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Description

Phosphoinositol-glycan-peptide with insulin-like action

5 The invention relates to phosphoinositol-glycan-peptides with insulin-like action, a process for the preparation thereof and the use, in particular as pharmaceutical for treating diabetes mellitus or non-insulin-dependent diabetes.

10 Insulin exerts a multiplicity of actions on insulin-sensitive tissue. One noteworthy effect is the rapid reduction in the glucose level in mammals when insulin is administered. This is brought about by a rapid uptake of the glucose from the blood by myocytes and adipocytes. Insulin furthermore activates glycogen synthetase and
15 inhibits lipolysis. Insulin promotes protein synthesis from amino acids and enhances the induction of pyruvate dehydrogenase and phosphofructokinase and inhibits the formation of certain enzymes of gluconeogenesis, such as pyruvate carboxylase and fructose-1,5-bisphosphatase.

20 Type II diabetes, non-insulin-dependent diabetes, is associated with insulin resistance by peripheral tissue such as muscle tissue or adipose tissue. The glucose utilization reduced thereby is caused by the absence of insulin stimulation of glucose transport and of sub-
25 sequent metabolic processes (glucogenesis, lipogenesis). This multiple resistance suggests that there is a defect at the receptor or post-receptor level, i.e. before production of the second messenger (Garvey, Diabetes/-Metabolism Reviews, 5, (1989), 727-742).

30 To date no active substances which avoid the insulin receptor and nevertheless display an insulin-like action have been disclosed.

It has now been found that phosphoinositol-glycan-peptides which can be obtained from adenosine 3',5'-cyclic monophosphate (cAMP)-binding protein display an insulin-like action in vitro and also display an
5 insulin-like action on insulin-resistant tissue.

The invention therefore relates to phosphoinositol-glycan-peptides obtainable by cleavage of adenosine 3',5'-cyclic monophosphate-binding protein and/or the physiologically tolerated salts thereof.

10 The term insulin-resistant tissue means, for example, rat adipocytes which no longer have an insulin receptor. cAMP-binding protein are proteins which have the property of binding adenosine 3',5'-cyclic monophosphate.

Structural data to date on the phosphoinositol-glycan-peptides according to the invention indicate a phosphoinositol which has a glycan portion which contains galactose, glucosamine and mannose, and which is coupled via a phosphorylethanolamine residue with an amide linkage to the carboxyl end of a peptide. The latter
15 reappears within the covalently bonded glycolipids, which act as membrane anchor, in similar structure in plasma membrane proteins of higher eukaryotes (Roberts et al., J. Biol. Chem., 263, (1983), 18776-18784). The glycan residue contains glucosamine, galactose, mannose and at
20 least two phosphate residues/mole. The peptide has the sequence -Asn-Cys-Tyr- and is bonded to the carboxyl end of the aspartic acid via an amide linkage to the amino group of the phosphoinositol glycan. The phosphoinositol glycan portion is necessary for the activity. The peptide
25 enhances the insulin-like action. It also emerges that an insulin-like action is shown not only by the complete phosphoinositol-glycan-peptide but also by partial structures, for example truncated peptide sequences which are bonded to the phosphoinositol glycan also show an
30 insulin-like action or only the phosphoinositol glycan
35

without peptide.

Examples of suitable physiologically tolerated salts of the phosphoinositol-glycan-peptide according to the invention are alkali metal, alkaline earth metal or
5 ammonium salts, as well as those of physiologically tolerated organic ammonium or triethylamine bases.

The phosphoinositol-glycan-peptides according to the invention are prepared, for example, by

- a) using organisms which contain cAMP-binding protein,
- 10 b) isolating the cAMP-binding protein,
- c) eliminating the protein portion from cAMP-binding protein, and purifying the resulting glycosyl-phosphatidylinositol-peptide where appropriate,
- d) eliminating a mono- or diacylglycerol from the
15 product obtained in process step c) and
- e) isolating the phosphoinositol-glycan-peptide produced in process step d).

cAMP-binding protein can be obtained from numerous organisms, for example from microorganisms, plants, fungi
20 or animal organs. Also suitable is, for example, the yeast *Saccharomyces cerevisiae*, especially DSM 6649.

The preparation of cAMP-binding protein by *Saccharomyces cerevisiae* is carried out by fermentation in a nutrient solution which contains a carbon source and a nitrogen
25 source as well as customary inorganic salts. The cAMP-binding protein is preferentially accumulated in the plasma membrane of the yeast.

The best procedure for process step a) is as follows. The formation of cAMP-binding protein in *Saccharomyces cerevisiae* takes place well in the customary nutrient
30 solutions for *Saccharomyces cerevisiae*. Cultivation is carried out aerobically, that is to say, for example,

submerged with shaking or stirring in shaken flasks or fermenters, where appropriate introducing air or oxygen. It can be carried out in a temperature range from about 18 to 35°C, preferably at about 25 to 30°C, in particular
5 28 to 30°C. The pH range should be between 2 and 8, advantageously between 3 and 7. The yeast is cultivated under these conditions generally until there are about 10^7 cells/ml of nutrient solution.

The best procedure for process step b) is such that the
10 yeast cells are separated from the nutrient medium for the isolation of the cAMP-binding protein and are washed with buffer. Isolation takes place, for example, as described by Müller and Bandlow (Biochemistry, 28, (1989), 9957-9967). For this purpose, the yeast cells are
15 converted enzymatically (zymolyase) into spheroplasts and comminuted with a homogenizer in the presence of protease inhibitors in the cold (0-4°C). Yeast lysates are centrifuged, and the cell precipitate is washed with buffer and again centrifuged. The supernatants are combined and
20 purified in a ^oPercoll gradient (28% Percoll) and sucrose gradient (15 to 28% sucrose). These centrifugation steps result in cytoplasm, plasma membrane, microsomes and mitochondria being separated from one another.

The cAMP-binding protein is bound from the plasma membrane fraction, for example by an N^6 -(2-aminoethyl)-cAMP-Sepharose column, and the cAMP-binding protein is eluted from the column with cAMP and desalted.

The best procedure for process step c) is such that the protein portion of the cAMP-binding protein is eliminated
30 enzymatically. Used for the enzymatic cleavage are, for example, proteases such as Pronase, endoprotease Lys-C (Lysobacter enzymogenes) or V8 protease (Staphylococcus aureus). This achieves breakdown of the protein portion. The result with the protease V8 is a glycosylphosphatidylinositol with the peptide sequence
35

Asn-Cys-Tyr; incubation with the protease Pronase yields a glycosyl-phosphatidylinositol-peptide wherein the peptide portion is composed only of the amino acid Asn.

5 The protease is precipitated, for example by acids such as trichloroacetic acid. The glycosyl-phosphatidylinositol-peptides are separated from the proteases by centrifugation, concentrated with a phenyl-Sepharose column and purified by thin-layer chromatography.

10 The best procedure for process step d) is such that the mono- or diacylglycerol residue attached to the glycosyl-phosphatidylinositol-peptide is eliminated enzymatically, and the phosphoinositol-glycan-peptide is liberated in this way. Used for the enzymatic cleavage are, for
15 example, phospholipases such as phosphatidylinositol-specific phospholipase C (*Bacillus cereus*). This achieves elimination of the mono- or diacylglycerol residue which is bonded via the phosphate group to the myo-inositol. The glycerol-containing residue is not eliminated by the
20 protease treatment in process step c). Process steps c) and d) can also be carried out in the reverse sequence.

The enzymatic reactions in process steps c) and d) are carried out under conditions which are favorable for the enzymatic reaction. It is not difficult for a person
25 skilled in the art to establish the optimal reaction conditions on the basis of the known reaction conditions for the said enzymes.

The best procedure for process step e) is such that the phospholipases are precipitated by acids such as tri-
30 chloroacetic acid. The phosphoinositol-glycan-peptide is separated from the phospholipase by centrifugation, purified with a Biogel P-4 column and concentrated by thin-film electrophoresis.

The phosphoinositol-glycan-peptides according to the invention and the physiologically tolerated salts thereof are primarily used as active substances for pharmaceutical compositions for the treatment of diabetes mellitus
5 or non-insulin-dependent diabetes.

The invention therefore also relates to a pharmaceutical which has an effective content of phosphoinositol-glycan-peptide and/or at least one of the physiologically tolerated salts thereof in dissolved, amorphous and/or
10 crystalline form.

The pharmaceutical is preferably a solution or suspension for injection with a pH between about 3.0 and 9.0, preferably between 5.0 and 8.5, which contains a suitable isotonicizing agent, a suitable preservative and, where
15 appropriate, a suitable buffer, as well as, where appropriate, also a depot principle, all of course in sterile aqueous solution or suspension. The totality of the components of the composition, apart from the active substance, forms the composition vehicle.

20 Examples of suitable isotonicizing agents are glycerol, glucose, mannitol, NaCl, calcium or magnesium compounds such as, for example, CaCl_2 or MgCl_2 .

Examples of suitable preservatives are phenol, m-cresol, benzyl alcohol and/or p-hydroxybenzoic esters.

25 Examples of buffer substances which can be used, especially for adjusting the pH between about 5.0 and 8.5, are sodium acetate, sodium citrate and sodium phosphate. Otherwise, physiologically acceptable dilute acids (typically HCl) or alkalis (typically NaOH) are also
30 suitable for adjusting the pH.

It is also possible, for the purpose of altering the profile of action of the pharmaceuticals according to the

invention, to admix modified (cf. EP-B- 132 769 and EP-B 132 770) and/or unmodified insulins, preferably bovine, porcine or human insulin, especially human insulin.

- 5 The pharmaceutical is prepared by converting the phosphoinositol-glycan-peptide and/or at least one of the physiologically tolerated salts thereof, where appropriate together with modified and/or unmodified insulin or derivatives thereof, with a physiologically acceptable
10 vehicle and, where appropriate, with suitable additives and ancillary substances into a suitable dosage form.

The invention is now explained in more detail by the following examples.

Example 1

- 15 Fermentation of *Saccharomyces cerevisiae* DSM 6649

Saccharomyces cerevisiae DSM is cultivated aerobically in a fermenter. The medium contains the following components in one liter of water:

	Yeast extract	3 g
20	Glucose	1 g
	KH ₂ PO ₄	1 g
	NH ₄ Cl	1 g
	CaCl ₂ · 2H ₂ O	0.5 g
	NaCl	0.5 g
25	MgSO ₄ · H ₂ O	0.6 g
	FeCl ₃	0.3 ml of a 1% aqueous solution
	Lactic acid	22 ml of a 90% solution.

- The pH is adjusted to 5.5 with KOH. Aeration is carried
30 out with 1 l of air per l of fermenter volume. The cells are cultured until the cell density is 1×10^7 cells/ml of culture solution; yield about 3 g wet weight per l of

culture solution. The cells are harvested by centrifugation ($3,000 \times g$, 5 min) and washed with phosphate buffer, pH 6.

Example 2

5 Isolation of cAMP-binding protein

The cells from Example 2 are converted enzymatically (zymolase, 2,000, Seikagaku Kogyo, Tokyo) into spheroplasts, comminuted with a glass homogenizer (Arthur H. Thomas and Co.) at 0°C . The following isolation steps
10 take place in the presence of protease inhibitors (phenylmethanesulfonyl fluoride (PMSF), leupeptin, aprotinin, α_2 -macroglobulin, trypsin inhibitor; Boehringer Mannheim). The cell lysate is centrifuged ($1,000 \times g$, 3 min, 4°C), the cell sediment is washed with SEM buffer
15 (0.25 M sucrose, 0.5 mM ethylenediaminetetraacetic acid (EDTA), 20 mM 3-[N-morpholino]propanesulfonic acid (MOPS)/KOH, pH 7.4) and again centrifuged. The supernatants are combined and centrifuged ($18,000 \times g$, 15 min, 4°C) in a $^{\circ}$ Percoll gradient (Pharmacia, Freiburg; 28%
20 Percoll, SEM buffer, 0.5 mg of protein/ml). Cytoplasm, plasma membrane, microsomes and mitochondria are separated from one another in this gradient. The plasma membranes float in the upper third of the gradient. They are removed from the gradient with a syringe, diluted
25 with 5 times the volume of SEM buffer and centrifuged ($48,000 \times g$, 30 min, 4°C). The sediment is suspended in MOPS buffer (5 mg of protein/ml) and incubated with N-[^3H]acetyl-concanavalin A (Amersham Buchler, Brunswick; 1 mg of protein with 55 μCi , in 500 μl of MOPS buffer
30 (Boehringer Mannheim), 20 mM, pH 7.4, 0.5 mM EDTA, 50 mM KCl, 5 mM CaCl_2 , 200 μg of bovine serum albumin; Behringwerke, Marburg) at 4°C in an ultrasonic bath for 60 minutes. The binding of concanavalin A serves as marker. The suspensions are pipetted onto a sucrose
35 gradient (15 to 28% sucrose in MOPS buffer) and centrifuged (25,000 revolutions per minute, 90 min, 4°C ,

Beckmann SW 27 rotor). The sucrose gradients are fractionated, and the radioactive fractions (about 23% sucrose) are combined, diluted 3-fold with a MOPS buffer (50 mM concanavalin A; Sigma Deisenhofen, 250 mM KCl) and
5 centrifuged ($200,000 \times g$, 60 min, 4°C, Beckmann TL-100 rotor). The sediment is washed with SEM buffer (250 mM KCl), centrifuged and resuspended in SEM buffer without KCl (2.5 mg of protein/ml).

About 500 μg of the plasma membrane proteins are solubilized in the buffer (25 mM MOPS/KOH, pH 7.0, 150 mM NaCl, 4 mM $MgCl_2$, 0.4 mM EGTA (ethylene glycol bis(β -aminoethyl ether)tetraacetic acid), 0.5 mM DTT (dithiothreitol), 0.5% deoxycholate, 0.1 mM IBMX (isobutylmethylxanthine), 0.1 mM PMSF, 50 μM leupeptin,
15 0.1 mM aprotinin (2 mg/ml). The solution is loaded onto a 2 ml N^6 -(2-aminoethyl)-cAMP-Sepharose column (Pharmacia, Freiburg), which has been equilibrated with the same buffer, at 4°C. The column is washed five times with 2 ml each time of buffer (25 mM MOPS/KOH, pH 7.2, 100 mM Na
20 citrate, 5 mM DTT, 5 mM $MgCl_2$, 150 mM NaCl, 250 mM sucrose, 7.5% ethylene glycol (Merck, Darmstadt), 10% glycerol, 1 mg/ml bovine serum albumin, 1 mM IBMX). Elution is carried out at 4°C with 2 ml of the same buffer which additionally contains 100 μM cAMP. The first
25 250 μl of the eluate are desalted by centrifugation of a 1 ml Sephadex G-25 column which was equilibrated with a buffer (25 mM MOPS/KOH, pH 7.0, 50 mM KCl, 5 mM $MgCl_2$, 10 mM DTT, 50 μM EDTA, 50 μM PMSF, 0.1% deoxycholate, 5% glycerol). The desalted material is incubated with the
30 same volume of 8% polyethylene glycol 4000 (Pharmacia, Freiburg) in buffer (10 mM MOPS/KOH, pH 7.2, 1 mM EDTA) at 4°C for 30 minutes. After centrifugation for 15 minutes, the sediment is dissolved in a buffer (20 mM MOPS/KOH, pH 7.2, 1 mM EDTA, 100 μM PMSF, 0.5% deoxy-
35 cholate) (2 mg of protein/ml).

Example 3

Preparation of phosphoglycan-peptides

a) Digestion with Pronase (*Streptomyces griseus*; Boehringer Mannheim): 100 μ g of cAMP-binding protein are
5 incubated with 450 μ g/ml Pronase in 1 ml of 0.1 M
4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid
(HEPES)/KOH (pH 8.0), 15 mM CaCl_2 , 1% Triton X-100
(Boehringer Mannheim) at 50°C for 10 hours. After addi-
tion of 1% SDS (sodium dodecyl sulfate), the incubation
10 is continued with a second aliquot of Pronase at 50°C for
7 h. Automated Edmann degradation shows that Pronase
degradation results in phosphoinositol glycan with amide-
like linkage of asparagine to the amino end of the
ethanolamine. This phosphoinositol-glycan-peptide is
15 called PIG-N hereinafter.

b) Digestion with endoproteinase Glu-C, EC 3.4.21.19,
(V8 protease) (*Staphylococcus aureus*; Boehringer
Mannheim): 100 μ g cAMP-binding protein are incubated with
300 μ g of V8 protease in 1 ml of 20 mM $(\text{NH}_4)_2\text{CO}_3$ (pH 7.8),
20 0.5% octyl glucoside (Boehringer Mannheim) at 37°C for
18 hours.

Automated Edmann degradation shows that the V8 protease
digestion results in phosphoinositol glycan with the
peptide Asn-Cys-Tyr. The amino acid aspartic acid is
25 bonded by the carboxyl terminus to the phosphoinositol
glycan. The compound of phosphoinositol glycan with the
tripeptide Asn-Cys-Tyr is called PIG-NCY hereinafter.

c) Digestion with endoprotease Lys-C (*Lysobacter*
enzymogenes; Boehringer Mannheim): 100 μ g of cAMP-binding
30 protein are incubated with 55 μ g of endoprotease Lys-C in
0.5 ml of 50 mM $(\text{NH}_4)_2\text{CO}_3$ (pH 8.2), 0.5% octyl glucoside
at 37°C for 18 hours.

Automated Edmann degradation shows that endoprotease Lys-C results in the phosphoinositol glycan with the peptide Asn-Cys-Try-Glu. The peptide is linked to the phosphoinositol glycan via the carboxyl end of asparagine. It is called PIG-NCYE hereinafter.

d) Removal of the carboxy-terminal amino acid: Pronase-digested cAMP-binding protein (see a) is subjected to a manual Edmann degradation. The resulting phosphoinositol glycan free of amino acids is called PIG hereinafter.

10 After the proteolytic cleavages, the proteases are removed by precipitation with 5% trichloroacetic acid (TCA). After centrifugation ($10,000 \times g$, 15 min), the phosphoinositol-glycan-peptide derivatives contained in the supernatant, as well as the phosphoinositol glycan
15 from the Edmann degradation, are concentrated and purified by binding to a phenyl-Sepharose column. After elution with 2% octylphenol ethylene glycol ether (TX-100) the phosphoinositol-glycan-peptide derivatives are purified by thin-layer chromatography with two
20 different solvent systems. After the first run in an acid system (chloroform/acetone/methanol/glacial acetic acid/water 10:4:2:2:1), the phosphoinositol-glycan-peptides near the application point on a silica gel plate (type 60) are eluted with methanol and subsequently
25 rechromatographed in a second run in a basic system (chloroform/methanol/ammonia/water 15:45:3.5:10). The phosphoinositol-glycan-peptide derivatives are again eluted from the plate ($R_f = 0.45$) and extracted with chloroform/methanol (2:1). The organic phase is washed
30 and evaporated and the material is suspended in phosphate buffer containing 0.5% TX-100.

e) The phosphoinositol glycans or phosphoinositol-glycan-peptides obtained in a) to d) are incubated with 10 units of phosphatidylinositol-specific phospholipase C, EC 3.1.1.5, (Bacillus cereus; Sigma, Deisenhofen) in
35

0.2 ml of 0.2 M potassium phosphate (pH 7.2), 2 mM DTT, 10 mM MgCl₂, 50 mM NaCl, 0.05% TX-100 at 37°C for 2 hours. After addition of 10 mM EDTA, the cleavage products are separated from one another by thin-layer chromatography in the basic solvent system (see d). Material in the direct vicinity of the application point is eluted from the plate and mixed with 2% poly(ethylene glycol)₈ mono-(octylphenyl ether) (TX-114). Phase separation is initiated by heating and centrifugation. The aqueous phase is concentrated in a Speedvac concentrator.

f) To standardize the phosphoglycan-peptides, the nitrogen of the free glucosamine in the material from process steps a) to d) is converted by permethylation into a radioactively labeled trimethylammonium cation. To do this, the sample is dried in vacuo, and 100 µl of dimethyl sulfoxide are added. After ultrasonic treatment (1 min), 10 mg of NaOH and 40 µl of methyl [¹²⁵I]iodide (0.2 µCi; NEN-Dupont, Dreieich) are added. Stirring at 25°C for 45 minutes is followed by removal of the solvent in a Speedvac and addition of 400 µl of H₂O. The sample is washed three times with chloroform and the chloroform extracts are washed three times with H₂O. The chloroform is evaporated under N₂. The permethylation is linear and quantitative over a wide concentration range. In the tests for an insulin-like action, equivalent volumes (equal dpm values) of phosphoinositol-glycan-peptides are employed (1-100 arbitrary units).

g) Incubation of the material obtained in a) to d) with nitrous acid leads to cleavage of the phosphoinositol glycan.

Example 4

Structural features of the phosphoinositol-glycan-peptides

a) Yeast cells are cultured as shown in Example 1 in the presence of radioactively labeled substrates (supplied by NEN-Dupont, Dreieich):

stearic acid

5 myo-inositol

ethanolamine

glucosamine or

mannose.

10 The complete plasma membrane fraction or the cAMP-binding protein purified by affinity chromatography (see Example 2) is subjected to an SDS polyacrylamide gel electrophoresis. Staining with Coomassie blue or autoradiography of the components shows that all the abovementioned radioactive components are incorporated into the
15 phosphoinositol-glycan-peptide.

b) The phosphoinositol-glycan-peptide obtainable as in Example 3 a) is further cleaved chemically and enzymatically. The cleavage products are analysed by thin-layer chromatography and measurement of the radioactivity
20 distribution ($[^3\text{H}]$ stearic acid and $[^{14}\text{C}]$ myo-inositol). The remaining radioactively labeled structure is eluted from the plate and subjected to the next cleavage reaction. Deamination with nitrous acid of the structure produced after Pronase digestion liberates phosphatidylinositol
25 (PI). The latter is converted by phospholipase D into phosphatidic acid or by phospholipase C into diacylglycerol. This involves loss of the myo-inositol label but the radioactive labeling by stearic acid is retained. The phosphatidic acid is subsequently converted by acetolysis
30 into diglyceride acetate. Finally, stearic acid is liberated by alkaline hydrolysis from the latter structure as well as from the diacylglycerol.

c) The structure obtained as in Example 3a) and 3e) is dried and treated with HF (60% in water, 0°C, 16 hours),
35 and the resulting oligosaccharides are hydrolysed with 2 M trifluoroacetic acid (100°C, 4 hours). The reaction

solution is subsequently dried, and the sugars which are present are reduced (1% NaBH₄, in 0.1 M ammonium hydroxide, 37°C, 1 hour) and finally acetylated (1:1 mixture of pyridine and acetic anhydride, 60°C, 1 hour).

- 5 The gas chromatography is carried out with a Packard gas chromatograph, model 428; column .00/120 Supelcoport (Supelco, Bellefonte, USA) at 60°C. The following qualitative composition emerged:

mannose, galactose, myo-inositol and glucosamine.

- 10 d) The structure obtained as in Example 3a) and 3e) was hydrolysed as in c) with HF (60% in water) and 4 M HCl at 100°C for 16 hours. Separation in an amino-acid analyzer (Biotronic, LC 6001) revealed the following components:

aspartic acid, NH₃, ethanolamine and glucosamine.

- 15 In view of the hydrolysis conditions, the ratio of aspartic acid and NH₃, and the results in Example 3a), the amino acid present in the native phosphoinositol-glycan-peptide is asparagine.

Example 5

- 20 The biological activity of the phosphoinositol-glycan-peptides (PGP) according to the invention is determined using adipocytes and pieces of diaphragm isolated by dissection from the rat.

- The term "PIG" means phosphoinositol glycan without peptide, obtained as in Example 3d) and 3e); "PIG-N" means phosphoinositol glycan with asparagine, obtained as in Example 3a) and 3e); "PIG-NCY" means phosphoinositol glycan with the peptide Asn-Cys-Tyr, obtained as in Example 3b) and 3e); "PIG-NCYE" means phosphoinositol glycan with the peptide Asn-Cys-Tyr-Glu, obtained as in Example 3c) and 3e); "PIG-NCY (na)" means material obtained as in Example 3b) and 3e) which has been cleaved

with nitrous acid (see Example 3g). The term "basal" stands for activity without stimulation, insulin stands for human insulin and dpm stands for radioactive disintegrations per minute.

- 5 The preparation of adipocytes from the rat was carried out as follows:

Adipose tissue from the epididymis (Wistar rat, 160-180 g, no feed restriction) is digested with collagenase, and the resulting isolated adipocytes are
10 washed several times by flotation.

Preparation of pieces of diaphragm from the rat:

Small pieces of tissue (5 mm diameter) were punched out of hemidiaphragms (Wistar rat, 60-70 g, no feed restriction) washed several times.

- 15 To inactivate the insulin receptor in rat adipocytes, the cells are treated with 10 to 40 μ g/ml trypsin. After addition of protease inhibitors, the cells are washed twice by flotation, and incubation is continued at 37°C for 15 min. These cells are then used for the test of
20 stimulation of lipogenesis by the phosphoinositol-glycan-peptides. A control incubation with insulin shows that the trypsin-treated cells display only very little lipogenesis which can be stimulated by insulin, and thus only a very limited number of functional insulin
25 receptors.

To inactivate the insulin receptor in rat diaphragm, the pieces of tissue are incubated in KRH buffer (0.1 mM glucose in the presence of 50 μ g/ml tetradecanoylphorbol acetate) at 25°C, passing O₂ through continuously, for
30 90 min. The pieces of tissue are subsequently washed twice with KRH buffer and used for the relevant tests.

The experimental results obtained in the following experiments with tissue or cells in which the insulin

receptor has been inactivated are indicated in parentheses in each case. In none of the following tests did PIG-NCYE show an effect.

a) Glycogenesis

- 5 This test determines the glycogen synthesis which can be stimulated by insulin in myocytes and which embraces glucose transport through the plasma membrane and the conversion of the glucose into glycogen including the functional insulin signal transmission cascade.
- 10 Pieces of diaphragm are incubated with 50 μ M D-[U- 14 C] glucose in KRH buffer in the presence or absence of insulin and PGP at 37°C for 15 min. The medium is removed by aspiration and then the pieces of tissue are thoroughly washed, frozen at -70°C and subsequently
- 15 homogenized in a Polytron homogenizer at 2°C. The homogenate is centrifuged (2,000 g) and the supernatant is pipetted onto filter paper. To determine the glycogen formed, the filters are transferred into TCA (5%), washed with ethanol and acetone and dried. and their radio-
- 20 activity is determined by scintillation measurement ([14 C]glycogen [dpm*10⁻³]). The units for the phosphoinositol-glycan-peptides are arbitrary units defined as in Example 3 f).

Table 1 shows the results:

Table 1: Glycogenesis [dpm·10⁻³]

	Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
5						
	10 nM	3.3(3.4)	8.4(4.1)			
10						
	1		3.2(3.1)			
	5		3.6(3.5)			
	25		4.4(3.9)			
	100					
15						
	1			3.0(2.5)		
	10			4.2(3.8)		
	100			6.7(7.2)		
20						
	1				3.2(2.7)	
	5				4.8(4.3)	
	25				6.5(5.8)	
	100				8.0(7.1)	
25						
	1					3.0(2.5)
	10					3.2(2.9)
	100					3.6(3.4)

b) Glycogen synthesis

The test determines the conversion, which can be stimulated by insulin, of activated glucose (UDP-glucose) into glycogen (glycogen synthase activity) including a functional insulin signal transmission cascade. Glucose transport and activation of glucose are avoided (which differs from the glycogen synthesis measurement, see a)).

Pieces of diaphragm are incubated with D-glucose (0.1 mM) in the presence or absence of insulin and PGP at 37°C for 30 min. A homogenate is prepared and centrifuged

(20,000 × g). The supernatant is incubated with U-[¹⁴C]UDP-glucose (0.3 mM) in the presence of either 0.1 mM or 10 mM glucose 6-phosphate at 37°C for 60 min. The mixtures are transferred to filter paper, and the filters are treated as above. The glycogen synthase activity is calculated as the fractional rate between the I form of the enzyme (independent of glucose 6-phosphate, dephosphorylated, corresponds to the amount of active enzyme in the homogenate) and the D form of the enzyme (dependent on glucose 6-phosphate, phosphorylated, corresponds to the total amount of activatable enzyme in the homogenate) ([¹⁴C]glycogen [dpm·10⁻³]).

Table 2 shows the results:

Table 2: Glycogen synthase [dpm·10⁻³]

	Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
10 nM	4.4(3.5)	10.1(6.0)				
1			3.9(3.5)			
5			4.8(3.8)			
25			5.7(4.5)			
100			6.7(6.0)			
1				3.9(3.5)		
10				5.7(5.0)		
100				7.6(6.2)		
1					3.8(3.4)	
5					5.7(5.1)	
25					7.2(6.4)	
100					8.8(8.1)	

		Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
5	1						3.2(3.0)
	10						4.0(3.5)
	100						4.5(4.0)

c) Lipogenesis

- 10 This test determines the conversion, which can be stimulated by insulin, of glucose into toluene-soluble products (triglycerides, phospholipids, fatty acids), which requires glucose transport and triglyceride (glycerol 3-P synthesis, esterification)/phospholipid/-
15 fatty acid synthesis including the insulin signal transmission cascade.

Rat adipocytes are incubated in KRH buffer with D-[3-³H]glucose (0.2 mM or 1 mM final concentration) in the presence or absence of insulin and PGP at 37°C for
20 90 min. The cells are disrupted by adding a toluene-soluble scintillation cocktail, and the lipids are separated from water-soluble products and the incubation medium. After phase separation, the radioactivity incorporated in lipids is determined by scintillation measurement directly without removing the aqueous phase
25 ([³H]lipid [dpm*10⁻³]).

Table 3 shows the results:

Table 3: Lipogenesis [dpm*10⁻³]

	Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
5						
	1.0(1.0)	11.2(1.9)				
10			1.0(0.9)			
			2.1(1.5)			
			3.1(3.0)			
			4.2(3.5)			
15				1.0(1.2)		
				3.5(3.3)		
				5.4(4.8)		
20					1.0(0.9)	
					3.5(3.0)	
					5.5(5.2)	
					6.8(5.9)	
25						1.0(0.9)
						1.0(1.5)
						2.1(2.5)

d) Intrinsic glucose transport activity

Isolated plasma membrane vesicles are obtained from rat adipocytes (see Example 5) by the adipocytes being washed
 30 twice in homogenization buffer (20 mM tris(hydroxy-
 methyl)aminomethane (Tris)/HCl, pH 7.4, 1 mM EDTA, 0.25 M
 sucrose) and then homogenized in 20 ml of the same buffer
 at 4°C (glass homogenizer with Teflon pestle).

The homogenate is centrifuged (16,000 × g, 15 min), and
 35 the sediment is suspended in the same buffer and cen-
 trifuged again. The sediment is suspended in 5 ml of

homogenization buffer and layered onto a sucrose cushion (1.12 M sucrose, 20 mM Tris/HCl, pH 7.4, 1 mM EDTA) and, after centrifugation (100,000 × g, 70 min), the inter-phase with the plasma membrane vesicles is removed with a syringe, diluted with 45 ml of buffer and centrifuged again (48,000 × g, 45 min). The sediment is suspended in 10 ml of buffer, centrifuged again, and suspended again in 3 ml of buffer.

Isolated plasma membrane vesicles are incubated in the presence or absence of insulin/PGP at 25°C for 30 min. The vesicles are subsequently incubated with 50 μM D-[3-³H]-glucose and L-[1-¹⁴C]glucose of the same specific radioactivity at 25°C for 90 sec. The mixtures are rapidly filtered off through nitrocellulose filters with suction. The filters are thoroughly washed and dried. Their radioactivity is determined by liquid scintillation measurement. The specific transport (D-[³H]glucose/-L-¹⁴C]glucose [dpm*10⁻³]) is calculated as the difference between the [³H] radioactivity and [¹⁴C] radioactivity.

Table 4 shows the results:

Table 4: Intrinsic glucose transport:

	Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
10 nM	2.4(2.6)	2.5(2.3)				
1			2.3(2.5)			
5			2.9(2.7)			
25			2.7(2.7)			
100			2.9(3.3)			

	Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
5				2.7(2.6) 3.5(3.7) 4.0(3.8)		
10					2.3(2.7) 3.5(3.7) 4.7(4.6) 6.9(5.8)	
15						2.5(2.3) 2.6(2.7) 2.7(3.0)

e) Protein synthesis

The stimulation of protein synthesis differs from the metabolic effects of insulin measured in the previous determinations in that it belongs to the long-term actions of insulin (as growth hormone). The assay includes the insulin signal cascade.

Rat adipocytes are incubated in primary culture in Dulbecco's modified essential medium (DMEM) deplete in leucine with 50 μ M L-[³H]-leucine in the presence of insulin and PGP at 37°C for 4 hours. The cells are separated from the surrounding medium by the oil centrifugation technique and mixed with water-compatible scintillation cocktail. After centrifugation, the protein precipitate is washed with acetone, suspended in 1% SDS and mixed with scintillation cocktail. The cell-associated radioactivity, determined by scintillation measurement, serves as a measure of the protein synthesis and the amino-acid transport through the plasma membrane ([³H]leucine [dpm*10⁻⁴]).

Table 5 shows the results:

Table 5: Protein synthesis

		Basal	Insulin	PIG	PIG-N	PIG-NCY	PIG-NCY (na)
5							
	10 nM	3.5(3.4)	10.1(4.0)				
10	1 5 25 100			3.5(3.3) 3.55(3.5) 4.0(3.5) 3.8(3.3)			
15	1 10 100				3.4(3.3) 4.1(3.2) 5.3(4.2)		
20	1 5 25 100					3.8(3.7) 4.4(4.2) 5.1(5.0) 6.9(5.8)	
25	1 10 100						3.7(3.5) 3.8(3.7) 4.1(3.8)

Patent claims

1. A phosphoinositol-glycan-peptide obtainable by cleavage of adenosine 3',5'-cyclic monophosphate-binding protein and/or the physiologically tolerated salts thereof.
5
2. A phosphoinositol-glycan-peptide as claimed in claim 1, which contains phosphoinositol glycan, ethanolamine, tripeptide and/or physiologically tolerated salts of phosphoinositol-glycan-peptide, and has an insulin-like action.
10
3. A phosphoinositol-glycan-peptide as claimed in claim 1 or 2, which contains at least one glucosamine, galactose, mannose, myo-inositol, phosphoric acid, ethanolamine residue and the peptide residue with the sequence Asn-Cys-Tyr, and has an insulin-like action.
15
4. A phosphoinositol-glycan-peptide as claimed in one or more of claims 1 to 3, which contains at least phosphoinositol glycan or phosphoinositol glycan and asparagine as peptide residue, and has an insulin-like action.
20
5. A process for the preparation of the phosphoinositol-glycan-peptide as claimed in one or more of claims 1 to 4, which comprises
25
 - a) using organisms which contain adenosine 3',5'-cyclic monophosphate binding protein,
 - b) isolating the adenosine 3',5'-cyclic monophosphate-binding protein,
 - c) eliminating the protein portion from adenosine 30 3',5'-cyclic monophosphate-binding protein, and purifying the resulting glycosylphosphatidylinositol-peptide where appropriate,

- d) eliminating a mono- or diacylglycerol from the product obtained in process step c) and
- e) isolating the phosphoinositol-glycan-peptide produced in process step d), and converting into
5 corresponding physiologically tolerated salts where appropriate.
6. The process as claimed in claim 5, wherein yeast cells are used, and the protein portion is eliminated enzymatically.
- 10 7. The process as claimed in claim 5 or 6, wherein the sequence of process steps c) and d) is reversed.
8. The process as claimed in one or more of claims 5 to 7, wherein *Saccharomyces cerevisiae* DSM 6649, endo-proteinase Glu-C, EC 3.4.21.19 and/or phospholipase C, EC 3.1.1.5, is used.
15
9. A pharmaceutical which has an effective content of phosphoinositol-glycan-peptide as claimed in one or more of claims 1 to 4.
10. A pharmaceutical as claimed in claim 9, which
20 contains an insulin, preferably bovine, porcine or human insulin.
11. A process for the preparation of a pharmaceutical as claimed in claim 9 or 10, which comprises converting at least one phosphoinositol-glycan-peptide as
25 claimed in one or more of claims 1 to 4 with a physiologically acceptable vehicle and, where appropriate, suitable additives, active substances and/or ancillary substances into a suitable dosage form.
- 30 12. The use of phosphoinositol-glycan-peptide as claimed in one or more of claims 1 to 7 for preparing a

pharmaceutical for the treatment of diabetes mellitus or non-insulin-dependent diabetes.