, while Cys^{181} is responsible for L-isomer recognition and racemization [180].

References: [308, 312, 182, 181, 279, 180, 8]

[EC 5.1.99.5 created 2008]

EC 5.2 *cis-trans*-Isomerases

This subclass contains a single sub-subclass for enzymes that rearrange the geometry at double bonds (*cis-trans* isomerases; EC 5.2.1).

EC 5.2.1 *cis-trans* Isomerases (only sub-subclass identified to date)

EC 5.2.1.1

Accepted name: maleate isomerase

Reaction: maleate = fumarate

Systematic name: maleate *cis-trans*-isomerase

References: [25]

[EC 5.2.1.1 created 1961]

EC 5.2.1.2

Accepted name: maleylacetoacetate isomerase

Reaction: 4-maleylacetoacetate = 4-fumarylacetoacetate

Other name(s): maleylacetoacetic isomerase; maleylacetone isomerase; maleylacetone *cis-trans*-isomerase

Systematic name: 4-maleylacetoacetate *cis-trans*-isomerase

Comments: Also acts on maleylpyruvate.

References: [68, 158, 252]

[EC 5.2.1.2 created 1961]

EC 5.2.1.3

Accepted name: retinal isomerase

Reaction: *all-trans*-retinal = 11-*cis*-retinal

Other name(s): retinene isomerase; retinoid isomerase

Systematic name: *all-trans*-retinal 11-*cis-trans*-isomerase

Comments: Light shifts the reaction towards the *cis*-isomer.

References: [119, 255]

[EC 5.2.1.3 created 1961, modified 1976]

EC 5.2.1.4

Accepted name: maleylpyruvate isomerase

Reaction: 3-maleylpyruvate = 3-fumarylpyruvate

Systematic name: 3-maleylpyruvate *cis*-*trans*-isomerase

References: [158]

[EC 5.2.1.4 created 1965]

EC 5.2.1.5

Accepted name: linoleate isomerase

Reaction: 9-*cis*,12-*cis*-octadecadienoate = 9-*cis*,11-*trans*-octadecadienoate

Other name(s): linoleic acid isomerase

Systematic name: linoleate Δ^{12}-*cis*-Δ^{11}-*trans*-isomerase

References: [141]

[EC 5.2.1.5 created 1972]

EC 5.2.1.6

Accepted name: furylfuramide isomerase

Reaction: (*E*)-2-(2-furyl)-3-(5-nitro-2-furyl)acrylamide = (*Z*)-2-(2-furyl)-3-(5-nitro-2-furyl)acrylamide

Systematic name: 2-(2-furyl)-3-(5-nitro-2-furyl)acrylamide *cis*-*trans*-isomerase

Comments: Requires NADH.

References: [291]

[EC 5.2.1.6 created 1978]

EC 5.2.1.7

Accepted name: retinol isomerase

Reaction: *all*-*trans*-retinol = 11-*cis*-retinol

Other name(s): *all*-*trans*-retinol isomerase

Systematic name: *all*-*trans*-retinol 11-*cis*-*trans*-isomerase

Comments: Converts *all*-*trans*-retinol to 11-*cis*-retinol in the dark, thus reversing the effect of EC 5.2.1.3 retinal isomerase.

References: [29, 38]

[EC 5.2.1.7 created 1989]

EC 5.2.1.8

Accepted name: peptidylprolyl isomerase

Reaction: peptidylproline (ω=180) = peptidylproline (ω=0)

Other name(s): PPIase; cyclophilin [misleading, see comments]; peptide bond isomerase; peptidyl-prolyl *cis*-*trans* isomerase

Systematic name: peptidylproline *cis*-*trans*-isomerase

Comments: The first type of this enzyme found [79] proved to be the protein cyclophilin, which binds the immunosuppressant cyclosporin A. Other distinct families of the enzyme exist, one being FK-506 binding proteins (FKBP) and another that includes parvulin from *Escherichia coli*. The three families are structurally unrelated and can be distinguished by being inhibited by cyclosporin A, FK-506 and 5-hydroxy-1,4-naphthoquinone, respectively.

References: [79, 80, 81, 280, 112, 78, 106, 71]

[EC 5.2.1.8 created 1989, modified 2002]

EC 5.2.1.9

Accepted name: farnesol 2-isomerase

Reaction: 2-*trans*,6-*trans*-farnesol = 2-*cis*,6-*trans*-farnesol

Other name(s): farnesol isomerase

Systematic name: 2-*trans*,6-*trans*-farnesol 2-*cis*-*trans*-isomerase

References: [10]

[EC 5.2.1.9 created 1989]

EC 5.2.1.10

Accepted name: 2-chloro-4-carboxymethylenebut-2-en-1,4-olide isomerase

Reaction: *cis*-2-chloro-4-carboxymethylenebut-2-en-1,4-olide = *trans*-2-chloro-4-carboxymethylenebut-2-en-1,4-olide

Other name(s): 2-chlorocarboxymethylenebutenolide isomerase; chlorodienelactone isomerase

Systematic name: 2-chloro-4-carboxymethylenebut-2-en-1,4-olide *cis*-*trans*-isomerase

References: [249]

[EC 5.2.1.10 created 1992]

[5.2.1.11 Deleted entry. 4-hydroxyphenylacetaldehyde-oxime isomerase. The existence of this enzyme has been called into question by one of the authors of the reference cited]

[EC 5.2.1.11 created 1992, deleted 2005]

EC 5.3 Intramolecular oxidoreductases

These enzymes bring about the oxidation of one part of a molecule with a corresponding reduction of another part. They include the enzymes interconverting, in the sugar series, aldoses and ketoses, and related compounds (sugar isomerases, EC 5.3.1), enzymes catalysing a keto-enol equilibrium (tautomerases, EC 5.3.2), enzymes shifting a carbon-carbon double bond from one position to another (EC 5.3.3), enzymes transposing S-S bonds (EC 5.3.4), and a group of miscellaneous enzymes (EC 5.3.99).

EC 5.3.1 Interconverting aldoses and ketoses, and related compounds

EC 5.3.1.1

Accepted name: triose-phosphate isomerase

Reaction: D-glyceraldehyde 3-phosphate = glycerone phosphate

Other name(s): phosphotriose isomerase; triose phosphoisomerase; triose phosphate mutase; D-glyceraldehyde-3-phosphate ketol-isomerase

Systematic name: D-glyceraldehyde-3-phosphate aldose-ketose-isomerase

References: [193, 194]

[EC 5.3.1.1 created 1961]

[5.3.1.2 Deleted entry. erythrose isomerase]

[EC 5.3.1.2 created 1961, deleted 1976]

EC 5.3.1.3

Accepted name: arabinose isomerase

Reaction: D-arabinose = D-ribulose

Other name(s): D-arabinose(L-fucose) isomerase; D-arabinose isomerase; L-fucose isomerase; D-arabinose ketol-isomerase
Systematic name: D-arabinose aldose-ketose-isomerase
Comments: Also acts on L-fucose and, more slowly, on L-galactose and D-altrose.
References: [49, 97]

[EC 5.3.1.3 created 1961]

EC 5.3.1.4
Accepted name: L-arabinose isomerase
Reaction: L-arabinose = L-ribulose
Other name(s): L-arabinose ketol-isomerase
Systematic name: L-arabinose aldose-ketose-isomerase
References: [109, 205]

[EC 5.3.1.4 created 1961]

EC 5.3.1.5
Accepted name: xylose isomerase
Reaction: D-xylose = D-xylulose
Other name(s): D-xylose isomerase; D-xylose ketoisomerase; D-xylose ketol-isomerase
Systematic name: D-xylose aldose-ketose-isomerase
Comments: Some enzymes also convert D-glucose to D-fructose.
References: [114, 263, 330]

[EC 5.3.1.5 created 1961 (EC 5.3.1.18 created 1972, part incorporated 1978)]

EC 5.3.1.6
Accepted name: ribose-5-phosphate isomerase
Reaction: D-ribose 5-phosphate = D-ribulose 5-phosphate
Other name(s): phosphopentosisomerase; phosphoriboisomerase; ribose phosphate isomerase; 5-phosphoribose isomerase; D-ribose 5-phosphate isomerase; D-ribose-5-phosphate ketol-isomerase
Systematic name: D-ribose-5-phosphate aldose-ketose-isomerase
Comments: Also acts on D-ribose 5-diphosphate and D-ribose 5-triphosphate.
References: [64, 115, 122]

[EC 5.3.1.6 created 1961]

EC 5.3.1.7
Accepted name: mannose isomerase
Reaction: D-mannose = D-fructose
Other name(s): D-mannose isomerase; D-mannose ketol-isomerase
Systematic name: D-mannose aldose-ketose-isomerase
Comments: Also acts on D-lyxose and D-rhamnose.
References: [219]

[EC 5.3.1.7 created 1961]

EC 5.3.1.8
Accepted name: mannose-6-phosphate isomerase
Reaction: D-mannose 6-phosphate = D-fructose 6-phosphate
Other name(s): phosphomannose isomerase; phosphohexomutase; phosphohexoisomerase; mannose phosphate isomerase; phosphomannoisomerase; D-mannose-6-phosphate ketol-isomerase

Systematic name: D-mannose-6-phosphate aldose-ketose-isomerase
Comments: A zinc protein.
References: [41, 96, 262]

[EC 5.3.1.8 created 1961, modified 1976]

EC 5.3.1.9
Accepted name: glucose-6-phosphate isomerase
Reaction: D-glucose 6-phosphate = D-fructose 6-phosphate
Other name(s): phosphohexose isomerase; phosphohexomutase; oxoisomerase; hexosephosphate isomerase; phosphosaccharomutase; phosphoglucoisomerase; phosphohexoisomerase; phosphoglucose isomerase; glucose phosphate isomerase; hexose phosphate isomerase; D-glucose-6-phosphate ketol-isomerase
Systematic name: D-glucose-6-phosphate aldose-ketose-isomerase
Comments: Also catalyses the anomerization of D-glucose 6-phosphate.
References: [18, 204, 209, 210, 231, 295]

[EC 5.3.1.9 created 1961, modified 1976 (EC 5.3.1.18 created part 1972, incorporated 1978)]

[5.3.1.10 Transferred entry. glucosamine-6-phosphate isomerase. Now EC 3.5.99.6, glucosamine-6-phosphate deaminase]

[EC 5.3.1.10 created 1961, deleted 2000]

[5.3.1.11 Deleted entry. acetylglucosaminephosphate isomerase]

[EC 5.3.1.11 created 1961, deleted 1978]

EC 5.3.1.12
Accepted name: glucuronate isomerase
Reaction: D-glucuronate = D-fructuronate
Other name(s): uronic isomerase; uronate isomerase; D-glucuronate isomerase; uronic acid isomerase; D-glucuronate ketol-isomerase
Systematic name: D-glucuronate aldose-ketose-isomerase
Comments: Also converts D-galacturonate to D-tagaturonate.
References: [17, 143]

[EC 5.3.1.12 created 1961]

EC 5.3.1.13
Accepted name: arabinose-5-phosphate isomerase
Reaction: D-arabinose 5-phosphate = D-ribulose 5-phosphate
Other name(s): arabinose phosphate isomerase; phosphoarabinoisomerase; D-arabinose-5-phosphate ketol-isomerase
Systematic name: D-arabinose-5-phosphate aldose-ketose-isomerase
References: [305]

[EC 5.3.1.13 created 1965]

EC 5.3.1.14
Accepted name: L-rhamnose isomerase
Reaction: L-rhamnose = L-rhamnulose
Other name(s): rhamnose isomerase; L-rhamnose ketol-isomerase
Systematic name: L-rhamnose aldose-ketose-isomerase
References: [66]

[EC 5.3.1.14 created 1965]

EC 5.3.1.15

Accepted name: D-lyxose ketol-isomerase

Reaction: D-lyxose = D-xylulose

Other name(s): D-lyxose isomerase; D-lyxose ketol-isomerase

Systematic name: D-lyxose aldose-ketose-isomerase

References: [11]

[EC 5.3.1.15 created 1972]

EC 5.3.1.16

Accepted name: 1-(5-phosphoribosyl)-5-[(5-phosphoribosylamino)methylideneamino]imidazole-4-carboxamide isomerase

Reaction: 1-(5-phosphoribosyl)-5-[(5-phosphoribosylamino)methylideneamino]imidazole-4-carboxamide = 5-[(5-phospho-1-deoxyribulos-1-ylamino)methylideneamino]-1-(5-phosphoribosyl)imidazole-4-carboxamide

Other name(s): *N*-(5′-phospho-D-ribosylformimino)-5-amino-1-(5″-phosphoribosyl)-4-imidazolecarboxamide isomerase; phosphoribosylformiminoaminophosphoribosylimidazolecarboxamide isomerase; *N*-(phosphoribosylformimino) aminophosphoribosylimidazolecarboxamide isomerase; 1-(5-phosphoribosyl)-5-[(5-phosphoribosylamino)methylideneamino]imidazole-4-carboxamide ketol-isomerase

Systematic name: 1-(5-phosphoribosyl)-5-[(5-phosphoribosylamino)methylideneamino]imidazole-4-carboxamide aldose-ketose-isomerase

References: [175]

[EC 5.3.1.16 created 1972, modified 2000]

EC 5.3.1.17

Accepted name: 4-deoxy-L-*threo*-5-hexosulose-uronate ketol-isomerase

Reaction: 4-deoxy-L-*threo*-5-hexosulose uronate = 3-deoxy-D-*glycero*-2,5-hexodiulosonate

Other name(s): 4-deoxy-L-*threo*-5-hexulose uronate isomerase

Systematic name: 4-deoxy-L-*threo*-5-hexosulose-uronate aldose-ketose-isomerase

References: [228]

[EC 5.3.1.17 created 1972]

[5.3.1.18 Deleted entry. glucose isomerase. Reaction is due to EC 5.3.1.9 glucose-6-phosphate isomerase, in the presence of arsenate, or EC 5.3.1.5 xylose isomerase]

[EC 5.3.1.18 created 1972, deleted 1978]

[5.3.1.19 Transferred entry. glucosaminephosphate isomerase. Now EC 2.6.1.16, glutamine—fructose-6-phosphate transaminase (isomerizing)]

[EC 5.3.1.19 created 1972, deleted 1984]

EC 5.3.1.20

Accepted name: ribose isomerase

Reaction: D-ribose = D-ribulose

Other name(s): D-ribose isomerase; D-ribose ketol-isomerase

Systematic name: D-ribose aldose-ketose-isomerase

Comments: Also acts on L-lyxose and L-rhamnose.

References: [124]

[EC 5.3.1.20 created 1978]

EC 5.3.1.21

Accepted name: corticosteroid side-chain-isomerase
Reaction: 11-deoxycorticosterone = 20-hydroxy-3-oxopregn-4-en-21-al
Systematic name: 11-deoxycorticosterone aldose-ketose-isomerase
Comments: An epimerization at C-20 and C-21 is probably catalysed by the same enzyme.
References: [178, 197]

[EC 5.3.1.21 created 1983]

EC 5.3.1.22

Accepted name: hydroxypyruvate isomerase
Reaction: hydroxypyruvate = 2-hydroxy-3-oxopropanoate
Systematic name: hydroxypyruvate aldose-ketose-isomerase
References: [316]

[EC 5.3.1.22 created 1983]

EC 5.3.1.23

Accepted name: *S*-methyl-5-thioribose-1-phosphate isomerase
Reaction: *S*-methyl-5-thio-α-D-ribose 1-phosphate = *S*-methyl-5-thio-D-ribulose 1-phosphate
Other name(s): methylthioribose 1-phosphate isomerase; 1-PMTR isomerase; 5-methylthio-5-deoxy-D-ribose-1-phosphate ketol-isomerase; *S*-methyl-5-thio-5-deoxy-D-ribose-1-phosphate ketol-isomerase; *S*-methyl-5-thio-5-deoxy-D-ribose-1-phosphate aldose-ketose-isomerase; 1-phospho-5′-*S*-methylthioribose isomerase; *S*-methyl-5-thio-D-ribose-1-phosphate aldose-ketose-isomerase
Systematic name: *S*-methyl-5-thio-α-D-ribose-1-phosphate aldose-ketose-isomerase
References: [90, 293, 86]

[EC 5.3.1.23 created 1989]

EC 5.3.1.24

Accepted name: phosphoribosylanthranilate isomerase
Reaction: *N*-(5-phospho-β-D-ribosyl)anthranilate = 1-(2-carboxyphenylamino)-1-deoxy-D-ribulose 5-phosphate
Other name(s): PRA isomerase; PRAI; IGPS:PRAI (indole-3-glycerol-phosphate synthetase/*N*-5′-phosphoribosylanthranilate isomerase complex); *N*-(5-phospho-β-D-ribosyl)anthranilate ketol-isomerase
Systematic name: *N*-(5-phospho-β-D-ribosyl)anthranilate aldose-ketose-isomerase
Comments: In some organisms, this enzyme is part of a multifunctional protein, together with one or more other components of the system for the biosynthesis of tryptophan [EC 2.4.2.18 (anthranilate phosphoribosyltransferase), EC 4.1.1.48 (indole-3-glycerol-phosphate synthase), EC 4.1.3.27 (anthranilate synthase) and EC 4.2.1.20 (tryptophan synthase)].
References: [36, 51, 123]

[EC 5.3.1.24 created 1990]

EC 5.3.1.25

Accepted name: L-fucose isomerase
Reaction: L-fucose = L-fuculose
Systematic name: L-fucose aldose-ketose-isomerase
References: [171]

[EC 5.3.1.25 created 1999]

EC 5.3.1.26

Accepted name: galactose-6-phosphate isomerase

Reaction: D-galactose 6-phosphate = D-tagatose 6-phosphate

Systematic name: D-galactose-6-phosphate aldose-ketose-isomerase

Comments: Involved in the tagatose 6-phosphate pathway of lactose catabolism in bacteria.

References: [306, 241]

[EC 5.3.1.26 created 1999]

EC 5.3.1.27

Accepted name: 6-phospho-3-hexuloisomerase

Reaction: D-*arabino*-hex-3-ulose 6-phosphate = D-fructose 6-phosphate

Other name(s): 3-hexulose-6-phosphate isomerase; phospho-3-hexuloisomerase; PHI; 6-phospho-3-hexulose isomerase; YckF

Systematic name: D-*arabino*-hex-3-ulose-6-phosphate isomerase

Comments: This enzyme, along with EC 4.1.2.43, 3-hexulose-6-phosphate synthase, plays a key role in the ribulose-monophosphate cycle of formaldehyde fixation, which is present in many microorganisms that are capable of utilizing C1-compounds [75]. The hyperthermophilic and anaerobic archaeon *Pyrococcus horikoshii* OT3 constitutively produces a bifunctional enzyme that sequentially catalyses the reactions of EC 4.1.2.43 (3-hexulose-6-phosphate synthase) and this enzyme [213].

References: [75, 339, 136, 213, 179, 283]

[EC 5.3.1.27 created 2008]

EC 5.3.1.28

Accepted name: D-sedoheptulose 7-phosphate isomerase

Reaction: D-sedoheptulose 7-phosphate = D-*glycero*-D-*manno*-heptose 7-phosphate

Other name(s): sedoheptulose-7-phosphate isomerase; phosphoheptose isomerase; *gmhA* (gene name); *lpcA* (gene name)

Systematic name: D-*glycero*-D-*manno*-heptose 7-phosphate aldose-ketose-isomerase

Comments: In Gram-negative bacteria the enzyme is involved in biosynthesis of ADP-L-*glycero*-β-D-*manno*-heptose, which is utilized for assembly of the lipopolysaccharide inner core. In Gram-positive bacteria the enzyme is involved in biosynthesis of GDP-D-*glycero*-α-D-*manno*-heptose, which is required for assembly of S-layer glycoprotein.

References: [150, 149, 301, 144, 285]

[EC 5.3.1.28 created 2010]

EC 5.3.2 Interconverting keto- and enol-groups

EC 5.3.2.1

Accepted name: phenylpyruvate tautomerase

Reaction: *keto*-phenylpyruvate = *enol*-phenylpyruvate

Other name(s): phenylpyruvic keto-enol isomerase

Systematic name: phenylpyruvate *keto*—*enol*-isomerase

Comments: Also acts on other arylpyruvates.

References: [31, 151, 152]

[EC 5.3.2.1 created 1961]

EC 5.3.2.2

Accepted name: oxaloacetate tautomerase

Reaction: *keto*-oxaloacetate = *enol*-oxaloacetate
Other name(s): oxalacetic keto-enol isomerase
Systematic name: oxaloacetate *keto*—*enol*-isomerase
References: [13]

[EC 5.3.2.2 created 1972]

EC 5.3.3 Transposing C=C bonds

EC 5.3.3.1
Accepted name: steroid Δ-isomerase
Reaction: a 3-oxo-Δ^5-steroid = a 3-oxo-Δ^4-steroid
Other name(s): hydroxysteroid isomerase; steroid isomerase; Δ^5-ketosteroid isomerase; Δ^5(or Δ^4)-3-keto steroid isomerase; Δ^5-steroid isomerase; 3-oxosteroid isomerase; Δ^5-3-keto steroid isomerase; Δ^5-3-oxosteroid isomerase
Systematic name: 3-oxosteroid Δ^5-Δ^4-isomerase
Comments: May be at least three distinct enzymes.
References: [72, 137, 281]

[EC 5.3.3.1 created 1961]

EC 5.3.3.2
Accepted name: isopentenyl-diphosphate Δ-isomerase
Reaction: isopentenyl diphosphate = dimethylallyl diphosphate
Other name(s): isopentenylpyrophosphate Δ-isomerase; methylbutenylpyrophosphate isomerase; isopentenylpyrophosphate isomerase
Systematic name: isopentenyl-diphosphate Δ^3-Δ^2-isomerase
Comments: The enzyme from *Streptomyces* sp. strain CL190 requires FMN and NAD(P)H as cofactors. Activity is reduced if FMN is replaced by FAD, but the enzyme becomes inactive when NAD(P)H is replaced by NAD^+ or $NADP^+$. That enzyme also requires Mg^{2+}, Mn^{2+} or Ca^{2+} for activity.
References: [134, 30, 3]

[EC 5.3.3.2 created 1961, modified 2002]

EC 5.3.3.3
Accepted name: vinylacetyl-CoA Δ-isomerase
Reaction: vinylacetyl-CoA = crotonyl-CoA
Other name(s): vinylacetyl coenzyme A Δ-isomerase; vinylacetyl coenzyme A isomerase; Δ^3-*cis*-Δ^2-*trans*-enoyl-CoA isomerase
Systematic name: vinylacetyl-CoA Δ^3-Δ^2-isomerase
Comments: Also acts on 3-methyl-vinylacetyl-CoA.
References: [172, 239]

[EC 5.3.3.3 created 1961]

EC 5.3.3.4
Accepted name: muconolactone Δ-isomerase
Reaction: (*S*)-5-oxo-2,5-dihydrofuran-2-acetate = 5-oxo-4,5-dihydrofuran-2-acetate
Other name(s): muconolactone isomerase
Systematic name: 5-oxo-4,5-dihydrofuran-2-acetate Δ^3-Δ^2-isomerase
References: [214, 216]

[EC 5.3.3.4 created 1961 as EC 3.1.1.16, part transferred 1972 to EC 5.3.3.4 rest to EC 5.3.3.4]

EC 5.3.3.5

Accepted name: cholestenol Δ-isomerase

Reaction: 5α-cholest-7-en-3β-ol = 5α-cholest-8-en-3β-ol

Systematic name: Δ^7-cholestenol Δ^7-Δ^8-isomerase

References: [315]

[EC 5.3.3.5 created 1972]

EC 5.3.3.6

Accepted name: methylitaconate Δ-isomerase

Reaction: methylitaconate = 2,3-dimethylmaleate

Other name(s): methylitaconate isomerase

Systematic name: methylitaconate Δ^2-Δ^3-isomerase

References: [156]

[EC 5.3.3.6 created 1972]

EC 5.3.3.7

Accepted name: aconitate Δ-isomerase

Reaction: *trans*-aconitate = *cis*-aconitate

Other name(s): aconitate isomerase

Systematic name: aconitate Δ^2-Δ^3-isomerase

Comments: *cis*-Aconitate is used to designate the isomer (*Z*)-prop-1-ene-1,2,3-tricarboxylate. This isomerization could take place either in a direct *cis*-*trans* interconversion or by an allelic rearrangement; the enzyme has been shown to catalyse the latter change.

References: [148, 147]

[EC 5.3.3.7 created 1972]

EC 5.3.3.8

Accepted name: dodecenoyl-CoA isomerase

Reaction: (3*Z*)-dodec-3-enoyl-CoA = (2*E*)-dodec-2-enoyl-CoA

Other name(s): dodecenoyl-CoA Δ-isomerase; Δ^3-*cis*-Δ^2-*trans*-enoyl-CoA isomerase; acetylene-allene isomerase; dodecenoyl-CoA Δ-isomerase; dodecenoyl-CoA Δ^3-*cis*-Δ^2-*trans*-isomerase

Systematic name: dodecenoyl-CoA (3*Z*)-(2*E*)-isomerase

Comments: Also catalyses the interconversion of 3-acetylenic fatty acyl thioesters and (+)-2,3-dienoyl fatty acyl thioesters, with fatty acid chain lengths C_6 to C_{12}.

References: [195, 273, 274, 275]

[EC 5.3.3.8 created 1978, modified 1980]

EC 5.3.3.9

Accepted name: prostaglandin-A_1 Δ-isomerase

Reaction: (13*E*)-(15*S*)-15-hydroxy-9-oxoprosta-10,13-dienoate = (13*E*)-(15*S*)-15-hydroxy-9-oxoprosta-11,13-dienoate

Other name(s): prostaglandin A isomerase

Systematic name: (13*E*)-(15*S*)-15-hydroxy-9-oxoprosta-10,13-dienoate Δ^{10}-Δ^{11}-isomerase

Comments: Interconverts prostaglandin A_1 and prostaglandin C_1.

References: [102]

[EC 5.3.3.9 created 1978]

EC 5.3.3.10

Accepted name: 5-carboxymethyl-2-hydroxymuconate Δ-isomerase

Reaction: 5-carboxymethyl-2-hydroxymuconate = 5-carboxy-2-oxohept-3-enedioate

Systematic name: 5-carboxymethyl-2-hydroxymuconate Δ^2,Δ^4-2-oxo,Δ^3-isomerase

References: [87]

[EC 5.3.3.10 created 1984]

EC 5.3.3.11

Accepted name: isopiperitenone Δ-isomerase

Reaction: isopiperitenone = piperitenone

Systematic name: isopiperitenone Δ^8-Δ^4-isomerase

Comments: Involved in the biosynthesis of menthol and related monoterpenes in peppermint (*Mentha piperita*) leaves.

References: [146]

[EC 5.3.3.11 created 1989]

EC 5.3.3.12

Accepted name: L-dopachrome isomerase

Reaction: L-dopachrome = 5,6-dihydroxyindole-2-carboxylate

Other name(s): dopachrome tautomerase; tyrosinase-related protein 2; TRP-1; TRP2; TRP-2; tyrosinase-related protein-2; dopachrome Δ^7,Δ^2-isomerase; dopachrome Δ-isomerase; dopachrome conversion factor; dopachrome isomerase; dopachrome oxidoreductase; dopachrome-rearranging enzyme; DCF; DCT; dopachrome keto-enol isomerase; L-dopachrome-methyl ester tautomerase

Systematic name: L-dopachrome keto-enol isomerase

Comments: A zinc enzyme. Stereospecific for L-dopachrome. Dopachrome methyl ester is a substrate, but dopaminochrome (2,3-dihydroindole-5,6-quinone) is not (see also EC 4.1.1.84, D-dopachrome decarboxylase).

References: [266, 220, 221]

[EC 5.3.3.12 created 1992, modified 1999, modified 2005]

EC 5.3.3.13

Accepted name: polyenoic fatty acid isomerase

Reaction: (5*Z*,8*Z*,11*Z*,14*Z*,17*Z*)-icosapentaenoate = (5*Z*,7*E*,9*E*,14*Z*,17*Z*)-icosapentaenoate

Other name(s): PFI; eicosapentaenoate *cis*-$\Delta^{5,8,11,14,17}$-eicosapentaenoate *cis*-Δ^5-*trans*-$\Delta^{7,9}$-*cis*-$\Delta^{14,17}$ isomerase; (5*Z*,8*Z*,11*Z*,14*Z*,17*Z*)-eicosapentaenoate $\Delta^{8,11}$-$\Delta^{7,8}$-isomerase (incorrect); (5*Z*,8*Z*,11*Z*,14*Z*,17*Z*)-eicosapentaenoate $\Delta^{8,11}$-$\Delta^{7,9}$-isomerase (*trans*-double-bond-forming)

Systematic name: (5*Z*,8*Z*,11*Z*,14*Z*,17*Z*)-icosapentaenoate $\Delta^{8,11}$-$\Delta^{7,9}$-isomerase (*trans*-double-bond-forming)

Comments: The enzyme from the red alga *Ptilota filicina* catalyses the isomerization of skip dienes (methylene-interrupted double bonds) in a broad range of fatty acids and fatty-acid analogues, such as arachidonate and γ-linolenate, to yield a conjugated triene.

References: [317, 319, 318, 341]

[EC 5.3.3.13 created 2004]

EC 5.3.3.14

Accepted name: *trans*-2-decenoyl-[acyl-carrier protein] isomerase

Reaction: a *trans*-dec-2-enoyl-[acyl-carrier protein] = a *cis*-dec-3-enoyl-[acyl-carrier protein]

Other name(s): β-hydroxydecanoyl thioester dehydrase; *trans*-2-*cis*-3-decenoyl-ACP isomerase; *trans*-2,*cis*-3-decenoyl-ACP isomerase; *trans*-2-decenoyl-ACP isomerase; FabM; decenoyl-[acyl-carrier-protein] Δ^2-*trans*-Δ^3-*cis*-isomerase

Systematic name: decenoyl-[acyl-carrier protein] Δ^2-*trans*-Δ^3-*cis*-isomerase

Comments: While the enzyme from *Escherichia coli* is highly specific for the 10-carbon enoyl-ACP, the enzyme from *Streptococcus pneumoniae* can also use the 12-carbon enoyl-ACP as substrate in vitro but not 14- or 16-carbon enoyl-ACPs [177]. ACP can be replaced by either CoA or *N*-acetylcysteamine thioesters. The *cis*-3-enoyl product is required to form unsaturated fatty acids, such as palmitoleic acid and *cis*-vaccenic acid, in dissociated (or type II) fatty-acid biosynthesis.

References: [39, 32, 177, 52]

[EC 5.3.3.14 created 2006]

EC 5.3.3.15

Accepted name: ascopyrone tautomerase

Reaction: 1,5-anhydro-4-deoxy-D-*glycero*-hex-3-en-2-ulose = 1,5-anhydro-4-deoxy-D-*glycero*-hex-1-en-3-ulose

Other name(s): ascopyrone isomerase; ascopyrone intramolecular oxidoreductase; 1,5-anhydro-D-*glycero*-hex-3-en-2-ulose tautomerase; APM tautomerase; ascopyrone P tautomerase; APTM

Systematic name: 1,5-anhydro-4-deoxy-D-*glycero*-hex-3-en-2-ulose Δ^3-Δ^1-isomerase

Comments: This enzyme catalyses one of the steps in the anhydrofructose pathway, which leads to the degradation of glycogen and starch via 1,5-anhydro-D-fructose [338, 337]. The other enzymes involved in this pathway are EC 4.2.1.110 (aldos-2-ulose dehydratase), EC 4.2.1.111 (1,5-anhydro-D-fructose dehydratase) and EC 4.2.2.13 [exo-(1→4)-α-D-glucan lyase]. Ascopyrone P is an anti-oxidant [337].

References: [338, 337]

[EC 5.3.3.15 created 2006]

EC 5.3.4 Transposing S-S bonds

EC 5.3.4.1

Accepted name: protein disulfide-isomerase

Reaction: Catalyses the rearrangement of -S-S- bonds in proteins

Other name(s): S-S rearrangase

Systematic name: protein disulfide-isomerase

Comments: Needs reducing agents or partly reduced enzyme; the reaction depends on sulfhydryl-disulfide interchange.

References: [170, 84]

[EC 5.3.4.1 created 1972]

EC 5.3.99 Other intramolecular oxidoreductases

[5.3.99.1 Deleted entry. hydroperoxide isomerase. Reaction due to combined action of EC 4.2.1.92 (hydroperoxide dehydratase) and EC 5.3.99.6 (allene-oxide cyclase)]

[EC 5.3.99.1 created 1972, deleted 1992]

EC 5.3.99.2

Accepted name: prostaglandin-D synthase

Reaction: (5*Z*,13*E*,15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate = (5*Z*,13*E*,15*S*)-9α,15-dihydroxy-11-oxoprosta-5,13-dienoate

Other name(s): prostaglandin-H_2 Δ-isomerase; prostaglandin-R-prostaglandin D isomerase; PGH-PGD isomerase(5,13)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate Δ-isomerase (incorrect); (5,13)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate D-isomerase; prostaglandin endoperoxide Δ-isomerase; prostaglandin D synthetase
Systematic name: (5*Z*,13*E*,15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate D-isomerase
Comments: Brings about the opening of the epidioxy bridge. Some enzymes require glutathione.
References: [48, 257]

[EC 5.3.99.2 created 1976, modified 1990]

EC 5.3.99.3
Accepted name: prostaglandin-E synthase
Reaction: (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate = (5*Z*,13*E*)-(15*S*)-11α,15-dihydroxy-9-oxoprosta-5,13-dienoate
Other name(s): prostaglandin-H_2 E-isomerase; endoperoxide isomerase; endoperoxide isomerase; prostaglandin *R*-prostaglandin E isomerase; prostaglandin endoperoxide E isomerase; PGE isomerase; PGH-PGE isomerase; PGE_2 isomerase; prostaglandin endoperoxide E_2 isomerase; prostaglandin H-E isomerase
Systematic name: (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate E-isomerase
Comments: Brings about the opening of the epidioxy bridge. Requires glutathione.
References: [211, 282]

[EC 5.3.99.3 created 1976, modified 1990]

EC 5.3.99.4
Accepted name: prostaglandin-I synthase
Reaction: (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate = (5*Z*,13*E*)-(15*S*)-6,9α-epoxy-11α,15-dihydroxyprosta-5,13-dienoate
Other name(s): prostacyclin synthase; prostacycline synthetase; prostagladin I2 synthetase; PGI_2 synthase; PGI_2 synthetase
Systematic name: (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate 6-isomerase
Comments: Converts prostaglandin H_2 into prostaglandin I_2 (prostacyclin). A heme-thiolate protein.
References: [63, 297]

[EC 5.3.99.4 created 1984, modified 1990]

EC 5.3.99.5
Accepted name: thromboxane-A synthase
Reaction: (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate = (5*Z*,13*E*)-(15*S*)-9α,11α-epoxy-15-hydroxythromboxa-5,13-dienoate
Other name(s): thromboxane synthase; (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate thromboxane-A2-isomerase
Systematic name: (5*Z*,13*E*)-(15*S*)-9α,11α-epidioxy-15-hydroxyprosta-5,13-dienoate isomerase
Comments: Converts prostaglandin H_2 into thromboxane A_2. A heme-thiolate protein.
References: [253, 298]

[EC 5.3.99.5 created 1984, modified 1990]

EC 5.3.99.6
Accepted name: allene-oxide cyclase
Reaction: (9*Z*)-(13*S*)-12,13-epoxyoctadeca-9,11,15-trienoate = (15*Z*)-12-oxophyto-10,15-dienoate
Systematic name: (9*Z*)-(13*S*)-12,13-epoxyoctadeca-9,11,15-trienoate isomerase (cyclizing)
Comments: Allene oxides formed by the action of EC 4.2.1.92 hydroperoxide dehydratase, are converted into cyclopentenone derivatives.
References: [104]

[EC 5.3.99.6 created 1992]

EC 5.3.99.7

Accepted name: styrene-oxide isomerase
Reaction: styrene oxide = phenylacetaldehyde
Other name(s): SOI
Systematic name: styrene-oxide isomerase (epoxide-cleaving)
Comments: Highly specific.
References: [107]

[EC 5.3.99.7 created 1992]

EC 5.3.99.8

Accepted name: capsanthin/capsorubin synthase
Reaction: (1) violaxanthin = capsorubin
(2) antheraxanthin = capsanthin
Other name(s): CCS; ketoxanthophyll synthase; capsanthin-capsorubin synthase
Systematic name: violaxanthin—capsorubin isomerase (ketone-forming)
Comments: This multifunctional enzyme is induced during chromoplast differentiation in plants [34]. Isomerization of the epoxide ring of violaxanthin gives the cyclopentyl-ketone of capsorubin or capsanthin.
References: [34, 163, 327]

[EC 5.3.99.8 created 2005]

EC 5.3.99.9

Accepted name: neoxanthin synthase
Reaction: violaxanthin = neoxanthin
Other name(s): NSY
Systematic name: violaxanthin—neoxanthin isomerase (epoxide-opening)
Comments: The opening of the epoxide ring of violaxanthin generates a chiral allene. Neoxanthin is a precursor of the plant hormone abscisic acid and the last product of carotenoid synthesis in green plants [33].
References: [6, 33]

[EC 5.3.99.9 created 2005]

EC 5.4 Intramolecular transferases

This subclass contains enzymes that transfer a group from one position to another within a molecule. Sub-subclasses are based on the group transferred: acyl group (EC 5.4.1), phospho group (EC 5.4.2), amino group (EC 5.4.3), hydroxy group (EC 5.4.4), or some other group (EC 5.4.99).

EC 5.4.1 Transferring acyl groups

EC 5.4.1.1

Accepted name: lysolecithin acylmutase
Reaction: 2-lysolecithin = 3-lysolecithin
Other name(s): lysolecithin migratase
Systematic name: lysolecithin 2,3-acylmutase
References: [300]

[EC 5.4.1.1 created 1961]

EC 5.4.1.2

Accepted name: precorrin-8X methylmutase

Reaction: precorrin-8X = hydrogenobyrinate

Other name(s): precorrin isomerase; hydrogenobyrinic acid-binding protein

Systematic name: precorrin-8X 11,12-methylmutase

References: [287, 244, 240, 54]

[EC 5.4.1.2 created 1999]

EC 5.4.2 Phosphotransferases (phosphomutases)

Most of these enzymes were previously listed as sub-subclass EC 2.7.5, under the heading: 'Phosphotransferases with regeneration of donors, apparently catalysing intramolecular transfers'. The reaction for these enzymes was written in the form:¡p¿

X-(P)2 + AP = BP + X-$(P)_2$.

In fact, since phosphorylation of the acceptor produces a bisphosphate that is identical to the donor, the overall reaction is an isomerization of AP into BP, with the bisphosphate acting catalytically. It has been shown in some cases that the enzyme has a functional phosphate group, which can act as the donor. Phosphate is transferred to the substrate, forming the intermediate bisphosphate; the other phosphate group is subsequently transferred to the enzyme:¡p¿

E-P + AP = E + X-$(P)_2$¡p¿

X-$(P)_2$ + E = BP + E-P.

The bisphosphate may be firmly attached to the enzyme during the catalytic cycle, or, in other cases, may be released so that free bisphosphate is required as an activator. Under these circumstances, it was agreed in 1983 that all of these enzymes should be listed together in this sub-subclass based on the overall isomerase reaction.

EC 5.4.2.1

Accepted name: phosphoglycerate mutase

Reaction: 2-phospho-D-glycerate = 3-phospho-D-glycerate

Other name(s): phosphoglycerate phosphomutase; phosphoglyceromutase; glycerate phosphomutase (diphosphoglycerate cofactor); monophosphoglycerate mutase; monophosphoglyceromutase; diphosphoglycomutase; diphosphoglycerate mutase; bisphosphoglyceromutase; GriP mutase; MPGM; PGA mutase; PGAM-i; PGAM; PGAM-d; PGM

Systematic name: D-phosphoglycerate 2,3-phosphomutase

Comments: The enzymes from mammals and from yeast are phosphorylated by (2*R*)-2,3-bis-phosphoglycerate, which is also an intermediate (see introduction to section EC 5.4.2). With the rabbit muscle enzyme, dissociation of bisphosphate from the enzyme is much slower than the overall isomerization. These enzymes also catalyse, slowly, the reactions of EC 5.4.2.4 bisphosphoglycerate mutase; they were formerly listed as EC 2.7.5.3. Enzymes from wheat, rice, insects and some fungi, however, have maximum activity in the absence of 2,3-bisphosphoglycerate, and were formerly listed under the present number as phosphoglycerate phosphomutase.

References: [99, 234, 243]

[EC 5.4.2.1 created 1961 (EC 2.7.5.3 created 1961, incorporated 1984)]

EC 5.4.2.2

Accepted name: phosphoglucomutase

Reaction: α-D-glucose 1-phosphate = D-glucose 6-phosphate

Other name(s): glucose phosphomutase; phosphoglucose mutase

Systematic name: α-D-glucose 1,6-phosphomutase

Comments: Maximum activity is only obtained in the presence of α-D-glucose 1,6-bisphosphate. This bisphosphate is an intermediate in the reaction, being formed by transfer of a phosphate residue from the enzyme to the substrate, but the dissociation of bisphosphate from the enzyme complex is much slower than the overall isomerization. The enzyme also catalyses (more slowly) the interconversion of 1-phosphate and 6-phosphate isomers of many other α-D-hexoses, and the interconversion of α-D-ribose 1-phosphate and 5-phosphate.
References: [130, 201, 235, 234, 278]

[EC 5.4.2.2 created 1961 as EC 2.7.5.1, transferred 1984 to EC 5.4.2.2]

EC 5.4.2.3
Accepted name: phosphoacetylglucosamine mutase
Reaction: *N*-acetyl-α-D-glucosamine 1-phosphate = *N*-acetyl-D-glucosamine 6-phosphate
Other name(s): acetylglucosamine phosphomutase; acetylglucosamine phosphomutase; acetylaminodeoxyglucose phosphomutase; phospho-*N*-acetylglucosamine mutase; *N*-acetyl-D-glucosamine 1,6-phosphomutase
Systematic name: *N*-acetyl-α-D-glucosamine 1,6-phosphomutase
Comments: The enzyme is activated by *N*-acetyl-α-D-glucosamine 1,6-bisphosphate.
References: [44, 165, 234, 237]

[EC 5.4.2.3 created 1961 as EC 2.7.5.2, transferred 1984 to EC 5.4.2.3]

EC 5.4.2.4
Accepted name: bisphosphoglycerate mutase
Reaction: 3-phospho-D-glyceroyl phosphate = 2,3-bisphospho-D-glycerate
Other name(s): diphosphoglycerate mutase; glycerate phosphomutase; bisphosphoglycerate synthase; bisphosphoglyceromutase; biphosphoglycerate synthase; diphosphoglyceric mutase; 2,3-diphosphoglycerate mutase; phosphoglyceromutase; 2,3-diphosphoglycerate synthase; DPGM; 2,3-bisphosphoglycerate mutase; BPGM; diphosphoglyceromutase; 2,3-diphosphoglyceromutase
Systematic name: 3-phospho-D-glycerate 1,2-phosphomutase
Comments: In the direction shown, this enzyme is phosphorylated by 3-phosphoglyceroyl phosphate, to give phosphoenzyme and 3-phosphoglycerate. The latter is rephosphorylated by the enzyme to yield 2,3-bisphosphoglycerate, but this reaction is slowed by dissociation of 3-phosphoglycerate from the enzyme, which is therefore more active in the presence of added 3-phosphoglycerate. This enzyme also catalyses, slowly, the reactions of EC 3.1.3.13 (bisphosphoglycerate phosphatase) and EC 5.4.2.1 (phosphoglycerate mutase).
References: [234, 242, 243]

[EC 5.4.2.4 created 1961 as EC 2.7.5.4, transferred 1984 to EC 5.4.2.4]

EC 5.4.2.5
Accepted name: phosphoglucomutase (glucose-cofactor)
Reaction: α-D-glucose 1-phosphate = D-glucose 6-phosphate
Other name(s): glucose phosphomutase; glucose-1-phosphate phosphotransferase
Systematic name: α-D-glucose 1,6-phosphomutase (glucose-cofactor)
Comments: The enzyme is activated by D-glucose, which probably acts as an acceptor for a phosphate residue from the substrate, thus being itself converted into the product.
References: [85, 234]

[EC 5.4.2.5 created 1972 as EC 2.7.5.5, transferred 1984 to EC 5.4.2.5]

EC 5.4.2.6
Accepted name: β-phosphoglucomutase
Reaction: β-D-glucose 1-phosphate = β-D-glucose 6-phosphate

Systematic name: β-D-glucose 1,6-phosphomutase
Comments: No cofactor requirement has been demonstrated.
References: [26, 234]

[EC 5.4.2.6 created 1984]

EC 5.4.2.7
Accepted name: phosphopentomutase
Reaction: α-D-ribose 1-phosphate = D-ribose 5-phosphate
Other name(s): phosphodeoxyribomutase; deoxyribose phosphomutase; deoxyribomutase; phosphoribomutase; α-D-glucose-1,6-bisphosphate:deoxy-D-ribose-1-phosphate phosphotransferase; D-ribose 1,5-phosphomutase
Systematic name: α-D-ribose 1,5-phosphomutase
Comments: Also converts 2-deoxy-α-D-ribose 1-phosphate into 2-deoxy-D-ribose 5-phosphate. α-D-Ribose 1,5-bisphosphate, 2-deoxy-α-D-ribose 1,5-bisphosphate, or α-D-glucose 1,6-bisphosphate can act as cofactor.
References: [105, 132, 234]

[EC 5.4.2.7 created 1972 as EC 2.7.5.6, transferred 1984 to EC 5.4.2.7]

EC 5.4.2.8
Accepted name: phosphomannomutase
Reaction: α-D-mannose 1-phosphate = D-mannose 6-phosphate
Other name(s): mannose phosphomutase; phosphomannose mutase; D-mannose 1,6-phosphomutase
Systematic name: α-D-mannose 1,6-phosphomutase
Comments: α-D-Mannose 1,6-bisphosphate or α-D-glucose 1,6-bisphosphate can act as cofactor.
References: [264]

[EC 5.4.2.8 created 1981 as EC 2.7.5.7, transferred 1984 to EC 5.4.2.8]

EC 5.4.2.9
Accepted name: phospho*enol*pyruvate mutase
Reaction: phospho*enol*pyruvate = 3-phosphonopyruvate
Other name(s): phospho*enol*pyruvate-phosphonopyruvate phosphomutase; PEP phosphomutase; phosphoenolpyruvate phosphomutase; PEPPM; PEP phosphomutase
Systematic name: phospho*enol*pyruvate 2,3-phosphonomutase
Comments: Involved in the biosynthesis of the C-P bond, although the equilibrium greatly favours phospho*enol*pyruvate.
References: [35, 113, 251]

[EC 5.4.2.9 created 1990]

EC 5.4.2.10
Accepted name: phosphoglucosamine mutase
Reaction: α-D-glucosamine 1-phosphate = D-glucosamine 6-phosphate
Systematic name: α-D-glucosamine 1,6-phosphomutase
Comments: The enzyme is involved in the pathway for bacterial cell-wall peptidoglycan and lipopolysaccharide biosyntheses, being an essential step in the pathway for UDP-*N*-acetylglucosamine biosynthesis. The enzyme from *Escherichia coli* is activated by phosphorylation and can be autophosphorylated in vitro by α-D-glucosamine 1,6-bisphosphate, which is an intermediate in the reaction, α-D-glucose 1,6-bisphosphate or ATP. It can also catalyse the interconversion of α-D-glucose 1-phosphate and glucose 6-phosphate, although at a much lower rate.
References: [190, 60, 129, 127, 128]

[EC 5.4.2.10 created 2001]

EC 5.4.3 Transferring amino groups

*[5.4.3.1 Deleted entry. ornithine 4,5-aminomutase. This reaction was due to a mixture of EC 5.1.1.12 (ornithine racemase) and EC 5.4.3.5 (*D*-ornithine 4,5-aminomutase)]*

[EC 5.4.3.1 created 1972, deleted 1976]

EC 5.4.3.2

Accepted name: lysine 2,3-aminomutase
Reaction: L-lysine = (3*S*)-3,6-diaminohexanoate
Systematic name: L-lysine 2,3-aminomutase
Comments: Activity is stimulated by *S*-adenosyl-L-methionine and pyridoxal phosphate.
References: [1, 340]

[EC 5.4.3.2 created 1972]

EC 5.4.3.3

Accepted name: β-lysine 5,6-aminomutase
Reaction: (3*S*)-3,6-diaminohexanoate = (3*S*,5*S*)-3,5-diaminohexanoate
Other name(s): β-lysine mutase; L-β-lysine 5,6-aminomutase
Systematic name: (3*S*)-3,6-diaminohexanoate 5,6-aminomutase
Comments: Requires a cobamide coenzyme.
References: [238, 270]

[EC 5.4.3.3 created 1972]

EC 5.4.3.4

Accepted name: D-lysine 5,6-aminomutase
Reaction: D-lysine = 2,5-diaminohexanoate
Other name(s): D-α-lysine mutase; adenosylcobalamin-dependent D-lysine 5,6-aminomutase
Systematic name: D-2,6-diaminohexanoate 5,6-aminomutase
Comments: Requires a cobamide coenzyme.
References: [198, 271]

[EC 5.4.3.4 created 1972, modified 2003]

EC 5.4.3.5

Accepted name: D-ornithine 4,5-aminomutase
Reaction: D-ornithine = (2*R*,4*S*)-2,4-diaminopentanoate
Other name(s): D-α-ornithine 5,4-aminomutase; D-ornithine aminomutase
Systematic name: D-ornithine 4,5-aminomutase
Comments: A pyridoxal-phosphate protein that requires a cobamide coenzyme for activity.
References: [267]

[EC 5.4.3.5 created 1972 as EC 5.4.3.1, transferred 1976 to EC 5.4.3.5, modified 2003]

EC 5.4.3.6

Accepted name: tyrosine 2,3-aminomutase
Reaction: L-tyrosine = 3-amino-3-(4-hydroxyphenyl)propanoate
Other name(s): tyrosine α,β-mutase

Systematic name: L-tyrosine 2,3-aminomutase
Comments: Requires ATP.
References: [157]

[EC 5.4.3.6 created 1976]

EC 5.4.3.7
Accepted name: leucine 2,3-aminomutase
Reaction: (2*S*)-α-leucine = (3*R*)-β-leucine
Systematic name: (2*S*)-α-leucine 2,3-aminomutase
Comments: Requires a cobamide coenzyme.
References: [83, 227, 226]

[EC 5.4.3.7 created 1982]

EC 5.4.3.8
Accepted name: glutamate-1-semialdehyde 2,1-aminomutase
Reaction: L-glutamate 1-semialdehyde = 5-aminolevulinate
Other name(s): glutamate-1-semialdehyde aminotransferase
Systematic name: (*S*)-4-amino-5-oxopentanoate 4,5-aminomutase
Comments: Requires pyridoxal phosphate.
References: [95]

[EC 5.4.3.8 created 1983]

EC 5.4.4 Transferring hydroxy groups

EC 5.4.4.1
Accepted name: (hydroxyamino)benzene mutase
Reaction: (hydroxyamino)benzene = 2-aminophenol
Other name(s): HAB mutase; hydroxylaminobenzene hydroxymutase; hydroxylaminobenzene mutase
Systematic name: (hydroxyamino)benzene hydroxymutase
References: [108, 59]

[EC 5.4.4.1 created 2003]

EC 5.4.4.2
Accepted name: isochorismate synthase
Reaction: chorismate = isochorismate
Other name(s): MenF
Systematic name: isochorismate hydroxymutase
Comments: Requires Mg^{2+}. The reaction is reversible.
References: [336, 303, 55, 58]

[EC 5.4.4.2 created 1972 as EC 5.4.99.6, transferred 2003 to EC 5.4.4.2]

EC 5.4.4.3
Accepted name: 3-(hydroxyamino)phenol mutase
Reaction: 3-hydroxyaminophenol = aminohydroquinone
Other name(s): 3-hydroxylaminophenol mutase; 3*H*AP mutase
Systematic name: 3-(hydroxyamino)phenol hydroxymutase
References: [246]

[EC 5.4.4.3 created 2003]

EC 5.4.99 Transferring other groups

EC 5.4.99.1

Accepted name: methylaspartate mutase

Reaction: L-*threo*-3-methylaspartate = L-glutamate

Other name(s): glutamate mutase; glutamic mutase; glutamic isomerase; glutamic acid mutase; glutamic acid isomerase; methylaspartic acid mutase; β-methylaspartate-glutamate mutase; glutamate isomerase

Systematic name: L-*threo*-3-methylaspartate carboxy-aminomethylmutase

Comments: Requires a cobamide coenzyme.

References: [21, 309]

[EC 5.4.99.1 created 1961]

EC 5.4.99.2

Accepted name: methylmalonyl-CoA mutase

Reaction: (*R*)-methylmalonyl-CoA = succinyl-CoA

Other name(s): methylmalonyl-CoA CoA-carbonyl mutase; methylmalonyl coenzyme A mutase; methylmalonyl coenzyme A carbonylmutase; (*S*)-methylmalonyl-CoA mutase; (*R*)-2-methyl-3-oxopropanoyl-CoA CoA-carbonylmutase [incorrect]

Systematic name: (*R*)-methylmalonyl-CoA CoA-carbonylmutase

Comments: Requires a cobamide coenzyme.

References: [20]

[EC 5.4.99.2 created 1961, modified 1983]

EC 5.4.99.3

Accepted name: 2-acetolactate mutase

Reaction: 2-acetolactate = 3-hydroxy-3-methyl-2-oxobutanoate

Other name(s): acetolactate mutase; acetohydroxy acid isomerase

Systematic name: 2-acetolactate methylmutase

Comments: Requires ascorbic acid; also converts 2-aceto-2-hydroxybutanoate to 3-hydroxy-3-methyl-2-oxopentanoate.

References: [7]

[EC 5.4.99.3 created 1972]

EC 5.4.99.4

Accepted name: 2-methyleneglutarate mutase

Reaction: 2-methyleneglutarate = 2-methylene-3-methylsuccinate

Other name(s): α-methyleneglutarate mutase

Systematic name: 2-methyleneglutarate carboxy-methylenemethylmutase

Comments: Requires a cobamide coenzyme.

References: [155, 156]

[EC 5.4.99.4 created 1972]

EC 5.4.99.5

Accepted name: chorismate mutase

Reaction: chorismate = prephenate

Other name(s): hydroxyphenylpyruvate synthase
Systematic name: chorismate pyruvatemutase
References: [50, 169, 268, 325]

[EC 5.4.99.5 created 1972]

[5.4.99.6 Transferred entry. isochorismate synthase. Now EC 5.4.4.2, isochorismate synthase]

[EC 5.4.99.6 created 1972, deleted 2003]

EC 5.4.99.7
Accepted name: lanosterol synthase
Reaction: (*S*)-2,3-epoxysqualene = lanosterol
Other name(s): 2,3-epoxysqualene lanosterol cyclase; squalene-2,3-oxide-lanosterol cyclase; lanosterol 2,3-oxidosqualene cyclase; squalene 2,3-epoxide:lanosterol cyclase; 2,3-oxidosqualene sterol cyclase; oxidosqualene cyclase; 2,3-oxidosqualene cyclase; 2,3-oxidosqualene-lanosterol cyclase; oxidosqualene-lanosterol cyclase; squalene epoxidase-cyclase
Systematic name: (*S*)-2,3-epoxysqualene mutase (cyclizing, lanosterol-forming)
References: [61]

[EC 5.4.99.7 created 1961 as EC 1.99.1.13, transferred 1965 to EC 1.14.1.3, part transferred 1972 to EC 5.4.99.7 rest to EC 1.14.99.7]

EC 5.4.99.8
Accepted name: cycloartenol synthase
Reaction: (*S*)-2,3-epoxysqualene = cycloartenol
Other name(s): 2,3-epoxysqualene cycloartenol-cyclase; squalene-2,3-epoxide-cycloartenol cyclase; 2,3-epoxysqualene cycloartenol-cyclase; 2,3-epoxysqualene-cycloartenol cyclase; 2,3-oxidosqualene-cycloartenol cyclase
Systematic name: (*S*)-2,3-epoxysqualene mutase (cyclizing, cycloartenol-forming)
References: [236]

[EC 5.4.99.8 created 1972]

EC 5.4.99.9
Accepted name: UDP-galactopyranose mutase
Reaction: UDP-D-galactopyranose = UDP-D-galacto-(1→4)-furanose
Systematic name: UDP-D-galactopyranose furanomutase
References: [294]

[EC 5.4.99.9 created 1984]

[5.4.99.10 Deleted entry. isomaltulose synthetase. Now included with EC 5.4.99.11, isomaltulose synthase]

[EC 5.4.99.10 created 1984, deleted 1992]

EC 5.4.99.11
Accepted name: isomaltulose synthase
Reaction: sucrose = 6-*O*-α-D-glucopyranosyl-D-fructofuranose
Other name(s): isomaltulose synthetase; sucrose α-glucosyltransferase; trehalulose synthase
Systematic name: sucrose glucosylmutase
Comments: The enzyme simultaneously produces isomaltulose (6-*O*-α-D-glucopyranosyl-D-fructose) and smaller amounts of trehalulose (1-*O*-α-D-glucopyranosyl-β-D-fructose) from sucrose.
References: [45, 46]

[EC 5.4.99.11 created 1989 (EC 5.4.99.10 created 1984, incorporated 1992)]

EC 5.4.99.12

Accepted name: tRNA-pseudouridine synthase I

Reaction: tRNA uridine = tRNA pseudouridine

Other name(s): tRNA-uridine isomerase; tRNA pseudouridylate synthase I; transfer ribonucleate pseudouridine synthetase; pseudouridine synthase; transfer RNA pseudouridine synthetase

Systematic name: tRNA-uridine uracilmutase

Comments: The uridylate residues at positions 38, 39 and 40 of nearly all tRNAs are isomerized to pseudouridine.

References: [15, 133]

[EC 5.4.99.12 created 1990]

EC 5.4.99.13

Accepted name: isobutyryl-CoA mutase

Reaction: 2-methylpropanoyl-CoA = butanoyl-CoA

Other name(s): isobutyryl coenzyme A mutase; butyryl-CoA:isobutyryl-CoA mutase

Systematic name: 2-methylpropanoyl-CoA CoA-carbonylmutase

Comments: Requires a cobamide coenzyme.

References: [37]

[EC 5.4.99.13 created 1992]

EC 5.4.99.14

Accepted name: 4-carboxymethyl-4-methylbutenolide mutase

Reaction: 4-carboxymethyl-4-methylbut-2-en-1,4-olide = 4-carboxymethyl-3-methylbut-2-en-1,4-olide

Other name(s): 4-methyl-2-enelactone isomerase; 4-methylmuconolactone methylisomerase; 4-methyl-3-enelactone methyl isomerase

Systematic name: 4-carboxymethyl-4-methylbut-2-en-1,4-olide methylmutase

References: [40]

[EC 5.4.99.14 created 1992]

EC 5.4.99.15

Accepted name: (1→4)-α-D-glucan 1-α-D-glucosylmutase

Reaction: 4-[(1→4)-α-D-glucosyl]$_{n-1}$-D-glucose = 1-α-D-[(1→4)-α-D-glucosyl]$_{n-1}$-α-D-glucopyranoside

Other name(s): malto-oligosyltrehalose synthase; maltodextrin α-D-glucosyltransferase

Systematic name: (1→4)-α-D-glucan 1-α-D-glucosylmutase

Comments: The enzyme from *Arthrobacter sp.*, *Sulfolobus acidocaldarius* acts on (1→4)-α-D-glucans containing three or more (1→4)-α-linked D-glucose units. Not active towards maltose.

References: [183, 203, 202]

[EC 5.4.99.15 created 1999]

EC 5.4.99.16

Accepted name: maltose α-D-glucosyltransferase

Reaction: maltose = α,α-trehalose

Other name(s): trehalose synthase; maltose glucosylmutase

Systematic name: maltose α-D-glucosylmutase

References: [207, 208]

[EC 5.4.99.16 created 1999]

EC 5.4.99.17

Accepted name: squalene—hopene cyclase

Reaction: (1) squalene = hop-22(29)-ene
(2) squalene + H_2O = hopan-22-ol

Systematic name: squalene mutase (cyclizing)

Comments: The enzyme produces a constant ratio of about 5:1 hopene:hopanol.

References: [250, 117]

[EC 5.4.99.17 created 2002]

EC 5.4.99.18

Accepted name: 5-(carboxyamino)imidazole ribonucleotide mutase

Reaction: 5-carboxyamino-1-(5-phospho-D-ribosyl)imidazole = 5-amino-1-(5-phospho-D-ribosyl)imidazole-4-carboxylate

Other name(s): N^5-CAIR mutase; PurE; N^5-carboxyaminoimidazole ribonucleotide mutase; class I PurE

Systematic name: 5-carboxyamino-1-(5-phospho-D-ribosyl)imidazole carboxymutase

Comments: In eubacteria, fungi and plants, this enzyme, along with EC 6.3.4.18, 5-(carboxyamino)imidazole ribonucleotide synthase, is required to carry out the single reaction catalysed by EC 4.1.1.21, phosphoribosylaminoimidazole carboxylase, in vertebrates [76]. In the absence of EC 6.3.2.6, phosphoribosylaminoimidazolesuccinocarboxamide synthase, the reaction is reversible [191]. The substrate is readily converted into 5-amino-1-(5-phospho-D-ribosyl)imidazole by non-enzymic decarboxylation [191].

References: [192, 200, 191, 184, 77, 76]

[EC 5.4.99.18 created 2006]

EC 5.5 Intramolecular lyases

This subclass contains a single sub-subclass for enzymes that catalyse reactions in which a group can be regarded as being eliminated from one part of a molecule, leaving a double bond, while remaining covalently attached to the molecule (intramolecular lyases; EC 5.5.1).

EC 5.5.1 Intramolecular lyases (only sub-subclass identified to date)

EC 5.5.1.1

Accepted name: muconate cycloisomerase

Reaction: 2,5-dihydro-5-oxofuran-2-acetate = *cis*,*cis*-hexadienedioate

Other name(s): muconate cycloisomerase I; *cis*,*cis*-muconate-lactonizing enzyme; *cis*,*cis*-muconate cycloisomerase; muconate lactonizing enzyme; 4-carboxymethyl-4-hydroxyisocrotonolactone lyase (decyclizing); CatB; MCI

Systematic name: 2,5-dihydro-5-oxofuran-2-acetate lyase (decyclizing)

Comments: Requires Mn^{2+}. Also acts (in the reverse reaction) on 3-methyl-*cis*,*cis*-hexadienedioate and, very slowly, on *cis*,*trans*-hexadienedioate. Not identical with EC 5.5.1.7 (chloromuconate cycloisomerase) or EC 5.5.1.11 (dichloromuconate cycloisomerase).

References: [214, 216, 261]

[EC 5.5.1.1 created 1961]

EC 5.5.1.2

Accepted name: 3-carboxy-*cis*,*cis*-muconate cycloisomerase

Reaction: 2-carboxy-2,5-dihydro-5-oxofuran-2-acetate = *cis*,*cis*-butadiene-1,2,4-tricarboxylate

Other name(s): β-carboxymuconate lactonizing enzyme; 3-carboxymuconolactone hydrolase
Systematic name: 2-carboxy-2,5-dihydro-5-oxofuran-2-acetate lyase (decyclizing)
References: [215, 216]

[EC 5.5.1.2 created 1972]

EC 5.5.1.3
Accepted name: tetrahydroxypteridine cycloisomerase
Reaction: tetrahydroxypteridine = xanthine-8-carboxylate
Systematic name: tetrahydroxypteridine lyase (isomerizing)
References: [188]

[EC 5.5.1.3 created 1972]

EC 5.5.1.4
Accepted name: inositol-3-phosphate synthase
Reaction: D-glucose 6-phosphate = 1D-*myo*-inositol 3-phosphate
Other name(s): *myo*-inositol-1-phosphate synthase; D-glucose 6-phosphate cycloaldolase; inositol 1-phosphate synthatase; glucose 6-phosphate cyclase; inositol 1-phosphate synthetase; glucose-6-phosphate inositol monophosphate cycloaldolase; glucocycloaldolase; 1L-*myo*-inositol-1-phosphate lyase (isomerizing)
Systematic name: 1D-*myo*-inositol-3-phosphate lyase (isomerizing)
Comments: Requires NAD^{+}, which dehydrogenates the -CHOH- group to -CO- at C-5 of the glucose 6-phosphate, making C-6 into an active methylene, able to condense with the -CHO at C-1. Finally, the enzyme-bound NADH reconverts C-5 into the -CHOH- form.
References: [70, 254, 22, 23]

[EC 5.5.1.4 created 1972, modified 2001]

EC 5.5.1.5
Accepted name: carboxy-*cis*,*cis*-muconate cyclase
Reaction: 3-carboxy-2,5-dihydro-5-oxofuran-2-acetate = 3-carboxy-*cis*,*cis*-muconate
Other name(s): 3-carboxymuconate cyclase
Systematic name: 3-carboxy-2,5-dihydro-5-oxofuran-2-acetate lyase (decyclizing)
References: [100]

[EC 5.5.1.5 created 1972]

EC 5.5.1.6
Accepted name: chalcone isomerase
Reaction: a chalcone = a flavanone
Other name(s): chalcone-flavanone isomerase
Systematic name: flavanone lyase (decyclizing)
References: [199]

[EC 5.5.1.6 created 1972]

EC 5.5.1.7
Accepted name: chloromuconate cycloisomerase
Reaction: 2-chloro-2,5-dihydro-5-oxofuran-2-acetate = 3-chloro-*cis*,*cis*-muconate
Other name(s): muconate cycloisomerase II
Systematic name: 2-chloro-2,5-dihydro-5-oxofuran-2-acetate lyase (decyclizing)

Comments: Requires Mn^{2+}. The product of cycloisomerization of 3-chloro-*cis*,*cis*-muconate spontaneously eliminates chloride to produce *cis*-4-carboxymethylenebut-2-en-4-olide. Also acts (in the reverse direction) on 2-chloro-*cis*,*cis*-muconate. Not identical with EC 5.5.1.1 (muconate cycloisomerase) or EC 5.5.1.11 (dichloromuconate cycloisomerase).
References: [247]

[EC 5.5.1.7 created 1983]

EC 5.5.1.8
Accepted name: bornyl diphosphate synthase
Reaction: geranyl diphosphate = (+)-bornyl diphosphate
Other name(s): bornyl pyrophosphate synthase; bornyl pyrophosphate synthetase; (+)-bornylpyrophosphate cyclase; geranyl-diphosphate cyclase (ambiguous)
Systematic name: (+)-bornyl-diphosphate lyase (decyclizing)
References: [53]

[EC 5.5.1.8 created 1984]

EC 5.5.1.9
Accepted name: cycloeucalenol cycloisomerase
Reaction: cycloeucalenol = obtusifoliol
Other name(s): cycloeucalenol—obtusifoliol isomerase
Systematic name: cycloeucalenol lyase (cyclopropane-decyclizing)
Comments: Opens the cyclopropane ring of a number of related 4α-methyl-9β-19-cyclosterols, but not those with a 4β-methyl group, with formation of an 8(9) double bond. Involved in the synthesis of plant sterols.
References: [111, 230]

[EC 5.5.1.9 created 1986]

EC 5.5.1.10
Accepted name: α-pinene-oxide decyclase
Reaction: α-pinene oxide = (*Z*)-2-methyl-5-isopropylhexa-2,5-dienal
Other name(s): α-pinene oxide lyase
Systematic name: α-pinene-oxide lyase (decyclizing)
Comments: Both rings of pinene are cleaved in the reaction.
References: [98]

[EC 5.5.1.10 created 1990]

EC 5.5.1.11
Accepted name: dichloromuconate cycloisomerase
Reaction: 2,4-dichloro-2,5-dihydro-5-oxofuran-2-acetate = 2,4-dichloro-*cis*,*cis*-muconate
Systematic name: 2,4-dichloro-2,5-dihydro-5-oxofuran-2-acetate lyase (decyclizing)
Comments: Requires Mn^{2+}. The product of cycloisomerization of dichloro-*cis*,*cis*-muconate spontaneously eliminates chloride to produce *cis*-4-carboxymethylene-3-chlorobut-2-en-4-olide. Also acts, in the reverse direction, on *cis*,*cis*-muconate and its monochloro-derivatives, but with lower affinity. Not identical with EC 5.5.1.1 (muconate cycloisomerase) or EC 5.5.1.7 (chloromuconate cycloisomerase).
References: [154]

[EC 5.5.1.11 created 1992]

EC 5.5.1.12

Accepted name: copalyl diphosphate synthase
Reaction: geranylgeranyl diphosphate = (+)-copalyl diphosphate
Systematic name: (+)-copalyl-diphosphate lyase (decyclizing)
Comments: Part of a bifunctional enzyme involved in the biosynthesis of abietadiene. See also EC 4.2.3.18 (abietadiene synthase)
References: [224, 225, 223, 233, 222]

[EC 5.5.1.12 created 2002]

EC 5.5.1.13
Accepted name: *ent*-copalyl diphosphate synthase
Reaction: geranylgeranyl diphosphate = *ent*-copalyl diphosphate
Other name(s): *ent*-kaurene synthase A; *ent*-kaurene synthetase A; *ent*-CDP synthase
Systematic name: *ent*-copalyl-diphosphate lyase (decyclizing)
Comments: Part of a bifunctional enzyme involved in the biosynthesis of kaurene. See also EC 4.2.3.19 (*ent*-kaurene synthase)
References: [73, 277, 138, 292]

[EC 5.5.1.13 created 2002]

EC 5.5.1.14
Accepted name: *syn*-copalyl-diphosphate synthase
Reaction: geranylgeranyl diphosphate = 9α-copalyl diphosphate
Other name(s): OsCyc1; OsCPSsyn; *syn*-CPP synthase; *syn*-copalyl diphosphate synthase
Systematic name: 9α-copalyl-diphosphate lyase (decyclizing)
Comments: Requires a divalent metal ion, preferably Mg^{2+}, for activity. This class II terpene synthase produces *syn*-copalyl diphosphate, a precursor of several rice phytoalexins, including oryzalexin S and momilactones A and B. Phytoalexins are diterpenoid secondary metabolites that are involved in the defense mechanism of the plant, and are produced in response to pathogen attack through the perception of elicitor signal molecules such as chitin oligosaccharide, or after exposure to UV irradiation. The enzyme is constitutively expressed in the roots of plants where one of its products, momilactone B, acts as an allelochemical (a molecule released into the environment to suppress the growth of neighbouring plants). In other tissues the enzyme is upregulated by conditions that stimulate the biosynthesis of phytoalexins.
References: [217, 328]

[EC 5.5.1.14 created 2008]

EC 5.5.1.15
Accepted name: terpentedienyl-diphosphate synthase
Reaction: geranylgeranyl diphosphate = terpentedienyl diphosphate
Other name(s): terpentedienol diphosphate synthase; Cyc1; clerodadienyl diphosphate synthase
Systematic name: terpentedienyl-diphosphate lyase (decyclizing)
Comments: Requires Mg^{2+}. Contains a DXDD motif, which is a characteristic of diterpene cylases whose reactions are initiated by protonation at the 14,15-double bond of geranylgeranyl diphosphate (GGDP) [103]. The triggering proton is lost at the end of the cyclization reaction [69]. The product of the reaction, terpentedienyl diphosphate, is the substrate for EC 4.2.3.36, terpentetriene synthase and is a precursor of the diterpenoid antibiotic terpentecin.
References: [57, 103, 69]

[EC 5.5.1.15 created 2008]

EC 5.5.1.16

Accepted name: halimadienyl-diphosphate synthase
Reaction: geranylgeranyl diphosphate = halima-5(6),13-dien-15-yl diphosphate
Other name(s): Rv3377c; halimadienyl diphosphate synthase; tuberculosinol diphosphate synthase
Systematic name: halima-5(6),13-dien-15-yl-diphosphate lyase (cyclizing)
Comments: Requires Mg^{2+} for activity. This enzyme is found in pathogenic prokaryotes such as *Mycobacterium tuberculosis* but not in non-pathogens such as *Mycobacterium smegmatis* so may play a role in pathogenicity. The product of the reaction is subsequently dephosphorylated yielding tuberculosinol [halima-5(6),13-dien-15-ol].
References: [206]

[EC 5.5.1.16 created 2008]

EC 5.99 Other isomerases

This subclass contains miscellaneous enzymes in a single sub-subclass (EC 5.99.1).

EC 5.99.1 Sole sub-subclass for isomerases that do not belong in the other subclasses

EC 5.99.1.1
Accepted name: thiocyanate isomerase
Reaction: benzyl isothiocyanate = benzyl thiocyanate
Other name(s): isothiocyanate isomerase
Systematic name: benzyl-thiocyanate isomerase
References: [304]

[EC 5.99.1.1 created 1965]

EC 5.99.1.2
Accepted name: DNA topoisomerase
Reaction: ATP-independent breakage of single-stranded DNA, followed by passage and rejoining
Other name(s): type I DNA topoisomerase; untwisting enzyme; relaxing enzyme; nicking-closing enzyme; swivelase; ω-protein; deoxyribonucleate topoisomerase; topoisomerase; type I DNA topoisomerase
Systematic name: DNA topoisomerase
Comments: These enzymes bring about the conversion of one topological isomer of DNA into another, *e.g.,* the relaxation of superhelical turns in DNA, the interconversion of simple and knotted rings of single-stranded DNA, and the intertwisting of single-stranded rings of complementary sequences, *cf.* EC 5.99.1.3 DNA topoisomerase (ATP-hydrolysing).
References: [89]

[EC 5.99.1.2 created 1984]

EC 5.99.1.3
Accepted name: DNA topoisomerase (ATP-hydrolysing)
Reaction: ATP-dependent breakage, passage and rejoining of double-stranded DNA
Other name(s): type II DNA topoisomerase; DNA-gyrase; deoxyribonucleate topoisomerase; deoxyribonucleic topoisomerase; topoisomerase; DNA topoisomerase II;
Systematic name: DNA topoisomerase (ATP-hydrolysing)
Comments: The enzyme can introduce negative superhelical turns into double-stranded circular DNA. One unit has nicking-closing activity, and another catalyses super-twisting and hydrolysis of ATP (*cf.* EC 5.99.1.2 DNA topoisomerase).
References: [89]

[EC 5.99.1.3 created 1984]

EC 5.99.1.4

Accepted name: 2-hydroxychromene-2-carboxylate isomerase

Reaction: 2-hydroxy-2*H*-chromene-2-carboxylate = (3*E*)-4-(2-hydroxyphenyl)-2-oxobut-3-enoate

Other name(s): HCCA isomerase; 2HC2CA isomerase; 2-hydroxychromene-2-carboxylic acid isomerase

Systematic name: 2-hydroxy-2*H*-chromene-2-carboxylate—(3*E*)-4-(2-hydroxyphenyl)-2-oxobut-3-enoate isomerase

Comments: This enzyme is involved in naphthalene degradation.

References: [212, 139, 67, 290]

[EC 5.99.1.4 created 2010]

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