

## 4.2. CRYSTALLIZATION OF MEMBRANE PROTEINS

Table 4.2.1.1. *Compilation of membrane proteins with known structures, including crystallization conditions and key references for the structure determinations*

This table is continuously updated and can be inspected at <http://www.mpibp-frankfurt.mpg.de/michel/public/memprotstruct.html>. The membrane proteins listed are divided into polytopic membrane proteins from inner membranes of bacteria and mitochondria (a), membrane proteins from the outer membrane of Gram-negative bacteria (b) and monotopic membrane proteins [(c); these are proteins that are only inserted into the membrane, but do not span it]. Within parts (a), (b) and (c) the membrane proteins are listed in chronological order of structure determination.

(a) Polytopic membrane proteins from inner membranes of bacteria and mitochondria.

Membrane protein	Crystallization conditions (detergent/additive/precipitating agent)	Key references (and pdb reference code, if available)
Photosynthetic reaction centre from <i>Rhodospseudomonas viridis</i>	<i>N,N</i> -Dimethyldodecylamine- <i>N</i> -oxide/heptane-1,2,3-triol/ammonium sulfate	[1], [2] (1PRC), [3], [4] (2PRC, 3PRC, 4PRC, 5PRC, 6PRC, 7PRC)
from <i>Rhodobacter sphaeroides</i>	<i>N,N</i> -Dimethyldodecylamine- <i>N</i> -oxide/heptane-1,2,3-triol/polyethylene glycol 4000	[5] (4RCR)
	Octyl- $\beta$ -D-glucopyranoside/polyethylene glycol 4000	[6] (2RCR)
	<i>N,N</i> -Dimethyldodecylamine- <i>N</i> -oxide/heptane-1,2,3-triol, dioxane/potassium phosphate	[7] (1PCR)
	Octyl- $\beta$ -D-glucopyranoside/benzamidine, heptane-1,2,3-triol/polyethylene glycol 4000	[8] (1AIG, 1AIJ)
Bacteriorhodopsin from <i>Halobacterium salinarium</i>	(Electron crystallography using naturally occurring two-dimensional crystals)	[9] (1BRD), [10] (2BRD), [11] (1AT9)
	(Type I crystal grown in lipidic cubic phases)	[12] (1AP9), [13] (1BRX)
	Octyl- $\beta$ -D-glucopyranoside/benzamidine/sodium phosphate (epitaxial growth on benzamidine crystals)	[14] (1BRR)
Light-harvesting complex II from pea chloroplasts	(Electron crystallography of two-dimensional crystals prepared from Triton X100 solubilized material)	[15]
Light-harvesting complex 2 from <i>Rhodospseudomonas acidophila</i>	Octyl- $\beta$ -D-glucopyranoside/benzamidine/phosphate	[16] (1KZU)
from <i>Rhodospirillum rubrum</i>	<i>N,N</i> -dimethylundecylamine- <i>N</i> -oxide/heptane-1,2,3-triol/ammonium sulfate	[17] (1LGH)
Cytochrome <i>c</i> oxidase from <i>Paracoccus denitrificans</i> , four-subunit enzyme complexed with antibody Fv fragment	Dodecyl- $\beta$ -D-maltoside/polyethylene glycol monomethylether 2000	[18]
two-subunit enzyme complexed with antibody Fv fragment	Undecyl- $\beta$ -D-maltoside/polyethylene glycol monomethylether 2000	[19] (1AR1)
from bovine heart mitochondria	Decyl- $\beta$ -D-maltoside with some residual cholate/polyethylene glycol 4000	[20], [21] (1OCC), [22] (2OCC, 1OCR)
Cytochrome <i>bc<sub>1</sub></i> complex from bovine heart mitochondria	Decanoyl- <i>N</i> -methylglucamide or diheptanoyl phosphatidyl choline/polyethylene glycol 4000	[23] (1QRC), [24]
	Octyl- $\beta$ -D-glucopyranoside/polyethylene glycol 4000	[25]
	Pure dodecyl- $\beta$ -D-maltoside or mixture with methyl-6- <i>O</i> -( <i>N</i> -heptylcarbamoyl)- $\alpha$ -D- glucopyranoside/polyethylene glycol 4000	[26]
from chicken heart mitochondria	Octyl- $\beta$ -D-glucopyranoside/polyethylene glycol 4000	[25] (1BCC, 3BCC)
Potassium channel from <i>Streptomyces lividans</i>	<i>N,N</i> -Dimethyldodecylamine/polyethylene glycol 400	[27] (1BL8)
Mechanosensitive ion channel from <i>Mycobacterium tuberculosis</i>	Dodecyl- $\beta$ -D-maltoside/triethylene glycol	[28]

#### 4. CRYSTALLIZATION

Table 4.2.1.1. *Compilation of membrane proteins with known structures, including crystallization conditions and key references for the structure determinations (cont.)*

(b) Membrane proteins from the outer membrane of Gram-negative bacteria and related proteins.

Membrane protein	Crystallization conditions (detergent/additive/precipitating agent)	Key references (and pdb reference code, if available)
16-Stranded porins from <i>Rhodobacter capsulatus</i> OmpF and PhoE from <i>Escherichia coli</i>	Octyltetraoxyethylene/polyethylene glycol 600 Mixture of <i>n</i> -octyl-2-hydroxyethylsulfoxide and octylpolyoxyethylene; or <i>N,N</i> -dimethyldecylamine- <i>N</i> -oxide/polyethylene glycol 2000	[29] (2POR) [30] (1OPF, 1PHO), [31]
from <i>Rhodopseudomonas blastica</i>	Octyltetraoxyethylene/heptane-1,2,3-triol/polyethylene glycol 600	[32] (1PRN)
from <i>Paracoccus denitrificans</i>	Octyl- $\beta$ -D-glucoside/polyethylene glycol 600	[33]
18-Stranded porins malto porin from <i>Escherichia coli</i>	Mixture of decyl- $\beta$ -D-maltoside and dodecylnonaoxyethylene/polyethylene glycol 2000	[34] (1MAL)
malto porin from <i>Salmonella typhimurium</i>	Mixture of octyltetraoxyethylene and <i>N,N</i> -dimethylhexylamine- <i>N</i> -oxide/polyethylene glycol 1500	[35] (1MPR, 2MPR)
sucrose-specific ScrY porin from <i>Salmonella typhimurium</i>	Mixture of octyl- $\beta$ -D-glucopyranoside and <i>N,N</i> -dimethylhexylamine- <i>N</i> -oxide/polyethylene glycol 2000	[36] (1AOS, 1AOT)
$\alpha$ -Haemolysin from <i>Staphylococcus aureus</i>	Octyl- $\beta$ -D-glucopyranoside/ammonium sulfate, polyethylene glycol monomethylether 5000	[37] (7AHL)
Eight-stranded $\beta$ -barrel membrane anchor OmpA fragment from <i>Escherichia coli</i>	Not yet available	[38] (1BXW)
22-Stranded receptors FhuA from <i>Escherichia coli</i>	<i>N,N</i> -Dimethyldecylamine- <i>N</i> -oxide/inositol/polyethylene glycol monomethylether 2000 <i>n</i> -Octyl-2-hydroxyethylsulfoxide/polyethylene glycol 2000	[39] (1FCP, 2FCP) [40] (1BY3, 1BY5)
ferric enterobacterin receptor (FepA) from <i>Escherichia coli</i>	<i>N,N</i> -dimethyldodecylamine- <i>N</i> -oxide/heptane-1,2,3-triol/polyethylene glycol 1000	[41] (1FEP)

(c) Proteins inserted into, but not crossing the membrane ('monotopic membrane proteins').

Membrane protein	Crystallization conditions (detergent/additive/precipitating agent)	Key references (and pdb reference code, if available)
Prostaglandin H <sub>2</sub> synthase 1 (cyclooxygenase 1) from sheep	Octyl- $\beta$ -D-glucopyranoside/polyethylene glycol 4000	[42] (1PRH)
Cyclooxygenase 2 from mouse	Octyl- $\beta$ -D-glucopyranoside/polyethylene glycol monomethylether 550	[43] (1CX2, 3PGH, 4COX, 5COX, 6COX)
from man	Octylpentaoxyethylene/polyethylene glycol 4000	[44]
Squalene cyclase from <i>Alicyclobacillus acidocaldarius</i>	Octyltetraoxyethylene/sodium citrate	[45] (1SQC)

References: [1] Diesenhofer *et al.* (1985); [2] Diesenhofer *et al.* (1995); [3] Lancaster & Michel (1997); [4] Lancaster & Michel (1999); [5] Allen *et al.* (1987); [6] Chang *et al.* (1991); [7] Ermler *et al.* (1994); [8] Stowell *et al.* (1997); [9] Henderson *et al.* (1990); [10] Grigorieff *et al.* (1996); [11] Kimura *et al.* (1997); [12] Pebay-Peyroula *et al.* (1997); [13] Luecke *et al.* (1998); [14] Essen *et al.* (1998); [15] Kühlbrandt *et al.* (1994); [16] McDermott *et al.* (1995); [17] Koepke *et al.* (1996); [18] Iwata *et al.* (1995); [19] Ostermeier *et al.* (1997); [20] Tsukihara *et al.* (1995); [21] Tsukihara *et al.* (1996); [22] Yoshikawa *et al.* (1998); [23] Xia *et al.* (1997); [24] Kim *et al.* (1998); [25] Zhang *et al.* (1998); [26] Iwata *et al.* (1998); [27] Doyle *et al.* (1998); [28] Chang *et al.* (1998); [29] Weiss *et al.* (1991); [30] Cowan *et al.* (1992); [31] Cowan *et al.* (1995); [32] Kreuzsch *et al.* (1994); [33] Hirsch *et al.* (1997); [34] Schirmer *et al.* (1995); [35] Meyer *et al.* (1997); [36] Forst *et al.* (1998); [37] Song *et al.* (1996); [38] Pautsch & Schulz (1998); [39] Ferguson *et al.* (1998); [40] Locher *et al.* (1998); [41] Buchanan *et al.* (1999); [42] Picot *et al.* (1994); [43] Kurumbail *et al.* (1996); [44] Luong *et al.* (1996); [45] Wendt *et al.* (1997).