



Bacterial and mycoplasmal lipopeptides activate Toll-like receptors 1, 2 and 6

1. Tools for Toll-like receptor research

Bacterial lipopeptides activate Toll-like receptors 1, 2 and 6 and interact with TLR10

Lipopeptides: Origin and biological activity

Bacterial - including mycoplasmal - lipoproteins (bLP) are characterised by the unusual amino acid dihydroxypropylcysteine (Dhc) acylated by two or three fatty acids. Lipoproteins are part of the outer membrane of Gram negative bacteria, Gram positive bacteria, *Rhodopseudomonas viridis*, and mycoplasma (Hantke and Braun 1973; Gomes-Miguel et al. 1988; Herrmann et al. 1996; Weyer et al. 1987; Mühlradt et al. 1997; Mühlradt et al. 1998; Shibata et al. 2000).

Synthetic analogues (sLP) and the N-terminal part of the lipoprotein of *E.coli* were synthesised for the first time in 1983 (Wiesmüller et al. 1983). They act as potent immunoadjuvants *in vivo* and *in vitro* (Wiesmüller et al. 1992). Immunisation of guinea pigs and swine with a totally synthetic vaccine consisting of the built-in lipotriptide adjuvant Pam₃Cys-Ser-Ser and of a B and T cell epitope of the foot-and-mouth disease virus lead to a long-lasting protection against virus challenge (Wiesmüller et al. 1989).

The conjugation of class I restricted peptides with Pam₃Cys-Ser-Ser resulted in efficient priming of virus-specific cytotoxic T cells for the first time in 1989 (Deres et al. 1989).

Potent hapten-specific immune responses were obtained by immunisation with conjugates of lipopeptide, hapten and (haplotype-specific) T helper cell epitopes (Hoffmann et al. 1997; Moran et al. 2002).

The outer membrane lipoprotein (OspA) from *Borrelia burgdorferi* was used in human vaccine trials (Keller et al. 1994) and proved to be protective in a mouse model even after oral immunisation (Huebner et al. 1997).

The efficacy of eight adjuvant formulations to prime cytotoxic T lymphocytes in mice was compared and the water soluble lipohexapeptide analogue of bacterial lipoproteins Pam₃Cys-Ser-(Lys)₄, (Fig. 1) proved to be the most effective additive for eliciting a cellular immune response in mice (Hioie et al. 1996).

Lipopeptides and Toll-like receptor research

Cell activation via lipoproteins and lipopeptides is mediated by their interaction with Toll-like receptors (TLR). Lipoproteins represent one of the molecular links between host defense mechanisms and microbial products (Aliprantis et al. 1999; Means et al. 2000). TLRs share sequence similarities with the cytoplasmic regions of the IL-1 receptor family and function through the same signalling molecules including MyD88, IRAK, TRAF, MAP kinases and NF- κ B.

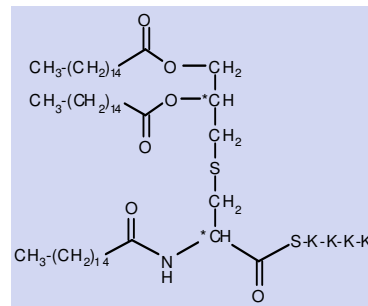


Figure 1: Structure of the water soluble lipopeptide Pam₃Cys-SKSKK

The N-terminal parts of bacterial lipoproteins are effectors of the innate immune defense. The corresponding mammalian Toll-like receptors TLR1, TLR2, and TLR6 have been identified (Akira 2003).

Lipopeptides like Pam₃Cys-SKSKK (Fig. 1), MALP-2 and FSL-1 are described to elicit cellular responses through heterodimers formed by TLR1/TLR2 or TLR2/TLR6 (Takeuchi et al. 2001, 2002; Alexopoulou et al. 2002; Okusawa et al. 2004). The crystal structures of the TLR1/TLR2 and TLR2/TLR6 heterodimers with the synthetic ligands Pam₃Cys-SKSKK (*RR*-stereoisomer) or Pam₂Cys-SKSKK (*RR*-stereoisomer) have been elucidated (Jin et al. 2007; Kang et al. 2009).

Structure-activity studies with synthetic lipopeptide analogues revealed the structural features of their interaction with TLR1, TLR2 and TLR6 (Buwitt-Beckmann et al. 2005, 2006; Farhat et al. 2007). Recently, the interaction of lipopeptides with TLR10 has been described (Guan et al. 2010).



1.1 Lipopeptides for Toll-like receptor 1 and 2 research

Toll-like receptors 1/2 heterodimers are activated by triacylated lipopeptides and their synthetic lipopeptide analogues.

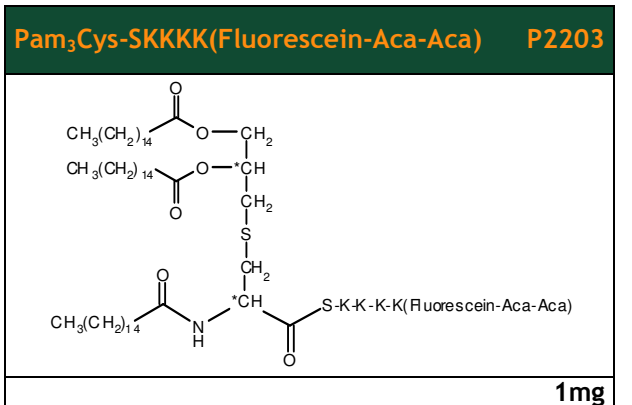
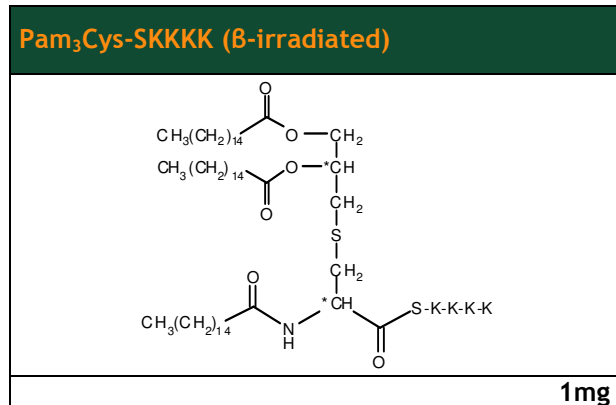
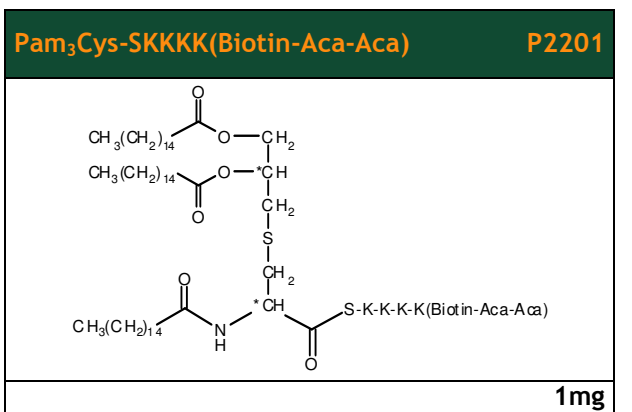
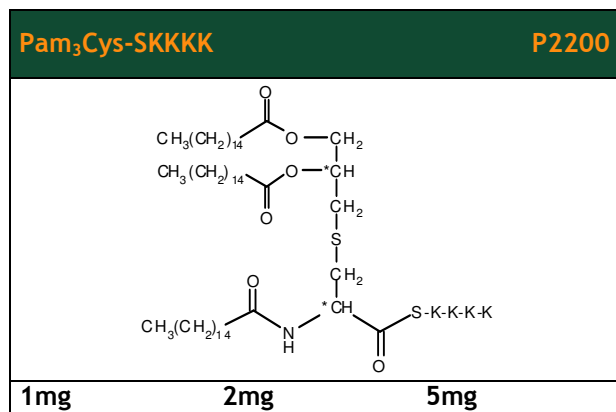
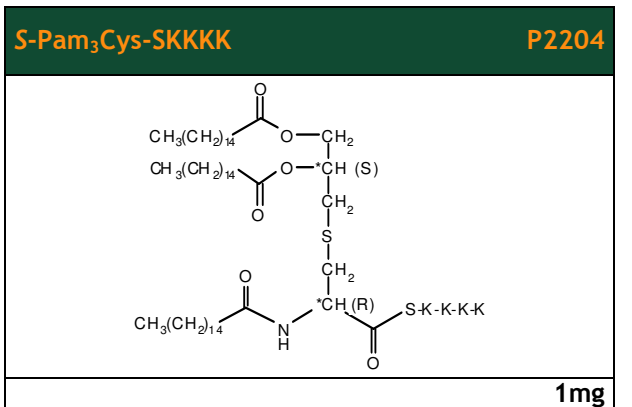
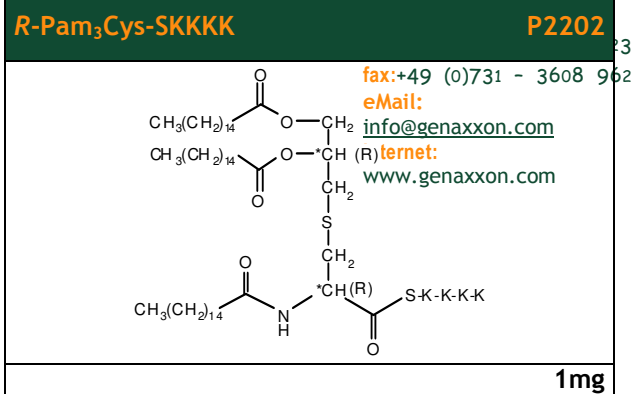
These triacylated lipopeptides are based on L-cysteine and are provided as lyophilised powders without any additives.

Pam₃Cys-SK₄ and analogues

Pam₃Cys-SK₄ is the mostly used synthetic analogue of naturally occurring lipopeptides and often described in literature as reference compound for TLR2/1 activation.

Pam₃Cys-SK₄ is provided as stereochemically defined compounds and as mixture of stereoisomers. Additionally, labelled analogues are available.

PHC-SK₄ is recommended as an appropriate negative control. This triacylated lipopeptide does not contain the dihydroxypropyl cysteine residue, which seems to be essential for the interaction with TLR1/2.





Pam₃Cys-SSGSKPSGGPLDAK **P2237**

Synthetic lipopeptide derived from *Mycobacterium tuberculosis* lipoprotein lprG (27 kDa lipoprotein)

1mg

Pam₃Cys-KQNVSSLDEKNSVSV **P2241**

Synthetic lipopeptide derived from *Borrelia burgdorferi* OspA

1mg

Pam₃Cys-SSGNKSAPSSSASSS **P2238**

Synthetic lipopeptide derived from *Mycobacterium avium* 1 kDa lipoprotein antigen

1mg

Pam₃Cys-NNSGKDGNTS NSAD **P2242**

Synthetic lipopeptide derived from *Borrelia burgdorferi* OspC

1mg

Pam₃Cys-GSHQMKSEGHANMQL **P2239**

Synthetic lipopeptide derived from *Haemophilus influenzae* outer membrane protein P4

1mg

Pam₃Cys-NNGGPELKSDEVAKS **P2243**

Synthetic lipopeptide derived from *Borrelia hermsii* outer membrane lipoprotein 3

1mg

Pam₃Cys-SSNNDAAAGNGAAQT **P2240**

Synthetic lipopeptide derived from *Haemophilus influenzae* outer membrane protein P6

1mg

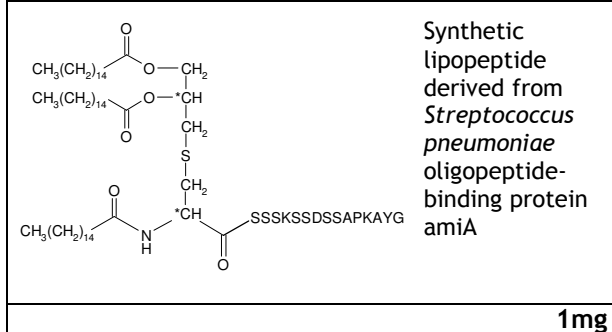
Pam₃Cys-SQEPAAPAAEATPAG **P2244**

Synthetic lipopeptide derived from *Neisseria gonorrhoeae* H.8 outer membrane protein

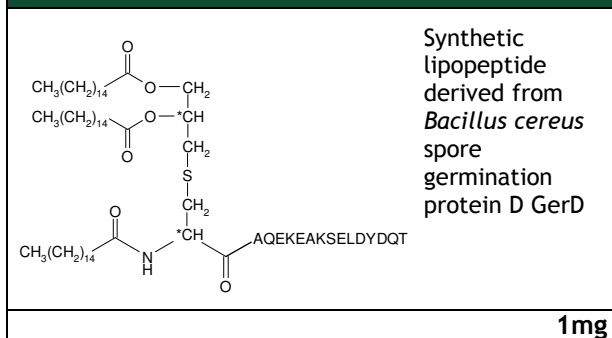
1mg



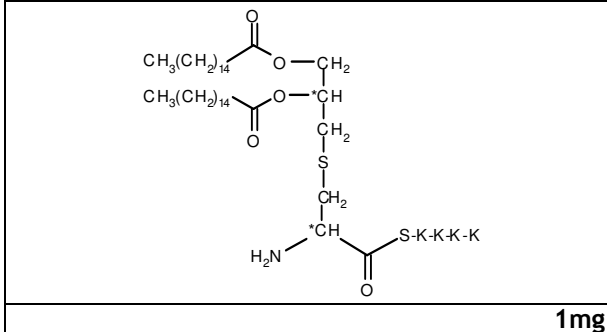
Pam₃Cys-SSSKSSDSSAPKAYG **P2245**



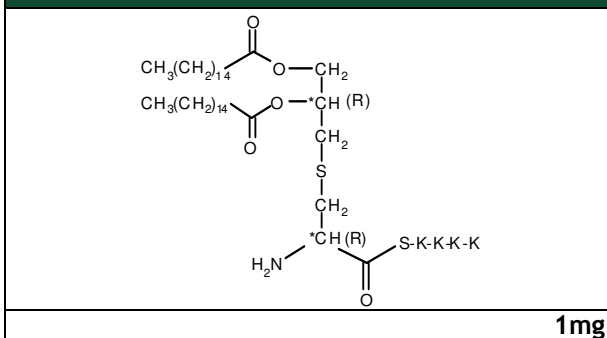
Pam₃Cys-AQEKEAKSELDYDQT **P2246**



Pam₂Cys-SK **P2206**



R-Pam₂Cy -SK **P2208**



1.2. Lipopeptides for Toll-like receptor 2 and 6 research

Toll-like receptors 2/6 heterodimers are activated by diacylated lipoproteins and their synthetic lipopeptide analogues.

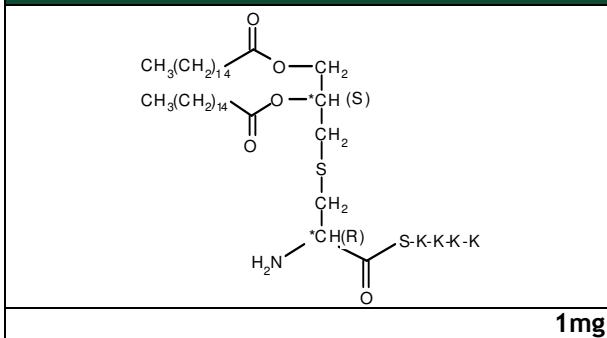
All offered diacylated lipopeptides are based on L-cysteine and are provided as lyophilised powders without any additives.

Pam₂Cys-SK and analogues

Pam₂Cys-SK is a frequently used synthetic analogue of naturally occurring mycoplasmal lipoproteins. The amphiphilic lipopeptide is water soluble due to its strongly hydrophilic amino acid sequence SK, which is not derived from natural lipoproteins.

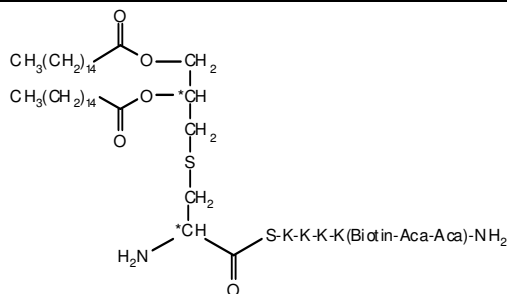
Pam₂Cys-SK is provided as stereochemically defined compounds and as mixture of stereoisomers. Lipopeptides with the S-dihydroxypropyl moiety are not active and therefore suitable as negative controls. Additionally, analogues with different labels are available.

S-Pam₂Cy -SK **P2210**



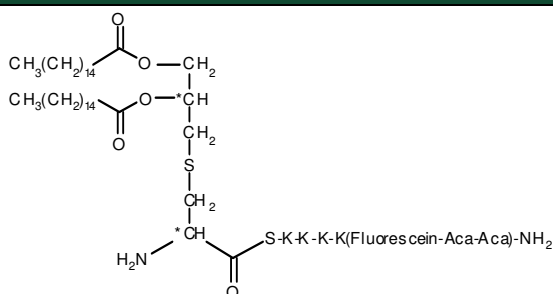


Pam₂Cys-SK K K K (Biot-Aca-Aca)-NH₂ **P2207**



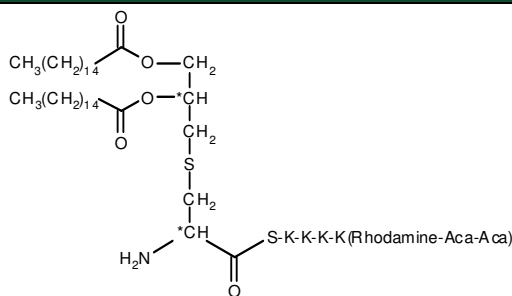
1mg

Pam₂Cys-SK K K K (Fluorescein Aca-Aca)-NH₂ **P2209**



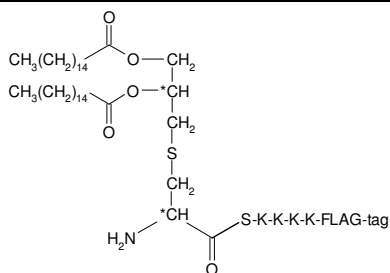
1mg

Pam₂Cys-SK K K K (Rhodamine-Aca-Aca)-NH₂ **P2211**



1mg

Pam₂Cys-SK K K K-FLAG-tag **P2218**



1mg

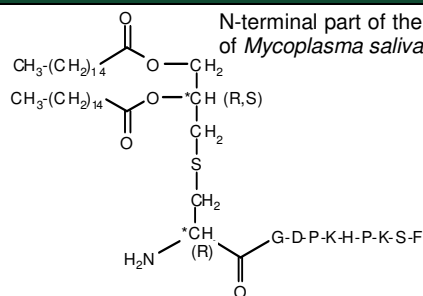
FSL-1 and derivatives

FSL-1, Pam₂Cys-GDPKHPKSF, represents the N-terminal part of the 44-kDa lipoprotein LP44 of *Mycoplasma salivarium*. Compared to *Mycoplasma fermentans* derived synthetic lipopeptide MALP-2, FSL-1 differs in the amino acid sequence but not in the N-terminal lipopeptide Pam₂Cys, which is essential for their biological activity. FSL-1 is highly active and favourable in comparison to many other lipopeptides derived from naturally occurring lipoproteins with respect to its good solubility in aqueous solutions without any detergent.

FSL-1 is provided as stereochemically defined compounds and as mixture of stereoisomers. Lipopeptides with the S-dihydroxypropyl moiety are not active and therefore suitable as negative controls. Additionally, analogues with different labels or tags are available.

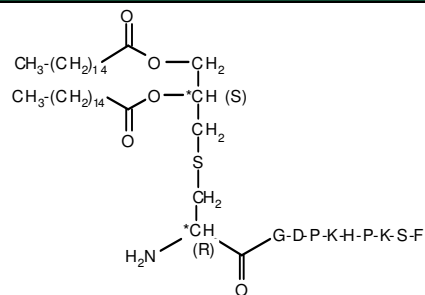
Genaxxon offers further TLR 2/6 ligands with improved physico-chemical features or with neutral charge. Please inquire.

FSL-1 (mixture of R,R and R,S stereoisomers) **P2212**



1mg

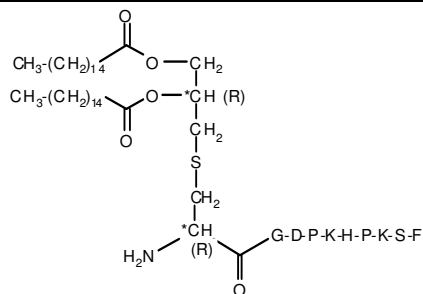
S-FSL-1 (R,S stereoisomer) **P2214**



1mg

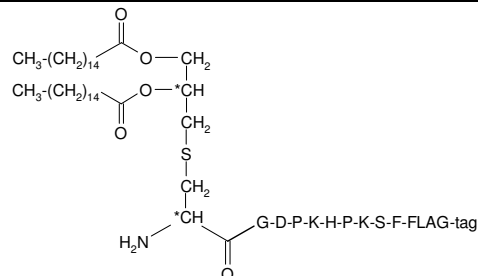


R-FSL-1 (R,R stereoisomer) P2213



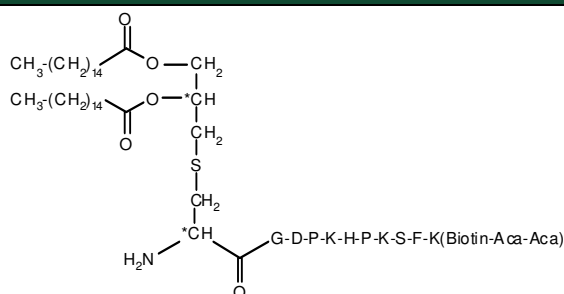
1mg

FSL-1-FLAG-tag P2219



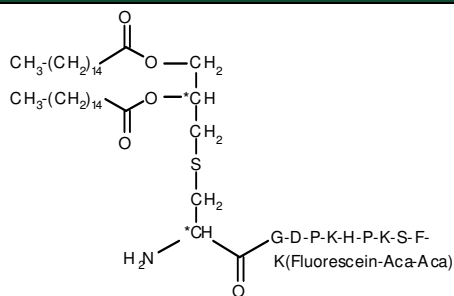
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FSL-1-Biotin P2215



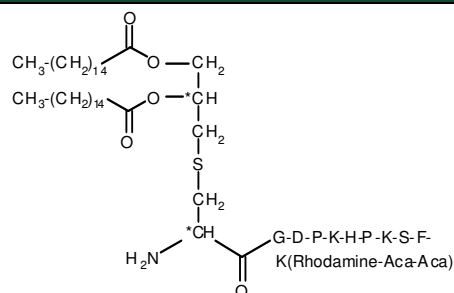
1mg

FSL-1-Fluorescein P2216



1mg

FSL-1-Rhodamine P2217



1mg

FSL-1 Ala-scan collection

Ala-scan collections are designed for the investigation of the biologically relevant amino acid residues of the peptide moiety of lipopeptides.

The FSL-1 Ala-scan collection includes nine lipopeptides with sequential alanine substitutions in the amino acid sequence of FSL-1, Pam₂Cys-GDPKHPKSF.

The FSL-1 Ala-scan collection contains 9 vials, each containing 0.2 mg lipopeptide.

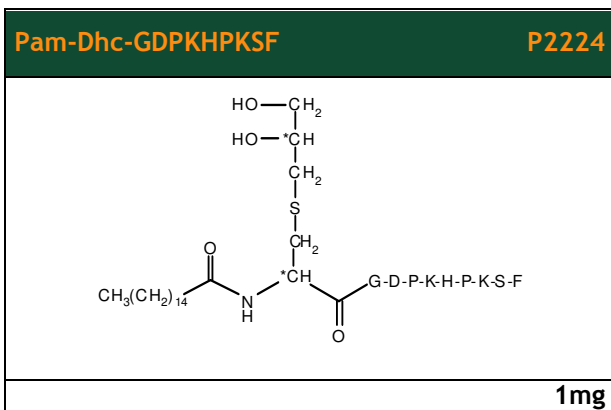
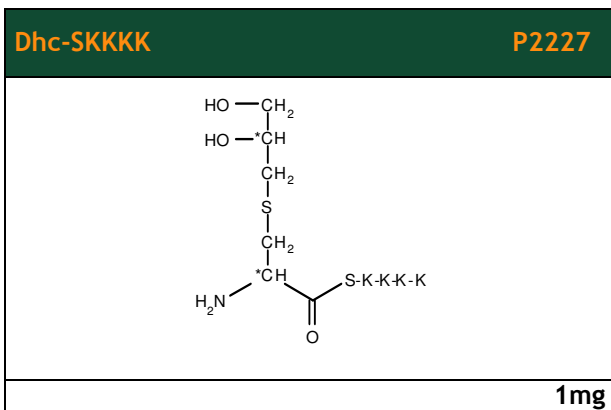
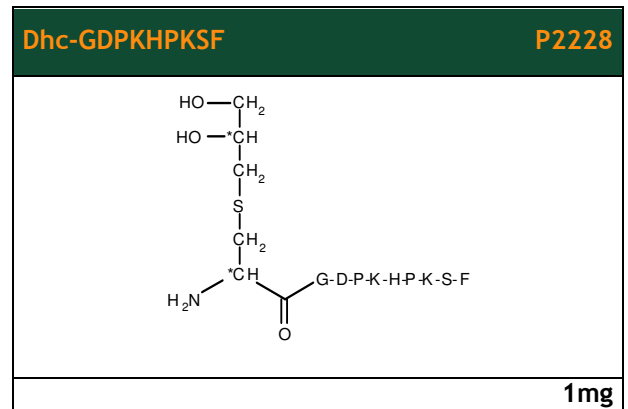
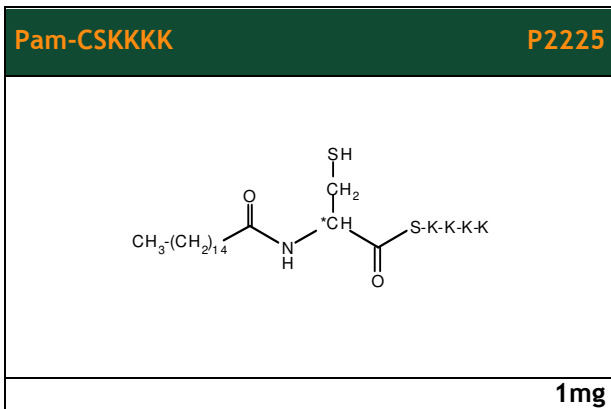
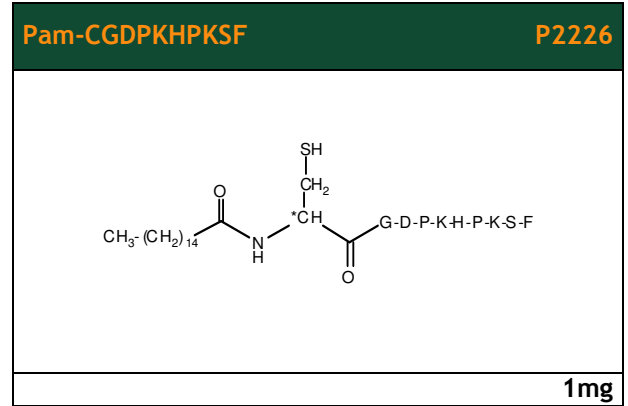
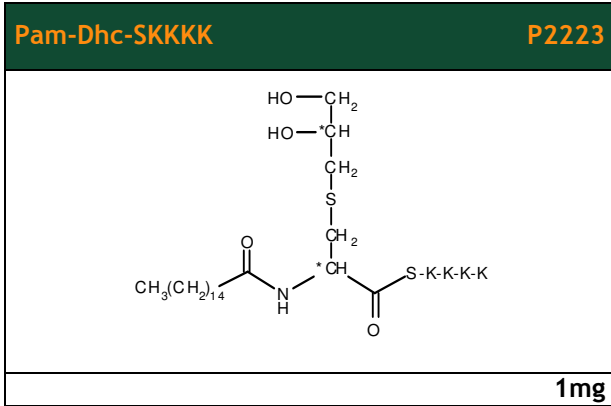
FSL-1 Ala-scan collection P2221

Pam ₂ Cys-ADPKHPKSF	0.2 mg
Pam ₂ Cys-GAPKHPKSF	0.2 mg
Pam ₂ Cys-GDAKHPKSF	0.2 mg
Pam ₂ Cys-GDP ^A HPKSF	0.2 mg
Pam ₂ Cys-GDPK ^A PKSF	0.2 mg
Pam ₂ Cys-GDPKH ^A KSF	0.2 mg
Pam ₂ Cys-GDPKHP ^A SF	0.2 mg
Pam ₂ Cys-GDPKHPK ^A F	0.2 mg
Pam ₂ Cys-GDPKHPKSA	0.2 mg

Collection of 9 lipopeptides, 0.2mg each

1.3. Miscellaneous peptides and lipopeptides for Toll-like receptor research

Monoacylated lipopeptides, peptides with the unusual amino acid dihydroxypropylcysteine (Dhc), or peptides representing the peptide moieties of Pam₃Cys-SK⁴KKK, Pam₂Cys-SK⁴KKK or FSL-1 are analogues or substructures of TLR2 ligands and valuable as negative controls. The Dhc is based on L-cysteine. All peptides are provided as lyophilised powder without any additives.





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General terms and conditions

The following terms and conditions shall exclusively apply to all sales and shall be an integral part of each single agreement concluded between the parties. Verbal agreements are only valid if confirmed in writing. By placing an order the Buyer acknowledges our terms and conditions. Other conditions require our previous consent in writing.

Offers and orders

Our offers are subject to change without prior notice with respect to price, quantity, delivery time and availability. The Buyer's orders shall become binding for Genaxxon upon receipt by the Buyers of Genaxxon's written order acknowledgment (or invoice or delivery note).

Statements and any details in advertising materials shall not constitute any kind of warranty.

Any information, statements or representations, written or oral, by Genaxxon's employees, agents or representatives are not binding unless confirmed in writing on our business paper signed by a duly authorized officer. Genaxxon reserves the right to insist on a written order and/or references from the Buyer before proceeding the order. There is no minimum order value.

Prices

All prices of this price list are net prices in Euro (EUR / €) except if otherwise indicated. Our prices are exclusive of VAT. Goods are charged with the prices valid on the date of delivery. Payment in other currency requires a written quotation in the foreign currency.

Any tax, duty or charge imposed by governmental authority or otherwise and any other applicable taxes, duties or charges shall be charged to the Buyer's account.

Freight and packing charges will be added, they can be invoiced as a lump-sum charge.

Delivery / transfer of perils

Unless otherwise agreed by the Buyer and GENAXXON, the price shall be for delivery ex factory, packing excluded.

From the time of delivery the goods shall be at the risk of the Buyer. We are not liable for damage or loss during transportation. Except when explicitly specified by the Buyer we will decide on the appropriate type of transportation. If the type of transportation is specified, the Buyer has to bear any additional costs. The same shall apply in the case of raised transportation costs, additional expenses incurred by deviation, storage, tec. unless freight free delivery was explicitly agreed upon, after signing the agreement but before delivery.

Date of delivery / force majeure

GENAXXON intends to ship the goods within 7 working days from receipt of order, if possible otherwise within 28 days. There shall be no fixed period of delivery. Notwithstanding the preceding paragraph, if a fixed period for delivery has been agreed upon, and should GENAXXON default with the supply, the Buyer shall grant GENAXXON a reasonable respite, normally four weeks. If GENAXXON is unable to meet Buyers written delivery conditions, or a 28 day delivery, GENAXXON will inform the Buyer at the earliest opportunity. Delivery shall be subject to punctual delivery of the appropriate goods by GENAXXON's own suppliers. The day of delivery shall be the day on which the goods leave GENAXXON's plant or, if that day cannot be ascertained, the day on which the goods are put at the Buyer's disposal.

Force Majeure and unforeseeable hindrances of any kind beyond the control of GENAXXON (e.g. shortage of raw materials and supplies, Force Majeure) shall relieve the party from its obligation to supply as long as and to the extent that the hindrance prevails.

If unforeseeable hindrances of any kind beyond the control of GENAXXON occur (e.g. shortage of raw materials, force majeure) delivery period shall be extended as long as and to the extent that the hindrance prevails.

If delivery is delayed due to the above reasons the Buyer cannot claim any rights.

Terms of payment

Terms for customers with an open account are 14 days from invoice date unless otherwise agreed in writing. Other terms of payment require our previous written consent. For unpaid invoices 20 days beyond maturity we will charge interest on arrears amounting to the usual bank rate, at least 7% per annum exceeding the base rate of the European Central Bank. Delayed payment or irregular payments entitle us to discontinue delivery to the Buyer without any compensation. Instead of the agreed terms of payment we can ask for advance payment or security deposit, should doubts as to the solvency of a Buyer arise. In case of liquidation of the Buyer's company, or if GENAXXON learns about an oath of manifestation or a change of ownership due to financial difficulties we reserve the right to withdraw from the contract. We reserve the right to use incoming payments for liquidation of the oldest debts, in sequence as follows: costs, interests and then debt claims. Prepayments and advance payments must be paid plus VAT.

Government/Corporate Visa, MasterCard and JCB credit card may be accepted on approved accounts for payment of the Products. Payment by credit card will only be taken when ordered by fax or mail.

Intellectual property rights / patents

No warranty or representation is given by GENAXXON that the Products do not infringe any letters patent, trademarks, registered designs or other industrial rights. The Buyer is liable for his infringements of copyrights and industrial or intellectual properties, especially patents and trademarks.

If products are custom-made to specification, the Buyer assumes the responsibility that the manufacture of these products does not infringe any patents or rights of a third party. The Buyer is liable for all damages and claims resulting from such infringement and hold the seller free and harmless from all claims.

The Buyer further warrants to GENAXXON that any use of the Products in the United States of America shall not result in the Products becoming adulterated or misbranded within the meaning of the Federal Food, Drug and Cosmetic Act (or such equivalent legislation in force in the Buyer's jurisdiction) and shall not be materials which may not, under sections 404, 505 or 512 of the Act, be introduced into interstate commerce.



Retention of title

Title of the goods shall not pass to the Buyer until he has fulfilled all liabilities arising from his business connection with GENAXXON, which shall include settling accessory claims and claims for damages and honouring cheques and bills. In the event of non-payment, we shall have the right to re-sell the goods to a third party. GENAXXON shall have the absolute authority to retake, sell or otherwise deal with or dispose of all or any part of the goods in which title remains vested in the seller. Until such time as the property in the goods passes to the Buyer, the Buyer shall hold the goods as the seller's fiduciary agent, and shall keep the goods properly stored, protected, and insured on his own costs.

Damages

No claims for compensation may be lodged by the Buyer including those of a non-contractual nature – for any minor negligent breach of duty by GENAXXON, his executive staff or other agents, unless such breach concerns damages resulting from death, injury or damage to health. However, this shall not affect the applicability of compelling statutory liability regulations.

Notifications of defects

All goods have to be checked immediately on receipt. Damage claims are only acceptable in writing within 8 working days of receipt of all the goods. In case of legitimate claims the Buyer can only require replacement of the goods. If replacement is not possible, the Buyer has the right to choose between alternative products with same value or refund. The Buyer cannot claim further compensation. All returns must first be authorized by us in writing.

Technical support, use and processing, properties of goods

Technical advice provided by GENAXXON verbally, in writing or by way of trials is given in good faith but without warranty, and this shall also apply where proprietary rights of third parties are involved. GENAXXON's technical advice shall not release the Buyer from the obligation to test the products supplied by GENAXXON as to their suitability for the intended processes and uses. The application, use and processing of the products are beyond GENAXXON's control and therefore entirely in the Buyer's responsibility.

Attention should be paid to the enclosed product descriptions, warnings and instruction leaflets.

Any arbitrary modification of the documents (e.g. instruction leaflets) and/or modification of the product is at your own risk.

Safety

At the Buyer's firm, all chemicals must be handled only by competent, suitably trained persons, familiar with laboratory procedures and potential chemical hazards. The burden of safe use of the Products of GENAXXON vests in the Buyer. The Buyer assumes all responsibility for warning his employees, and any person who might reasonably be expected to come into contact with the Products, of all risks to person and property in any way connected with the Products and for instructing them in their safe handling and use. The Buyer also assumes the responsibility for the safe disposal of all products in accordance with all applicable laws.

Product quality, specifications and technical information

Products are analysed in the laboratories of GENAXXON by methods and procedures which GENAXXON considers appropriate. In the event of any dispute concerning reported discrepancies arising from the Buyer's analytical results, determined by the Buyer's own analytical procedures, GENAXXON reserves the right to rely on the results of own analytical methods of GENAXXON. Certificates of Analysis or Certificates of Conformity are available at the discretion of GENAXXON for bulk orders but not normally for pre-pack orders. GENAXXON reserves the right to make a charge for such Certification.

Specifications may change and reasonable variation from any value listed should not form the basis of a dispute. Any supply by GENAXXON of bespoke or custom Product for a Buyer shall be to a specification agreed by both parties in writing.

Technical information provided orally, in writing, or by electronic means by or on behalf of GENAXXON, including any descriptions, references, illustrations or diagrams in any Catalogue or brochure, is provided for guidance purposes only and is subject to change.

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All products of GENAXXON bioscience GmbH are not for any commercial use or resale. They are intended solely for laboratory research and development purposes and are not to be used for any other purpose. GENAXXON bioscience GmbH offers no warranty regarding the fitness of any Product for a particular purpose and shall not be responsible for any loss or damage whatsoever arising there from.

The Buyer acknowledges that, since the products of GENAXXON are intended for research purposes, they may not be on the Toxic Substances Control Act 1976 ("TSCA") inventory. The Buyer warrants that it shall ensure that the Products are approved for use under the TSCA (or such other equivalent legislation in force in the Buyer's jurisdiction), if applicable. The Buyer shall be responsible for complying with any legislation or regulations governing the use of the Products and their import into the country of destination (for the avoidance of doubt to include, without limitation, the TSCA and all its amendments, all EINECS, ELINCS and NONS regulations).

If any licence or consent of any government or other authority shall be required for the acquisition, carriage or use of the products by the Buyer the Buyer shall obtain the same at its own expense and if necessary produce evidence of the same to GENAXXON on demand. Failure to do so shall not entitle the Buyer to withhold or delay payment. Any additional expenses or charges incurred by GENAXXON resulting from such failure shall be for the Buyer's account.

Workings and syntheses are undertaken with all due care and attention. In case(s) of claims involving negligence, liability for such claims shall be limited to the total amount paid in respect of the invoice. In particular, liability cannot be accepted for results obtained with the product(s) or for loss of profits.

Applicable law and jurisdiction / miscellaneous clauses

All contracts are subject to the laws of the Federal Republic of Germany. In the case of a legal dispute the jurisdiction of the court in Ulm (Germany) will be decisive and have exclusive jurisdiction. GENAXXON shall have the right to bring a claim before a court at the Buyer's principal place of business or at his discretion before any other court being competent according to any national or international law.



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b i o s c i e n c e

Application of the Uniform Law on the International Sale of Goods and the Uniform Law on the Formation of Contracts for the International Sale of Goods and of the UN agreement on the sale of goods shall be excluded. Customary clauses shall be interpreted in accordance with the applicable Incoterms.

Even if it has been agreed that GENAXXON pays the customs and import duties of the destination country, any increase in such duties which becomes effective between the date of the order acknowledgement and delivery of the goods shall be borne by the Buyer. All other charges, taxes and costs connected with the purchase contract shall also be borne by the Buyer.

In the event that any provision of these Terms and Conditions is invalid or becomes invalid, the remainder of the Terms and Conditions shall remain unaffected thereby. The invalid provision shall then be replaced by such provision as comes as close as possible to the economic purpose of such invalid provision, taking reasonable account of the interests of both Parties.