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(54) Titre : AGONISTES PEPTIDIQUES SELECTIFS DU RECEPTEUR VPAC2
(54) Title: SELECTIVE VPAC2 RECEPTOR PEPTIDE AGONISTS

(57) Abrégé/Abstract:
The present invention encompasses peptides that selectively activate the VPAC2 receptor and are useful in the treatment of diabetes.

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(54) Title: SELECTIVE VPAC2 RECEPTOR PEPTIDE AGONISTS

(57) Abstract: The present invention encompasses peptides that selectively activate the VPAC2 receptor and are useful in the treatment of diabetes.

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SELECTIVE VPAC2 RECEPTOR PEPTIDE AGONISTS

The present invention relates to selective VPAC2 receptor peptide agonists.

In particular, the present invention relates to selective VPAC2 receptor peptide agonists which are covalently attached to one or more molecules of polyethylene glycol or a derivative thereof.

Type 2 diabetes, or non-insulin dependent diabetes mellitus (NIDDM), is the most common form of diabetes, affecting 90% of people with diabetes. With NIDDM, patients have impaired β-cell function resulting in insufficient insulin production and/or decreased insulin sensitivity. If NIDDM is not controlled, excess glucose accumulates in the blood, resulting in hyperglycemia. Over time, more serious complications may arise including renal dysfunction, cardiovascular problems, visual loss, lower limb ulceration, neuropathy, and ischemia. Treatments for NIDDM include improving diet, exercise, and weight control as well as using a variety of oral medications. Individuals with NIDDM can initially control their blood glucose levels by taking such oral medications. These medications, however, do not slow the progressive loss of β-cell function that occurs in NIDDM patients and, thus, are not sufficient to control blood glucose levels in the later stages of the disease. Also, treatment with currently available medications exposes NIDDM patients to potential side effects such as hypoglycemia, gastrointestinal problems, fluid retention, oedema, and/or weight gain.

Pituitary adenylate cyclase-activating peptide (PACAP) and vasoactive intestinal peptide (VIP) belong to the same family of peptides as secretin and glucagon. PACAP and VIP work through three G-protein-coupled receptors that exert their action through the cAMP-mediated and other Ca^{2+}-mediated signal transduction pathways. These receptors are known as the PACAP-preferring type 1 (PAC1) receptor (Isobe, *et al.*, *Regul. Pept.*, 110:213-217 (2003); Ogi, *et al.*, *Biochem. Biophys. Res. Commun.*, 196:1511-1521 (1993)) and the two VIP-shared type 2 receptors (VPAC1 and VPAC2) (Sherwood *et al.*, *Endocr. Rev.*, 21:619-670 (2000); Hammar *et al.*, *Pharmacol Rev*, 50:265-270 (1998); Couvineau, *et al.*, *J. Biol. Chem.*, 278:24759-24766 (2003); Sreedharan, *et al.*, *Biochem. Biophys. Res. Commun.*, 193:546-553 (1993); Lutz, *et al.*, *FEBS Lett.*, 458: 197-203 (1999); Adamou, *et al.*, *Biochem. Biophys. Res. Commun.*, 209:

385-392 (1995)). A series of PACAP analogues is disclosed in US 6,242,563 and WO 2000/05260.

PACAP has comparable activities towards all three receptors, whilst VIP selectively activates the two VPAC receptors (Tsutsumi *et al.*, *Diabetes*, 51:1453-1460 (2002)). Both VIP (Eriksson *et al.*, *Peptides*, 10: 481-484 (1989)) and PACAP (Filipsson *et al.*, *JCEM*, 82:3093-3098 (1997)) have been shown to not only stimulate insulin secretion in man when given intravenously but also increase glucagon secretion and hepatic glucose output. As a consequence, PACAP or VIP stimulation generally does not result in a net improvement of glycemia. Activation of multiple receptors by PACAP or VIP also has broad physiological effects on nervous, endocrine, cardiovascular, reproductive, muscular, and immune systems (Gozes *et al.*, *Curr. Med. Chem.*, 6:1019-1034 (1999)). It appears that VIP-induced watery diarrhoea in rats is mediated by only one of the VPAC receptors, VPAC1 (Ito *et al.*, *Peptides*, 22:1139-1151 (2001); Tsutsumi *et al.*, *Diabetes*, 51:1453-1460 (2002)). The VPAC1 and PAC1 receptors are expressed on α-cells and hepatocytes and, thus, are most likely involved in the effects on hepatic glucose output.

Exendin-4 is found in the salivary excretions from the Gila Monster, *Heloderma Suspectum*, (Eng *et al., J.Biol.Chem.*, 267(11):7402-7405 (1992)). It is a 39 amino acid peptide, which has glucose dependent insulin secretagogue activity. Particular PEGylated Exendin and Exendin agonist peptides are described in WO 2000/66629.

Recent studies have shown that peptides selective for the VPAC2 receptor are able to stimulate insulin secretion from the pancreas without gastrointestinal (GI) side effects and without enhancing glucagon release and hepatic glucose output (Tsutsumi *et al.*, *Diabetes*, 51:1453-1460 (2002)). Peptides selective for the VPAC2 receptor were initially identified by modifying VIP and/or PACAP. (See, for example, Xia *et al.*, *J Pharmacol Exp Ther.*, 281:629-633 (1997); Tsutsumi *et al.*, *Diabetes*, 51:1453-1460 (2002); WO 01/23420 and WO 2004/06839.)

Many of the VPAC2 receptor peptide agonists reported to date have, however, less than desirable potency, selectivity, and stability profiles, which could impede their clinical viability. In addition, many of these peptides are not suitable for commercial candidates as a result of stability issues associated with the polypeptides in formulation, as well as issues with the short half-life of these polypeptides *in vivo*. It has, furthermore,

been identified that some VPAC2 receptor peptide agonists are inactivated by dipeptidyl-peptidase (DPP-IV). A short serum half-life could hinder the use of these agonists as therapeutic agents. There is, therefore, a need for new therapies, which overcome the problems associated with current medications for NIDDM.

The present invention seeks to provide improved compounds that are selective for the VPAC2 receptor and which induce insulin secretion from the pancreas only in the presence of high blood glucose levels. The compounds of the present invention are peptides, which are believed to also improve beta cell function. These peptides can have the physiological effect of inducing insulin secretion without GI side effects or a corresponding increase in hepatic glucose output and also generally have enhanced selectivity, potency, and/or *in vivo* stability of the peptide compared to known VPAC2 receptor peptide agonists.

The present invention also seeks to provide selective VPAC2 receptor peptide agonists, which have reduced clearance and improved *in vivo* stability. It is desirable that the agonists of the present invention be administered a minimum number of times during a prolonged period of time.

According to a first aspect of the invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising a sequence selected from:

SEQ ID NO: 17 HSDAVFTEQY(OMe)TRAibRAibQLAAAibOrnY(OMe)LQSIK AibOrn;

SEQ ID NO: 18 HSDAVFTEK(CO$(CH_2)_2$SH)Y(OMe)TOrnLRAibQVAAAibOrn YLQSIOrnOrn;

SEQ ID NO: 19 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnK(W) Orn;

SEQ ID NO: 20 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(CO$(CH_2)_2$SH)YLQ SIOrnOrn;

SEQ ID NO: 21 HSDAVFTEQY(OMe)TOrnLRAibQVAAK(CO$(CH_2)_2$SH)OrnYLQ SIOrnOrn;

SEQ ID NO: 22 HSDAVFTEQY(OMe)TOrnLRAibQVCAAibOrnYLQSIOrnOrn;

SEQ ID NO: 23 HSDAVFTEQY(OMe)TOrnLRCQVAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 24 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 25 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYAibQSIOrnOrn;

SEQ ID NO: 26 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQAibIOrnOrn;

SEQ ID NO: 27 HSDAVFTEQY(OMe)TOrnLRAibQVAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 28 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQAibIOrnOrn;

SEQ ID NO: 29 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQAibIOrnOrn;

SEQ ID NO: 30 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQSIOrnOrn;

SEQ ID NO: 31 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrn;

SEQ ID NO: 32 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQAibIOrn Orn;

SEQ ID NO: 33 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQSIOrnOrn;

SEQ ID NO: 34 HSDAVFTEQY(OMe)TOrnLRK(W)QVAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 35 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLK(W)SIOrnOrn;

SEQ ID NO: 36 HSDAVFTEQY(OMe)TOrnLRAibQK(W)AAAibOrnYLQSIOrnOrn;

SEQ ID NO: 37 HSDAVFTEQY(OMe)TOrnLRK(CO$(CH_2)_2$SH)QVAAAibOrnYLQ SIOrnOrn;

SEQ ID NO: 38 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(W)YLQSIOrnOrn;

SEQ ID NO: 39 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibCYLQSIOrnOrn;

SEQ ID NO: 40 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 41 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSK(W)OrnOrn;

SEQ ID NO: 42 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnC Orn;

SEQ ID NO: 43 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibCOrn Orn;

SEQ ID NO: 44 HSDAVFTEQY(OMe)TOrnLRAibQCAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 45 HSDAVFTEQY(OMe)TOrnLRCQLAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 94 HSDAVFTEQY(OMe)TOrnLRAibQVK(CO$(CH_2)_2$SH)AAibOrn YLQSIOrnOrn;

SEQ ID NO: 95 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnCOrn;

SEQ ID NO: 96 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSCOrnOrn;

SEQ ID NO: 97 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrn K(CO$(CH_2)_2$SH)Orn;

SEQ ID NO: 98 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrn

K(CO(CH_2)$_2$SH)Orn;

SEQ ID NO: 99 HSDAVFTEQY(OMe)TOrnLRK(W)QLAAbuAibOrnYLQAibIOrn Orn;

SEQ ID NO: 100 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSIOrnOrnC;

SEQ ID NO: 101 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnC;

SEQ ID NO: 102 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrnC;

SEQ ID NO: 103 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQAibI OrnOrn;

SEQ ID NO: 104 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQAibI OrnCOrn;

SEQ ID NO: 105 HSDAVFTEQY(OMe)TOrnLRAibQCAAbuAibOrnY(OMe)LQAibI OrnOrn;

SEQ ID NO: 106 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrn OrnC;

SEQ ID NO: 107 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSI OrnOrn;

SEQ ID NO: 108 HSDAVFTEQY(OMe)TOrnLRAibQCAAbuAibOrnY(OMe)LQSI OrnOrn;

SEQ ID NO: 109 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSI OrnCOrn;

SEQ ID NO: 110 HSDAVFTEQY(OMe)TOrnLRAibQLAbuAAibOrnYLQSIOrnOrn;

SEQ ID NO: 111 HSDAVFTEQY(OMe)TOrnLRAibQK(CO(CH_2)$_2$SH)AAbu AibOrnYLQAibIOrnOrn;

and

SEQ ID NO: 112 HSDAVFTEQY(OMe)TOrnLRAibQK(W)AAbuAibOrnYLQ AibIOrnOrn;

and a C-terminal extension wherein the N-terminus of the C-terminal extension is linked to the C-terminus of the peptide sequence and wherein the C-terminal extension comprises and amino acid sequence of the formula:

Xaa_1-Xaa_2-Xaa_3-Xaa_4-Xaa_5-Xaa_6-Xaa_7-Xaa_8-Xaa_9-Xaa_{10}-Xaa_{11}-Xaa_{12}

Formula 3 (SEQ ID NO: 3)

wherein:

Xaa_1 is: Gly, Cys, or absent;

Xaa_2 is: Gly, Arg, or absent;

Xaa_3 is: Pro, Thr, or absent;

Xaa_4 is: Ser, or absent;

Xaa_5 is: Ser, or absent;

Xaa_6 is: Gly, or absent;

Xaa_7 is: Ala, or absent;

Xaa_8 is: Pro, or absent;

Xaa_9 is: Pro, or absent;

Xaa_{10} is: Pro, or absent;

Xaa_{11} is: Ser, Cys, or absent; and

Xaa_{12} is: Cys, or absent;

wherein at least five of Xaa_1 to Xaa_{12} of the C-terminal extension are present, and wherein if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, or Xaa_{11} is absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated,

and wherein;

the peptide agonist comprises at least one Cys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one Lys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one K(W) which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one $K(CO(CH_2)_2SH)$ which is covalently attached to a PEG molecule, or

the carboxy-terminal amino acid of the peptide agonist is covalently attached to a PEG molecule, or

a combination thereof.

Preferably, at least six of Xaa_1 to Xaa_{12} of the C-terminal extension of Formula 3 is present. More preferably, at least seven, eight, nine, ten, eleven, or all of Xaa_1 to Xaa_{12} of the C-terminal extension are present.

More preferably, the C-terminal extension of the PEGylated VPAC2 receptor peptide agonist is selected from:

SEQ ID NO: 5	GGPSSGAPPPS
SEQ ID NO: 6	GGPSSGAPPPS-NH_2
SEQ ID NO: 7	GGPSSGAPPPC
SEQ ID NO: 8	GGPSSGAPPPC-NH_2
SEQ ID NO: 9	GRPSSGAPPPS
SEQ ID NO: 10	GRPSSGAPPPS-NH_2
SEQ ID NO: 11	GGPSSGAPPPCC
SEQ ID NO: 12	GGPSSGAPPPCC-NH_2

Even more preferably, the C-terminal extension of the PEGylated VPAC2 receptor peptide agonist is SEQ ID NO: 11 or SEQ ID NO: 12.

A PEG molecule(s) may be covalently attached to any Lys, Cys, K(W) or K($CO(CH_2)_2SH$) residues at any position in the VPAC2 receptor peptide agonist according to the first aspect of the present invention.

Where the PEGylated VPAC2 receptor peptide agonist comprises a sequence selected from SEQ ID NO: 22, 23, 39, 42, 43, 44, 45, 95, 96, 100, 101, 102, 104, 105, 106, 108 and 109, it is preferred that the cysteine residue is PEGylated.

Where the PEGylated VPAC2 receptor peptide agonist comprises a sequence selected from SEQ ID NO: 19, 34, 35, 36, 38, 41, 99 and 112, it is preferred that the K(W) residue is PEGylated.

Where the PEGylated VPAC2 receptor peptide agonist comprises a sequence selected from SEQ ID NO: 18, 20, 21, 37, 94, 97, 98 and 111, it is preferred that the K($CO(CH_2)_2SH$) residue is PEGylated.

Where the PEGylated VPAC2 receptor peptide agonist comprises a C-terminal extension, the PEG molecule(s) may be covalently attached to one or more Cys residues in said C-terminal extension. Where the sequence selected from SEQ ID NO: 17 to 45 and 94 to 112 comprises one or more Lys, Cys, K(W), or K($CO(CH_2)_2SH$) residues and the C-terminal extension comprises one or more Cys residues, there may be one or more PEGylated residues in either or both sequences.

Preferably, there is at least one PEG molecule covalently attached to a residue in the C-terminal extension of the VPAC2 receptor peptide agonist.

Where there is more than one PEG molecule, there may be a combination of Lys, Cys, K($CO(CH_2)_2SH$), K(W) and carboxy-terminal amino acid PEGylation. For example, if there are two PEG molecules, one may be attached to a Lys residue and one may be attached to a Cys residue.

Preferably, the PEG molecule is branched. Alternatively, the PEG molecule may be linear.

Preferably, the PEG molecule is between 1,000 daltons and 100,000 daltons in molecular weight. More preferably, the PEG molecule is selected from 10,000, 20,000, 30,000, 40,000, 50,000 and 60,000 daltons. Even more preferably, it is selected from 20,000, 30,000, 40,000, or 60,000 daltons. Where there are two PEG molecules covalently attached to the peptide agonist of the present invention, each is 1,000 to 40,000 daltons and preferably, they have molecular weights of 20,000 and 20,000 daltons, 10,000 and 30,000 daltons, 30,000 and 30,000 daltons, or 20,000 and 40,000 daltons.

The PEGylated VPAC2 receptor peptide agonist sequence may further comprise a histidine residue at the N-terminus of the peptide before Xaa_1.

Preferably, the PEGylated VPAC2 receptor peptide agonist according to the first aspect of the present invention further comprises a N-terminal modification at the N-terminus of the peptide agonist wherein the N-terminal modification is selected from:

(a) addition of D-histidine, isoleucine, methionine, or norleucine;

(b) addition of a peptide comprising the sequence Ser-Trp-Cys-Glu-Pro-Gly-Trp-Cys-Arg (SEQ ID NO: 93) wherein the Arg is linked to the N-terminus of the peptide agonist;

(c) addition of C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3;

(d) addition of –$C(O)R^1$ wherein R^1 is a C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen, -SH and -CF_3; an aryl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; an aryl C_1-C_4 alkyl optionally substituted with one or more substituents independently selected from

C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; -NR^2R^3 wherein R^2 and R^3 are independently hydrogen, C_1-C_6 alkyl, aryl or aryl C_1-C_4 alkyl; -OR^4 wherein R^4 is C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3, aryl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3, or aryl C_1-C_4 alkyl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; or 5-pyrrolidin-2-one;

(e) addition of –SO_2R^5 wherein R^5 is aryl, aryl C_1-C_4 alkyl or C_1-C_{16} alkyl;

(f) formation of a succinimide group optionally substituted with C_1-C_6 alkyl or –SR^6, wherein R^6 is hydrogen or C_1-C_6 alkyl;

(g) addition of methionine sulfoxide;

(h) addition of biotinyl-6-aminohexanoic acid (6-aminocaproic acid); and

(i) addition of –C(=NH)-NH_2.

Preferably, the N-terminal modification is the addition of a group selected from: acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid (6-aminocaproic acid), and –C(=NH)-NH_2. It is especially preferred that the N-terminal modification is the addition of acetyl or hexanoyl.

It will be appreciated by the person skilled in the art that PEGylated VPAC2 receptor peptide agonists comprising various combinations of peptide sequence selected from SEQ ID NO: 17 to 45 and 94 to 112, C-terminal extensions and N-terminal modifications as described herein, may be made based on the above disclosure.

It is preferred that the PEGylated VPAC2 receptor peptide agonist according to the first aspect of the present invention comprises an amino acid sequence selected from:

Agonist #	**SEQ ID NO**	**Sequence**
P410	46	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(W-PEG40K)YLQSIOrnOrnGGPSSGAPPPS-NH_2

P417	47	C6-HSDAVFTEQY(OMe)TRAibRAibQLAAAibOrnY(OMe)LQSIKAibOrnGGPSSGAPPPC(PEG40K)-NH_2
P451	48	C6-HSDAVFTEK(CO$(CH_2)_2$SPEG40K)Y(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P454	49	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnK(WPEG40K)OrnGGPSSGAPPPS-NH_2
P460	50	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibC(PEG40K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P472	51	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(CO$(CH_2)_2$SPEG40K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P473	52	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(CO$(CH_2)_2$SPEG20K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P475	53	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAK(CO$(CH_2)_2$SPEG40K)OrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P478	54	C6-HSDAVFTEQY(OMe)TOrnLRAibQVC(PEG40K)AAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P483	55	C6-HSDAVFTEQY(OMe)TOrnLRC(PEG40K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P485	56	C6-HSDAVFTEQY(OMe)TOrnLRK(CO$(CH_2)_2$SPEG40K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P507	57	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG40K)-NH_2
P509	58	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG40K)-NH_2
P511	59	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG40K)-NH_2
P513	60	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P515	61	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2

P517	62	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P519	63	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P521	64	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P523	65	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P525	66	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P529	67	C6-HSDAVFTEQY(OMe)TOrnLRK(WPEG40K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P531	68	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLK(WPEG40K)SIOrnOrnGGPSSGAPPPS-NH_2
P533	69	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(WPEG40K)AAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P535	70	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSK(WPEG40K)OrnOrnGGPSSGAPPPS-NH_2
P537	71	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P541	72	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibC(PEG40K)OrnOrnGGPSSGAPPPS-NH_2
P545	73	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG40K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P547	74	C6-HSDAVFTEQY(OMe)TOrnLRC(PEG40K)QLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P480	113	C6-HSDAVFTEQY(OMe)TOrnLRAibQVK(CO$(CH_2)_2$SPEG40K)AAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P481	114	C6-HSDAVFTEQY(OMe)TOrnLRAibQVK(CO$(CH_2)_2$SPEG20K)AAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P539	115	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P543	116	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSC(PEG40K)OrnOrnGGPSSGAPPPS-NH_2

P549	117	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYL QAibIOrnK(CO(CH_2)$_2$SPEG20K)OrnGGPSSGAPPPC(PEG20 K)-NH_2
P551	118	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYL QSIOrnK(CO(CH_2)$_2$SPEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P555	119	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSI OrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P557	120	C6-HSDAVFTEQY(OMe)TOrnLRK(WPEG40K)QLAAbuAib OrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P560	121	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSIOrn OrnC(PEG40K)GGPSSGAPPPS-NH_2
P562	122	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrn OrnC(PEG20K)GGPSSGAPPPC(PEG20K)-NH_2
P564	123	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibI OrnOrnC(PEG40K)GGPSSGAPPPS-NH_2
P566	124	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSI OrnOrnC(PEG40K)GGPSSGAPPPS-NH_2
P572	125	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSI OrnOrnC(PEG20K)GGPSSGAPPPC(PEG20K)-NH_2
P574	126	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)L QAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P576	127	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)L QAibIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P578	128	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG40K)AAbuAib OrnY(OMe)LQAibIOrnOrnGGPSSGAPPPS-NH_2
P580	129	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibI OrnOrnC(PEG20K)GGPSSGAPPPC(PEG20K)-NH_2
P582	130	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)L QSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P584	131	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)L QSIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P586	132	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG40K)AAbuAib OrnY(OMe)LQSIOrnOrnGGPSSGAPPPS-NH_2

P588	133	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSIOrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P590	134	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAbuAAibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P597	135	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(CO$(CH_2)_2$SPEG20K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)-NH_2
P599	136	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(CO$(CH_2)_2$SPEG40K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P601	137	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(WPEG40K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P469	139	C6-HSDAVFTEK(CO$(CH_2)_2$SPEG20K)Y(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P486	140	C6-HSDAVFTEQY(OMe)TOrnLRK(CO$(CH_2)_2$SPEG20K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P553	141	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P570	144	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG30K)C(PEG30K)-NH_2
P595	146	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG20K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)-NH_2
P476	147	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAK(CO$(CH_2)_2$SPEG20K)OrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P602	148	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG30K)C(PEG30K)-NH_2

It is more preferred that the PEGylated VPAC2 receptor peptide agonist according to the first aspect of the present invention comprises an amino acid sequence selected from: SEQ ID NO: 47, 64, 66, 115, 119, 122, 126, 130 and 144.

According to a second aspect of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising an amino acid sequence selected from:

Agonist #	SEQ ID NO	Sequence
P470	75	C6-HSDAVFTEQY(OMe)TOrnK(CO(CH$_2$)$_2$SPEG20K)RAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH$_2$
P490	76	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLK(CO(CH$_2$)$_2$SPEG20K)SIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P492	77	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAK(CO(CH$_2$)$_2$SPEG20K)AibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P495	78	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQK(CO(CH$_2$)$_2$SPEG20K)IOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P497	79	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSK(CO(CH$_2$)$_2$SPEG20K)OrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P499	80	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnK(CO(CH$_2$)$_2$SPEG20K)OrnGGPSSGAPPPC(PEG20K)-NH$_2$
P501	81	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLC(PEG20K)SIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P503	82	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSC(PEG20K)OrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P505	83	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH$_2$
P402	138	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPK(W-PEG40K)-NH$_2$
P558	142	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG20K)AAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH$_2$
P568	143	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG20K)AAAibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P593	145	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQAibIOrnOrnGGPSSGAPPPK(WPEG40K)-NH$_2$

It is more preferred that the PEGylated VPAC2 receptor peptide agonist according to the second aspect of the present invention comprises the amino acid sequence SEQ ID NO: 80 or SEQ ID NO: 83.

According to a third aspect of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising an amino acid sequence of the formula:

Xaa_1-Xaa_2-Xaa_3-Xaa_4-Xaa_5-Xaa_6-Thr-Xaa_8-Xaa_9-Xaa_{10}-Thr-Xaa_{12}-Xaa_{13}- Xaa_{14}-Xaa_{15}-Xaa_{16}-Xaa_{17}-Xaa_{18} -Abu-Xaa_{20}-Xaa_{21}-Xaa_{22}- Xaa_{23}-Xaa_{24}-Xaa_{25}-Xaa_{26}-Xaa_{27}-Xaa_{28}-Xaa_{29}-Xaa_{30}-Xaa_{31}-Xaa_{32}-Xaa_{33}-Xaa_{34}-Xaa_{35}-Xaa_{36}-Xaa_{37}-Xaa_{38}-Xaa_{39}-Xaa_{40}

Formula 4 (SEQ ID NO: 4)

wherein:

Xaa_1 is: His, dH, or is absent;

Xaa_2 is: dA, Ser, Val, Gly, Thr, Leu, dS, Pro, or Aib;

Xaa_3 is: Asp or Glu;

Xaa_4 is: Ala, Ile, Tyr, Phe, Val, Thr, Leu, Trp, Gly, dA, Aib, or NMeA;

Xaa_5 is: Val, Leu, Phe, Ile, Thr, Trp, Tyr, dV, Aib, or NMeV;

Xaa_6 is: Phe, Ile, Leu, Thr, Val, Trp, or Tyr;

Xaa_8 is: Asp, Glu, Ala, Lys, Leu, Arg, or Tyr;

Xaa_9 is: Asn, Gln, Asp, Glu, Ser, Cys, Lys, or $K(CO(CH_2)_2SH)$;

Xaa_{10} is: Tyr, Trp, Tyr(OMe), Ser, Cys, or Lys;

Xaa_{12} is: Arg, Lys, Glu, hR, Orn, Lys (isopropyl), Aib, Cit, Ala, Leu, Gln, Phe, Ser, or Cys;

Xaa_{13} is: Leu, Phe, Glu, Ala, Aib, Ser, Cys, Lys, or $K(CO(CH_2)_2SH)$;

Xaa_{14} is: Arg, Leu, Lys, Ala, hR, Orn, Lys (isopropyl), Phe, Gln, Aib, Cit, Ser, or Cys;

Xaa_{15} is: Lys, Ala, Arg, Glu, Leu, hR, Orn, Lys (isopropyl), Phe, Gln, Aib, K(Ac), Cit, Ser, Cys, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{16} is: Gln, Lys, Glu, Ala, hR, Orn, Lys (isopropyl), Cit, Ser, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{17} is: Val, Ala, Leu, Ile, Met, Nle, Lys, Aib, Ser, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{18} is: Ala, Ser, Cys, Lys, $K(CO(CH_2)_2SH)$, K(W), Abu, or Nle;

Xaa_{20} is: Lys, Gln, hR, Arg, Ser, His, Orn, Lys (isopropyl), Ala, Aib, Trp, Thr, Leu, Ile, Phe, Tyr, Val, K(Ac), Cit, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{21} is: Lys, His, Arg, Ala, Phe, Aib, Leu, Gln, Orn, hR, K(Ac), Cit, Ser, Cys, Val, Tyr, Ile, Thr, Trp, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{22} is: Tyr, Trp, Phe, Thr, Leu, Ile, Val, Tyr(OMe), Ala, Aib, Ser, Cys, Lys, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{23} is: Leu, Phe, Ile, Ala, Trp, Thr, Val, Aib, Ser, Cys, Lys, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{24} is: Gln, Glu, Asn, Ser, Cys, Lys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{25} is: Ser, Asp, Phe, Ile, Leu, Thr, Val, Trp, Gln, Asn, Tyr, Aib, Glu, Cys, Lys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{26} is: Ile, Leu, Thr, Val, Trp, Tyr, Phe, Aib, Ser, Cys, Lys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{27} is: Lys, hR, Arg, Gln, Ala, Asp, Glu, Phe, Gly, His, Ile, Met, Asn, Pro, Ser, Thr, Val, Trp, Tyr, Lys (isopropyl), Cys, Leu, Orn, dK, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{28} is: Asn, Asp, Gln, Lys, Arg, Aib, Orn, hR, Cit, Pro, dK, Ser, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{29} is: Lys, Ser, Arg, Asn, hR, Ala, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Pro, Gln, Thr, Val, Trp, Tyr, Cys, Orn, Cit, Aib, K(W), $K(CO(CH_2)_2SH)$, or is absent;

Xaa_{30} is: Arg, Lys, Ile, Ala, Asp, Glu, Phe, Gly, His, Leu, Met, Asn, Pro, Gln, Ser, Thr, Val, Trp, Tyr, Cys, hR, Cit, Aib, Orn, K(W), $K(CO(CH_2)_2SH)$, or is absent;

Xaa_{31} is: Tyr, His, Phe, Thr, Cys, Ser, Lys, Gln, K(W), $K(CO(CH_2)_2SH)$, or is absent;

Xaa_{32} is: Ser, Cys, Lys, or is absent;

Xaa_{33} is: Trp or is absent;

Xaa_{34} is: Cys or is absent;

Xaa_{35} is: Glu or is absent;

Xaa_{36} is: Pro or is absent;

Xaa_{37} is: Gly or is absent;

Xaa_{38} is: Trp or is absent;

Xaa_{39} is: Cys or is absent; and

Xaa_{40} is: Arg or is absent

wherein if Xaa_{29}, Xaa_{30}, Xaa_{31}, Xaa_{32}, Xaa_{33}, Xaa_{34}, Xaa_{35}, Xaa_{36}, Xaa_{37}, Xaa_{38}, or Xaa_{39} is absent, the next amino acid present downstream is the next amino acid in the peptide agonist sequence,

and a C-terminal extension wherein the N-terminus of the C-terminal extension is linked to the C-terminus of the peptide of Formula 4 and wherein the C-terminal extension comprises an amino acid sequence of the formula:

Xaa_1-Xaa_2-Xaa_3-Xaa_4-Xaa_5-Xaa_6-Xaa_7-Xaa_8-Xaa_9-Xaa_{10}-Xaa_{11}-Xaa_{12}

Formula 3 (SEQ ID NO: 3)

wherein:

Xaa_1 is: Gly, Cys, or absent;

Xaa_2 is: Gly, Arg, or absent;

Xaa_3 is: Pro, Thr, or absent;

Xaa_4 is: Ser, or absent;

Xaa_5 is: Ser, or absent;

Xaa_6 is: Gly, or absent;

Xaa_7 is: Ala, or absent;

Xaa_8 is: Pro, or absent;

Xaa_9 is: Pro, or absent;

Xaa_{10} is: Pro, or absent;

Xaa_{11} is: Ser, Cys, or absent; and

Xaa_{12} is: Cys, or absent;

wherein at least five of Xaa_1 to Xaa_{12} of the C-terminal extension are present and wherein if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, or Xaa_{11} is absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated,

and wherein;

the peptide agonist comprises at least one Cys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one Lys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one K(W) which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one $K(CO(CH_2)_2SH)$ which is covalently attached to a PEG molecule, or

the carboxy-terminal amino acid of the peptide agonist is covalently attached to a PEG molecule, or

a combination thereof.

Preferably, the PEGylated VPAC2 receptor peptide agonist of the third aspect of the present invention comprises a sequence of the Formula 4 (SEQ ID NO: 4) wherein Xaa_3 is Asp or Glu, Xaa_8 is Asp or Glu, Xaa_9 is Asn or Gln, Xaa_{10} is Tyr or Tyr(OMe), Xaa_{12} is Arg, hR, Lys, or Orn, Xaa_{14} is Arg, Gln, Aib, hR, Orn, Cit, Lys, Ala, or Leu, Xaa_{15} is Lys, Aib, Orn, or Arg, Xaa_{16} is Gln or Lys, Xaa_{17} is Val, Leu, Ala, Ile, Lys, or Nle, Xaa_{20} is Lys, Val, Leu, Aib, Ala, Gln, or Arg, Xaa_{21} is Lys, Aib, Orn, Ala, Gln, or Arg, Xaa_{23} is Leu or Aib, Xaa_{25} is Ser or Aib, Xaa_{27} is Lys, Orn, hR, or Arg, Xaa_{28} is Asn, Gln, Lys, hR, Aib, Orn, or Pro and Xaa_{29} is Lys, Orn, hR, or is absent.

Preferably, the PEGylated VPAC2 receptor peptide agonist of the third aspect of the present invention comprises a sequence of the Formula 4 (SEQ ID NO: 4), wherein either Xaa_{23} or Xaa_{25} is Aib. Even more preferably, Xaa_{23} and Xaa_{25} are both Aib.

Preferably, the PEGylated VPAC2 receptor peptide agonist of the third aspect of the present invention comprises a sequence of the Formula 4 wherein either Xaa_{14} or Xaa_{15} is Aib.

Alternatively, the PEGylated VPAC2 receptor peptide agonist of the third aspect of the present invention comprises a sequence of the Formula 4 wherein either Xaa_{20} or Xaa_{21} is Aib.

More preferably, either Xaa_{14} or Xaa_{15} is Aib and either Xaa_{20} or Xaa_{21} is Aib. It is especially preferred that Xaa_{15} is Aib and Xaa_{20} is Aib.

Preferably, the PEGylated VPAC2 receptor peptide agonist of the third aspect of the present invention comprises a sequence of the Formula 4 wherein Xaa_{15} is Aib, Xaa_{20} is Aib, and Xaa_{12}, Xaa_{21}, Xaa_{27} and Xaa_{28} are all Orn. More preferably, Xaa_{15} is Aib, Xaa_{20} is Aib, Xaa_{12}, Xaa_{21}, Xaa_{27} and Xaa_{28} are all Orn, Xaa_8 is Glu, Xaa_9 is Gln and Xaa_{10} is Tyr(OMe). Even more preferably, Xaa_{15} is Aib, Xaa_{20} is Aib, Xaa_{12}, Xaa_{21}, Xaa_{27} and Xaa_{28} are all Orn, Xaa_8 is Glu, Xaa_9 is Gln, Xaa_{10} is Tyr(OMe), and Xaa_{23} and/or Xaa_{25} is Aib. Any one or more of Xaa_8, Xaa_9, Xaa_{10}, Xaa_{12}, Xaa_{15}, Xaa_{20}, Xaa_{21}, Xaa_{23}, Xaa_{25}, Xaa_{27} and Xaa_{28} may be a PEGylated Lys, Cys, $K(CO(CH_2)_2SH)$ or K(W), whilst all the other positions have the preferred amino acid substitutions as described.

Preferably, at least six of Xaa_1 to Xaa_{12} of the C-terminal extension of Formula 3 is present. More preferably, seven, eight, nine, ten, eleven, or all of Xaa_1 to Xaa_{12} of the C-terminal extension are present.

Preferably, the C-terminal extension of the PEGyated VPAC2 receptor peptide agonist according to the third aspect of the present invention is selected from: SEQ ID NO: 5, 6, 7, 8, 9, 10, 11 and 12.

More preferably, the C-terminal extension of the PEGyated VPAC2 receptor peptide agonist according to the third aspect of the present invention is SEQ ID NO: 11 or SEQ ID NO: 12.

A PEG molecule(s) may be covalently attached to any Lys, Cys, K(W) or $K(CO(CH_2)_2SH)$ residue at any position in the VPAC2 receptor peptide agonist according to the third aspect of the present invention. The C-terminal extension may comprise one or more Cys residues which may be PEGylated. Where the sequence according to Formula 4 comprises one or more Lys, Cys, K(W), or $K(CO(CH_2)_2SH)$ residues and the C-terminal extension comprises one or more Cys residues, there may be one or more PEGylated residues in either or both sequences.

Preferably, there is at least one PEG molecule covalently attached to a residue in Formula 4. More preferably, there is a PEG molecule covalently attached to a residue at one or more of the following positions of Formula 4: 9, 13, 15, 16, 17, 18, 20, 21, 24, 25, 26 and 28.

Preferably, there is at least one PEG molecule covalently attached to a residue in the C-terminal extension of the VPAC2 receptor peptide agonist.

Where there is more than one PEG molecule, there may be a combination of Lys, Cys, $K(CO(CH_2)_2SH)$, K(W) and carboxy-terminal amino acid PEGylation. For example, if there are two PEG molecules, one may be attached to a Lys residue and one may be attached to a Cys residue.

Preferably, the PEG molecule is branched. Alternatively, the PEG molecule may be linear.

Preferably, the PEG molecule is between 1,000 daltons and 100,000 daltons in molecular weight. More preferably, the PEG molecule is selected from 10,000, 20,000, 30,000, 40,000, 50,000 and 60,000 daltons. Even more preferably, it is selected from 20,000, 30,000, 40,000, or 60,000 daltons. Where there are two PEG molecules covalently attached to the peptide agonist of the present invention, each is 1,000 to 40,000 daltons and preferably, they have molecular weights of 20,000 and 20,000 daltons, 10,000 and 30,000 daltons, 30,000 and 30,000 daltons, or 20,000 and 40,000 daltons.

Preferably, the PEGylated VPAC2 receptor peptide agonist of the third aspect of the present invention further comprises a N-terminal modification at the N-terminus of the peptide agonist wherein the N-terminal modification is selected from:

(a) addition of D-histidine, isoleucine, methionine, or norleucine;

(b) addition of a peptide comprising the sequence Ser-Trp-Cys-Glu-Pro-Gly-Trp-Cys-Arg (SEQ ID NO: 93) wherein the Arg is linked to the N-terminus of the peptide agonist;

(c) addition of C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3;

(d) addition of –C(O)R^1 wherein R^1 is a C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen, -SH and -CF_3; an aryl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; and aryl C_1-C_4 alkyl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; -NR^2R^3, wherein R^2 and R^3 are independently hydrogen, C_1-C_6 alkyl, aryl or aryl C_1-C_4 alkyl; -OR^4 wherein R^4 is C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3, aryl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3 or aryl C_1-C_4 alkyl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; or 5-pyrrolidin-2-one;

(e) addition of –SO_2R^5 wherein R^5 is aryl, aryl C_1-C_4 alkyl or C_1-C_{16} alkyl;

(f) formation of a succinimide group optionally substituted with C_1-C_6 alkyl or –SR^6, wherein R^6 is hydrogen or C_1-C_6 alkyl;

(g) addition of methionine sulfoxide;

(h) addition of biotinyl-6-aminohexanoic acid (6-aminocaproic acid); and

(i) addition of –C(=NH)-NH_2.

Preferably, the N-terminal modification is the addition of a group selected from: acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid (6-aminocaproic acid), and –C(=NH)-NH_2. It is especially preferred that the N-terminal modification is the addition of acetyl or hexanoyl.

It will be appreciated by the person skilled in the art that PEGylated VPAC2 receptor peptide agonists comprising various combinations of peptide sequence according to Formula 4, C-terminal extensions and N-terminal modifications as described herein, may be made based on the above disclosure.

It is preferred that the PEGylated VPAC2 receptor peptide agonist according to the third aspect of the present invention comprises an amino acid sequence selected from: SEQ ID NO: 59, 62, 64, 65, 66, 71, 72, 73, 74, 115, 116, 117, 118, 119, 120, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 135, 136, 137, 141, 144, 146 and 148.

According to a fourth aspect of the present invention, there is provided a pharmaceutical composition comprising a PEGylated VPAC2 receptor peptide agonist of the present invention and one or more pharmaceutically acceptable diluents, carriers and/or excipients.

According to a fifth aspect of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist of the present invention for use as a medicament.

According to a sixth aspect of the present invention, there is provided the use of a PEGylated VPAC2 receptor peptide agonist of the present invention for the manufacture of a medicament for the treatment non-insulin-dependent diabetes.

According to a further aspect of the present invention, there is provided the use of a PEGylated VPAC2 receptor peptide agonist of the present invention for the manufacture of a medicament for the treatment insulin-dependent diabetes.

The present invention provides a method of treating diabetes in a patient in need thereof comprising administering a PEGylated VPAC2 receptor peptide agonist of the present invention, wherein the diabetes may be non-insulin dependent diabetes or may be insulin-dependent diabetes.

The present invention further provides a pharmaceutical composition containing a PEGylated VPAC2 receptor peptide agonist of the present invention for treating non-insulin dependent diabetes or insulin-dependent diabetes.

According to an alternative embodiment of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising a sequence selected from SEQ ID NO: 17 to 45 and 94 to 112;

and a C-terminal extension wherein the N-terminus of the C-terminal extension is linked to the C-terminus of the peptide sequence and wherein the C-terminal extension comprises an amino acid sequence of the formula:

Xaa_1-Xaa_2-Xaa_3-Xaa_4-Xaa_5-Xaa_6-Xaa_7-Xaa_8-Xaa_9-Xaa_{10}-Xaa_{11}-Xaa_{12}-Xaa_{13}

Formula 1 (SEQ ID NO: 1)

wherein:

Xaa_1 is: Gly, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_2 is: Gly, Arg, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_3 is: Pro, Thr, Ser, Ala, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_4 is: Ser, Pro, His, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_5 is: Ser, Arg, Thr, Trp, Lys, Cys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_6 is: Gly, Ser, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_7 is: Ala, Asp, Arg, Glu, Lys, Gly, Cys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_8 is: Pro, Ser, Ala, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_9 is: Pro, Ser, Ala, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_{10} is: Pro, Ser, Ala, Arg, Lys, His, Cys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_{11} is: Ser, Cys, His, Pro, Lys, Arg, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_{12} is: His, Ser, Arg, Lys, Cys, K(W), K($CO(CH_2)_2SH$), or absent; and

Xaa_{13} is: His, Ser, Arg, Lys, Cys, K(W), K($CO(CH_2)_2SH$), or absent;

provided that if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, Xaa_{11}, or Xaa_{12} is absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated,

and wherein;

the peptide agonist comprises at least one Cys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one Lys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one K(W) which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one $K(CO(CH_2)_2SH)$ which is covalently attached to a PEG molecule, or

the carboxy-terminal amino acid of the peptide agonist is covalently attached to a PEG molecule, or

a combination thereof.

It is preferable that the C-terminal extension of Formula 1 has no more than three of any one of the following; Cys, Lys, K(W) or $K(CO(CH_2)_2SH)$. It is more preferable that the C-terminal extension has no more than two of any of these residues. If there are two Cys residues in the C-terminal extension, it is preferred that the Cys residues are at the C-terminus. It is even more preferable that the C-terminal extension has no more than one of any of these residues. If there is only one Cys residue in the C-terminal extension, it is preferred that the Cys residue is at the C-terminus.

Preferably, the C-terminal extension of the PEGylated VPAC2 receptor peptide agonist according to the above alternative embodiment comprises an amino acid sequence of the formula:

$$Xaa_1\text{-}Xaa_2\text{-}Xaa_3\text{-}Xaa_4\text{-}Xaa_5\text{-}Xaa_6\text{-}Xaa_7\text{-}Xaa_8\text{-}Xaa_9\text{-}Xaa_{10}\text{-}Xaa_{11}\text{-}Xaa_{12}\text{-}Xaa_{13}$$

Formula 2 (SEQ ID NO: 2)

wherein:

Xaa_1 is: Gly, Cys, Lys, or absent;

Xaa_2 is: Gly, Arg, Cys, Lys, or absent;

Xaa_3 is: Pro, Thr, Ser, Ala, Cys, Lys, or absent;

Xaa_4 is: Ser, Pro, His, Cys, Lys, or absent;

Xaa_5 is: Ser, Arg, Thr, Trp, Lys, Cys, or absent;

Xaa_6 is: Gly, Ser, Cys, Lys, or absent;

Xaa_7 is: Ala, Asp, Arg, Glu, Lys, Gly, Cys, or absent;

Xaa_8 is: Pro, Ser, Ala, Cys, Lys, or absent;

Xaa_9 is: Pro, Ser, Ala, Cys, Lys, or absent;

Xaa_{10} is: Pro, Ser, Ala, Arg, Lys, His, Cys, or absent;

Xaa_{11} is: Ser, Cys, His, Pro, Lys, Arg, or absent;

Xaa_{12} is: His, Ser, Arg, Lys, Cys, or absent; and

Xaa_{13} is: His, Ser, Arg, Lys, Cys, or absent;

provided that if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, Xaa_{11}, or Xaa_{12} is absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated.

Preferably, at least one of Xaa_1 to Xaa_{13} of the C-terminal extension of Formula 1 or 2 is present. More preferably, at least two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, or all of Xaa_1 to Xaa_{13} of the C-terminal extension are present.

More preferably, the C-terminal extension of the PEGylated VPAC2 receptor peptide agonist according to the above alternative embodiment comprises an amino acid sequence of the formula:

$$Xaa_1\text{-}Xaa_2\text{-}Xaa_3\text{-}Xaa_4\text{-}Xaa_5\text{-}Xaa_6\text{-}Xaa_7\text{-}Xaa_8\text{-}Xaa_9\text{-}Xaa_{10}\text{-}Xaa_{11}\text{-}Xaa_{12}$$

Formula 3 (SEQ ID NO: 3)

wherein:

Xaa_1 is: Gly, Cys, or absent;

Xaa_2 is: Gly, Arg, or absent;

Xaa_3 is: Pro, Thr, or absent;

Xaa_4 is: Ser, or absent;

Xaa_5 is: Ser, or absent;

Xaa_6 is: Gly, or absent;

Xaa_7 is: Ala, or absent;

Xaa_8 is: Pro, or absent;

Xaa_9 is: Pro, or absent;

Xaa_{10} is: Pro, or absent;

Xaa_{11} is: Ser, Cys, or absent; and

Xaa_{12} is: Cys, or absent;

provided that if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, or Xaa_{11} is absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated.

Preferably, at least one of Xaa_1 to Xaa_{12} of the C-terminal extension of Formula 3 is present. More preferably, at least two, three, four, five, six, seven, eight, nine, ten, eleven, or all of Xaa_1 to Xaa_{12} of the C-terminal extension are present.

An alternative C-terminal extension, which may be used in any of the aspects and embodiments of the present invention, comprises an amino acid sequence of the formula:

Xaa_1-Xaa_2-Xaa_3-Xaa_4-Xaa_5-Xaa_6-Xaa_7-Xaa_8-Xaa_9-Xaa_{10}

Formula 13 (SEQ ID NO: 13)

wherein:

Xaa_1 is: Ser, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_2 is: Arg, Ser, hR, Orn, His, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent,

Xaa_3 is: Thr, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_4 is: Ser, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_5 is: Pro, Ser, Ala, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_6 is: Pro, Ser, Ala, Arg, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_7 is: Pro, Ser, Ala, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent;

Xaa_8 is: Lys, K(W) , Pro, Cys, K($CO(CH_2)_2SH$), or absent;

Xaa_9 is: K(E-C_{16}), Ser, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent; and

Xaa_{10} is: Ser, Cys, Lys, K(W), K($CO(CH_2)_2SH$), or absent.

It is preferred that if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8 or Xaa_9 of Formula 13 is absent, the next amino acid downstream is the next amino acid in the C-terminal extension. The C-terminal amino acid may be amidated.

Preferably, at least one of Xaa_1 to Xaa_{10} of the C-terminal extension of Formula 13 is present. More preferably, at least two, three, four, five, six, seven, eight, nine or all of Xaa_1 to Xaa_{10} of the C-terminal extension are present.

More preferably, an alternative C-terminal extension, which may be used in any of the aspects and embodiments of the present invention, is selected from:

SEQ ID NO: 85	SRTSPPP
SEQ ID NO: 86	SRTSPPP-NH_2
SEQ ID NO: 87	SSTSPRPPSS
SEQ ID NO: 88	SSTSPRPPSS-NH_2
SEQ ID NO: 89	SRTSPPPK(W)

SEQ ID NO: 90	SRTSPPPK(W)-NH_2
SEQ ID NO: 91	SRTSPPPC
SEQ ID NO: 92	SRTSPPPC-NH_2

The VPAC2 receptor peptide agonists of the present invention have the advantage that they have enhanced selectivity, potency and/or stability over known VPAC2 receptor peptide agonists. In particular, the addition of the C-terminal sequence of Exendin-4, or a variant of this C-terminal sequence, as the c-capping sequence surprisingly increased the VPAC2 receptor selectivity as well as increasing proteolytic stability.

The covalent attachment of one or more molecules of PEG to particular residues of a VPAC2 receptor peptide agonist results in a biologically active, PEGylated VPAC2 receptor peptide agonist with an extended half-life and reduced clearance when compared to that of non-PEGylated VPAC2 receptor peptide agonists.

The term "VPAC2" is used to refer to and in conjunction with the particular receptor (Lutz, *et al.*, *FEBS Lett.*, 458: 197-203 (1999); Adamou, *et al.*, *Biochem. Biophys. Res. Commun.*, 209: 385-392 (1995)) that the agonists of the present invention activate. This term also is used to refer to and in conjunction with the agonists of the present invention.

A "selective VPAC2 receptor peptide agonist" or a "VPAC2 receptor peptide agonist" of the present invention is a peptide that selectively activates the VPAC2 receptor to induce insulin secretion. Preferably, the sequence for a selective VPAC2 receptor peptide agonist of the present invention has twenty-eight to forty naturally occurring and/or non-naturally occurring amino acids and may or may not additionally comprise a C-terminal extension.

A "selective PEGylated VPAC2 receptor peptide agonist" or a "PEGylated VPAC2 receptor peptide agonist" is a selective VPAC2 receptor peptide agonist covalently attached to one or more molecules of polyethylene glycol (PEG), or a derivative thereof, wherein each PEG is attached to a cysteine or lysine amino acid, to a K(W) or K($CO(CH_2)_2SH$), or to the carboxy terminus of a peptide.

Selective PEGylated VPAC2 receptor peptide agonists may have a C-terminal extension. The "C-terminal extension" of the present invention comprises a sequence having from one to thirteen naturally occurring or non-naturally occurring amino acids

linked to the C-terminus of the sequence at the N-terminus of the C-terminal extension via a peptide bond. Any Cys, Lys, K(W), or K($CO(CH_2)_2SH$) residues in the C-terminal extension may be covalently attached to a PEG molecule, and/or the carboxy-terminal amino acid of the C-terminal extension may be covalently attached to a PEG molecule.

As used herein, the term "linked to" with reference to the term C-terminal extension, includes the addition or attachment of amino acids or chemical groups directly to the C-terminus of the peptide sequence.

Optionally, the selective PEGylated VPAC2 receptor peptide agonist may also have an N-terminal modification. The term "N-terminal modification" as used herein includes the addition or attachment of amino acids or chemical groups directly to the N-terminus of a peptide and the formation of chemical groups, which incorporate the nitrogen at the N-terminus of a peptide.

The N-terminal modification may comprise the addition of one or more naturally occurring or non-naturally occurring amino acids to the VPAC2 receptor peptide agonist sequence, preferably there are not more than ten amino acids, with one amino acid being more preferred. Naturally occurring amino acids which may be added to the N-terminus include methionine and isoleucine. A modified amino acid added to the N-terminus may be D-histidine. Alternatively, the following amino acids may be added to the N-terminus: SEQ ID NO: 93 Ser-Trp-Cys-Glu-Pro-Gly-Trp-Cys-Arg, wherein the Arg is linked to the N-terminus of the peptide agonist. Preferably, any amino acids added to the N-terminus are linked to the N-terminus by a peptide bond.

The term "linked to" as used herein, with reference to the term N-terminal modification, includes the addition or attachment of amino acids or chemical groups directly to the N-terminus of the VPAC2 receptor agonist. The addition of the above N-terminal modifications may be achieved under normal coupling conditions for peptide bond formation.

The N-terminus of the peptide agonist may also be modified by the addition of an alkyl group (R), preferably a C_1-C_{16} alkyl group, to form (R)NH-.

Alternatively, the N-terminus of the peptide agonist may be modified by the addition of a group of the formula $-C(O)R^1$ to form an amide of the formula $R^1C(O)NH$-. The addition of a group of the formula $-C(O)R^1$ may be achieved by reaction with an organic acid of the formula R^1COOH. Modification of the N-terminus of an amino acid

sequence using acylation is demonstrated in the art (e.g. Gozes *et al., J. Pharmacol Exp Ther*, 273:161-167 (1995)). Addition of a group of the formula $-C(O)R^1$ may result in the formation of a urea group (see WO 01/23240, WO 2004/06839) or a carbamate group at the N-terminus. Also, the N-terminus may be modified by the addition of pyroglutamic acid, or 6-aminohexanoic acid.

The N-terminus of the peptide agonist may be modified by the addition of a group of the formula $-SO_2R^5$, to form a sulfonamide group at the N-terminus.

The N-terminus of the peptide agonist may also be modified by reacting with succinic anhydride to form a succinimide group at the N-terminus. The succinimide group incorporates the nitrogen at the N-terminus of the peptide.

The N-terminus may alternatively be modified by the addition of methionine sulfoxide, biotinyl-6-aminohexanoic acid, or $-C(=NH)-NH_2$. The addition of $-C(=NH)-NH_2$ is a guanidation modification, where the terminal NH_2 of the N-terminal amino acid becomes $-NH-C(=NH)-NH_2$.

Most of the sequences of the present invention, including the N-terminal modifications and the C-terminal extensions contain the standard single letter or three letter codes for the twenty naturally occurring amino acids. The other codes used are defined as follows:

C6 = hexanoyl

d = the D isoform (nonnaturally occurring) of the respective amino acid,

e.g., dA = D-alanine, dS = D-serine, dK = D-lysine

hR = homoarginine

Aib = amino isobutyric acid

OMe = methoxy

Nle = Nor-leucine

NMe = N-methyl attached to the alpha amino group of an amino acid,

e.g., NMeA = N-methyl alanine, NMeV = N-methyl valine

Orn = ornithine

$K(CO(CH_2)_2SH)$ = ε-(3'-mercaptopropionyl)-lysine

K(W) = ε-(L-tryptophyl)-lysine

Abu = α-amino-n-butyric acid or 2-aminobutanoic acid

Cit = citrulline

K(Ac) = ε-acetyl lysine

PEG = polyethylene glycol

PEG40K = 40,000 Dalton PEG molecule

PEG30K = 30,000 Dalton PEG molecule

PEG20K = 20,000 Dalton PEG molecule

VIP naturally occurs as a single sequence having 28 amino acids. However, PACAP exists as either a 38 amino acid peptide (PACAP-38) or as a 27 amino acid peptide (PACAP-27) with an amidated carboxyl (Miyata, *et al.*, *Biochem Biophys Res Commun*, 170:643-648 (1990)). The sequences for VIP, PACAP-27, and PACAP-38 are as follows:

Peptide	**Seq.ID #**	**Sequence**
VIP	SEQ ID NO: 14	HSDAVFTDNYTRLRKQMAVKKYLNSILN
PACAP-27	SEQ ID NO: 15	HSDGIFTDSYSRYRKQMAVKKYLAAVL-NH_2
PACAP-38	SEQ ID NO: 16	HSDGIFTDSYSRYRKQMAVKKYLAAVLGKRYQRVKNK-NH_2

The term "naturally occurring amino acid" as used herein means the twenty amino acids coded for by the human genetic code (i.e. the twenty standard amino acids). These twenty amino acids are: Alanine, Arginine, Asparagine, Aspartic Acid, Cysteine, Glutamine, Glutamic Acid, Glycine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Proline, Serine, Threonine, Tryptophan, Tyrosine and Valine.

Examples of "non-naturally occurring amino acids" include both synthetic amino acids and those modified by the body. These include D-amino acids, arginine-like amino acids (e.g., homoarginine), and other amino acids having an extra methylene in the side chain ("homo" amino acids), and modified amino acids (e.g norleucine, lysine (isopropyl) – wherein the side chain amine of lysine is modified by an isopropyl group). Also included are amino acids such as ornithine, amino isobutyric acid and 2-aminobutanoic acid.

"Selective" as used herein refers to a VPAC2 receptor peptide agonist with increased selectivity for the VPAC2 receptor compared to other known receptors. The

degree of selectivity is determined by a ratio of VPAC2 receptor binding affinity to VPAC1 receptor binding affinity or by a ratio of VPAC2 receptor binding affinity to PAC1 receptor binding affinity. Binding affinity is determined as described below in Example 4.

"Insulinotropic activity" refers to the ability to stimulate insulin secretion in response to elevated glucose levels, thereby causing glucose uptake by cells and decreased plasma glucose levels. Insulinotropic activity can be assessed by methods known in the art, including using experiments that measure VPAC2 receptor binding activity or receptor activation (e.g. insulin secretion by insulinoma cell lines or islets, intravenous glucose tolerance test (IVGTT), intraperitoneal glucose tolerance test (IPGTT), and oral glucose tolerance test (OGTT)). Insulinotropic activity is routinely measured in humans by measuring insulin levels or C-peptide levels. Selective PEGylated VPAC2 receptor peptide agonists of the present invention have insulinotropic activity.

"*In vitro* potency" as used herein is the measure of the ability of a peptide to activate the VPAC2 receptor in a cell-based assay. *In vitro* potency is expressed as the "EC_{50}" which is the effective concentration of compound that results in a 50% of maximum increase in activity in a single dose-response experiment. For the purposes of the present invention, *in vitro* potency is determined using two different assays: DiscoveRx and Alpha Screen. See Examples 3 and 5 for further details of these assays. Whilst these assays are performed in different ways, the results demonstrate a general correlation between the two assays.

The term "plasma half-life" refers to the time in which half of the relevant molecules circulate in the plasma prior to being cleared. An alternatively used term is "elimination half-life." The term "extended" or "longer" used in the context of plasma half-life or elimination half-life indicates there is a statistically significant increase in the half-life of a PEGylated VPAC2 receptor peptide agonist relative to that of the reference molecule (e.g., the non-PEGylated form of the peptide or the native peptide) as determined under comparable conditions. The half-life reported herein is the elimination half-life; it is that which corresponds to the terminal log-linear rate of elimination. The person skilled in the art appreciates that half-life is a derived parameter that changes as a function of both clearance and volume of distribution.

Clearance is the measure of the body's ability to eliminate a drug. As clearance decreases due, for example, to modifications to a drug, half-life would be expected to increase. However, this reciprocal relationship is exact only when there is no change in the volume of distribution. A useful approximate relationship between the terminal log-linear half-life ($t_{½}$), clearance (C), and volume of distribution (V) is given by the equation: $t_{½} \approx 0.693$ (V/C). Clearance does not indicate how much drug is being removed but, rather, the volume of biological fluid such as blood or plasma that would have to be completely freed of drug to account for the elimination. Clearance is expressed as a volume per unit of time.

"Percent (%) sequence identity" as used herein is used to denote sequences which when aligned have similar (identical or conservatively replaced) amino acids in like positions or regions, where identical or conservatively replaced amino acids are those which do not alter the activity or function of the protein as compared to the starting protein. For example, two amino acid sequences with at least 85% identity to each other have at least 85% similar (identical or conservatively replaced residues) in a like position when aligned optimally allowing for up to 3 gaps, with the proviso that in respect of the gaps a total of not more than 15 amino acid residues is affected.

The reference peptide used for the percentage sequence identity calculations herein is:

P487 SEQ ID NO:84	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSI OrnOrnGGPSSGAPPPS-NH_2

Percent sequence identity may be calculated by determining the number of residues that differ between a peptide encompassed by the present invention and a reference peptide such as P487 (SEQ ID NO: 84), taking that number and dividing it by the number of amino acids in the reference peptide (e.g. 39 amino acids for P487), multiplying the result by 100, and subtracting that resulting number from 100. For example, a sequence having 39 amino acids with four amino acids that are different from P487 would have a percent (%) sequence identity of 90% (e.g. 100 - ((4 / 39) x 100)). For a sequence that is longer than 39 amino acids, the number of residues that differ from the P487 sequence will include the additional amino acids over 39 for purposes of the aforementioned calculation. For example, a sequence having 40 amino acids, with four

amino acids different from the 39 amino acids in the P487 sequence and with one additional amino acid at the carboxy terminus which is not present in the P487 sequence, would have a total of five amino acids that differ from P487. Thus, this sequence would have a percent (%) sequence identity of 87% (e.g. 100 - ((5 / 39) x 100)). The degree of sequence identity may be determined using methods well known in the art (see, for example, Wilbur, W.J. and Lipman, D.J., *Proc. Natl. Acad. Sci. USA* 80:726-730 (1983) and Myers E. and Miller W., *Comput. Appl. Biosci.* 4:11-17 (1988)). One program which may be used in determining the degree of similarity is the MegAlign Lipman-Pearson one pair method (using default parameters) which can be obtained from DNAstar Inc, 1128, Selfpark Street, Madison, Wisconsin, 53715, USA as part of the Lasergene system. Another program, which may be used, is Clustal W. This is a multiple sequence alignment package developed by Thompson *et al* (*Nucleic Acids Research*, 22(22):4673-4680(1994)) for DNA or protein sequences. This tool is useful for performing cross-species comparisons of related sequences and viewing sequence conservation. Clustal W is a general purpose multiple sequence alignment program for DNA or proteins. It produces biologically meaningful multiple sequence alignments of divergent sequences. It calculates the best match for the selected sequences, and lines them up so that the identities, similarities and differences can be seen. Evolutionary relationships can be seen via viewing Cladograms or Phylograms.

The sequence for a selective PEGylated VPAC2 receptor peptide agonist of the present invention is selective for the VPAC2 receptor and preferably has a sequence identity in the range of 60% to 70%, 60% to 65%, 65% to 70%, 70% to 80%, 70% to 75%, 75% to 80%, 80% to 90%, 80% to 85%, 85% to 90%, 90% to 97%, 90% to 95%, or 95% to 97%, with P487 (SEQ ID NO: 84). Preferably, the sequence has a sequence identity of greater than 82% with P487 (SEQ ID NO: 84). More preferably, the sequence has greater than 90% sequence identity with P487 (SEQ ID NO: 84). Even more preferably, the sequence has greater than 92% sequence identity with P487 (SEQ ID NO: 84). Yet more preferably, the sequence has greater than 95% sequence identity or 97% sequence identity with P487 (SEQ ID NO: 84).

The term "C_1-C_{16} alkyl" as used herein means a monovalent saturated straight, branched or cyclic chain hydrocarbon radical having from 1 to 16 carbon atoms or when cyclic, having from 3 to 16 carbon atoms. Thus the term "C_1-C_{16} alkyl" includes, for

example, methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, n-heptyl, n-octyl, cyclopropyl, cyclobutyl, cyclopentyl and cyclohexyl. The C_1-C_{16} alkyl group may be optionally substituted with one or more substituents including, for example, aryl, C_1-C_6alkoxy, -OH, halogen, -CF_3 and -SH.

The term "C_1- C_6 alkyl" as used herein means a monovalent saturated straight, branched or cyclic chain hydrocarbon radical having from 1 to 6 carbon atoms or when cyclic, having from 3 to 6 carbon atoms. Thus the term "C_1-C_6 alkyl" includes, for example, methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, cyclopropyl, cyclobutyl, cyclopentyl and cyclohexyl. The C_1-C_6 alkyl group may be optionally substituted with one or more substituents.

The term "C_2-C_6 alkenyl" as used herein means a monovalent straight, branched or cyclic chain hydrocarbon radical having at least one double bond and having from 2 to 6 carbon atoms or when cyclic, having form 3 to 6 carbon atoms. Thus the term "C_2-C_6 alkenyl" includes vinyl, prop-2-enyl, but-3-enyl, pent-4-enyl and isopropenyl. The C_2-C_6 alkenyl group may be optionally substituted with one or more substituents.

The term "C_2-C_6 alkynyl" as used herein means a monovalent straight or branched chain hydrocarbon radical having at least one triple bond and having from 2 to 6 carbon atoms. Thus the term "C_2-C_6 alkynyl" includes prop-2-ynyl, but-3-ynyl and pent-4-ynyl. The C_2-C_6 alkynyl may be optionally substituted with one or more substituents.

The term "C_1-C_6 alkoxy" as used herein means a monovalent unsubstituted saturated straight-chain or branched-chain hydrocarbon radical having from 1 to 6 carbon atoms linked to the point of substitution by a divalent O radical. Thus the term "C_1-C_6 alkoxy" includes, for example, methoxy, ethoxy, n-propoxy, isopropoxy, n-butoxy, isobutoxy, sec-butoxy and tert-butoxy. The C_1-C_6 alkoxy group may be optionally substituted with one or more substituents.

The term "halo" or "halogen" means fluorine, chlorine, bromine or iodine.

The term "aryl" when used alone or as part of a group is a 5 to 10 membered aromatic or heteroaromatic group including a phenyl group, a 5 or 6- membered monocyclic heteroaromatic group, each member of which may be optionally substituted with 1, 2, 3, 4 or 5 substituents (depending upon the number of available substitution positions), a naphthyl group or an 8-, 9- or 10- membered bicyclic heteroaromatic group, each member of which may be optionally substituted with 1, 2, 3, 4, 5 or 6 substituents

(depending on the number of available substitution positions). Within this definition of aryl, suitable substitutions include C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, -NH_2, -OH, halogen, -SH and CF_3.

The term "aryl C_1-C_4 alkyl" as used herein means a C_1-C_4 alkyl group substituted with an aryl. Thus the term "aryl C_1-C_4 alkyl" includes benzyl, 1-phenylethyl (α-methylbenzyl), 2-phenylethyl, 1-naphthalenemethyl or 2-naphthalenemethyl.

The term "naphthyl" includes 1-naphthyl, and 2-naphthyl. 1-naphthyl is preferred.

The term "benzyl" as used herein means a monovalent unsubstituted phenyl radical linked to the point of substitution by a –CH_2- group.

The term "5- or 6-membered monocyclic heteroaromatic group" as used herein means a monocyclic aromatic group with a total of 5 or 6 atoms in the ring wherein from 1 to 4 of those atoms are each independently selected from N, O and S. Preferred groups have 1 or 2 atoms in the ring which are each independently selected from N, O and S. Examples of 5-membered monocyclic heteroaromatic groups include pyrrolyl (also called azolyl), furanyl, thienyl, pyrazolyl (also called 1H-pyrazolyl and 1,2-diazolyl), imidazolyl, oxazolyl (also called 1,3-oxazolyl), isoxazolyl (also called 1,2-oxazolyl), thiazolyl (also called 1,3-thiazolyl), isothiazolyl (also called 1,2-thiazolyl), triazolyl, oxadiazolyl, thiadiazolyl, tetrazolyl, oxatriazolyl and thiatriazolyl. Examples of 6-membered monocyclic heteroaromatic groups include pyridinyl, pyrimidyl, pyrazinyl, pyridazinyl and triazinyl.

The term "8-, 9- or 10-membered bicyclic heteroaromatic group" as used herein means a fused bicyclic aromatic group with a total of 8, 9 or 10 atoms in the ring system wherein from 1 to 4 of those atoms are each independently selected from N, O and S. Preferred groups have from 1 to 3 atoms in the ring system which are each independently selected from N, O and S. Suitable 8-membered bicyclic heteroaromatic groups include imidazo[2,1-b][1,3]thiazolyl, thieno[3,2-b]thienyl, thieno[2,3-d][1,3]thiazolyl and thieno[2,3-d]imidazolyl. Suitable 9-membered bicyclic heteroaromatic groups include indolyl, isoindolyl, benzofuranyl (also called benzo[b]furanyl), isobenzofuranyl (also called benzo[c]furanyl), benzothienyl (also called benzo[b]thienyl), isobenzothienyl (also called benzo[c]thienyl), indazolyl, benzimidazolyl, 1,3-benzoxazolyl, 1,2-benzisoxazolyl, 2,1-benzisoxazolyl, 1,3-benzothiazolyl, 1,2-benzoisothiazolyl, 2,1-benzoisothiazolyl,

benzotriazolyl, 1,2,3-benzoxadiazolyl, 2,1,3-benzoxadiazolyl, 1,2,3-benzothiadiazolyl, 2,1,3-benzothiadiazolyl, thienopyridinyl, purinyl and imidazo[1,2-a]pyridine. Suitable 10-membered bicyclic heteroaromatic groups include quinolinyl, isoquinolinyl, cinnolinyl, quinazolinyl, quinoxalinyl, 1,5-naphthyridyl, 1,6-naphthyridyl, 1,7-naphthyridyl and 1,8-naphthyridyl.

The term "PEG" as used herein means a polyethylene glycol molecule. In its typical form, PEG is a linear polymer with terminal hydroxyl groups and has the formula HO-CH_2CH_2-(CH_2CH_2O)*n*-CH_2CH_2-OH, where *n* is from about 8 to about 4000. The terminal hydrogen may be substituted with a protective group such as an alkyl or alkanol group. Preferably, PEG has at least one hydroxy group, more preferably it is a terminal hydroxy group. It is this hydroxy group which is preferably activated to react with the peptide. There are many forms of PEG useful for the present invention. Numerous derivatives of PEG exist in the art and are suitable for use in the invention. (See, e.g., U.S. Patent Nos: 5,445,090; 5,900,461; 5,932,462; 6,436,386; 6,448,369; 6,437,025; 6,448,369; 6,495,659; 6,515,100 and 6,514,491 and Zalipsky, S. *Bioconjugate Chem.* 6:150-165, 1995). The PEG molecule covalently attached to VPAC2 receptor peptide agonists in the present invention is not intended to be limited to a particular type. The molecular weight of the PEG molecule is preferably from 500-100,000 daltons. PEG may be linear or branched. PEGylated VPAC2 receptor peptide agonists of the invention may have one, two or three PEG molecules attached to the peptide. It is more preferable that there be one or two PEG molecules per PEGylated VPAC2 receptor peptide agonist, however, when there is more than one PEG molecule per peptide molecule, it is preferred that there be no more than three. It is further contemplated that both ends of the PEG molecule may be homo- or hetero-functionalized for crosslinking two or more VPAC2 receptor peptide agonists together. Where there are two PEG molecules present, the PEG molecules will preferably each be 20,000 dalton PEG molecules or each be 30,000 dalton PEG molecules. However, PEG molecules having a different molecular weight may be used, for example, one 10,000 dalton PEG molecule and one 30,000 PEG molecule, or one 20,000 dalton PEG molecule and one 40,000 dalton PEG molecule.

In the present invention, a PEG molecule may be covalently attached to a Cys or Lys residue or to the C-terminal residue. The PEG molecule may also be covalently attached to a Trp residue which is coupled to the side chain of a Lys residue (K(W)).

Alternatively, a K($CO(CH_2)_2SH$) group may be PEGylated to form K($CO(CH_2)_2S$-PEG). Any Lys residue in the peptide agonist may be substituted for a K(W) or K($CO(CH_2)_2SH$), which may then be PEGylated. In addition, any Cys residue in the peptide agonist may be substituted for a modified cysteine residue, for example, hC. The modified Cys residue may be covalently attached to a PEG molecule.

The term "PEGylation" as used herein means the covalent attachment of one or more PEG molecules as described above to the VPAC2 receptor peptide agonists of the present invention.

According to a preferred embodiment of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising a peptide sequence selected from: SEQ ID NO: 17 to 45 and 94 to 112, and a C-terminal extension selected from: SEQ ID NO: 5, 6, 7, 8, 9, 10, 11 and 12. It is especially preferred that the C-terminal extension is SEQ ID NO: 11 or SEQ ID NO: 12.

According to a more preferred embodiment of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising a peptide sequence selected from: SEQ ID NO: 17 to 45 and 94 to 112, and a C-terminal extension selected from: SEQ ID NO: 5, 6, 7, 8, 9, 10, 11 and 12, and wherein the VPAC2 receptor peptide agonist further comprises a N-terminal modification, which modification is the addition of acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid (6-aminocaproic acid), and –$C(=NH)\text{-}NH_2$. In this embodiment, it is more preferred that the N-terminal modification is the addition of acetyl or hexanoyl.

According to a further preferred embodiment of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising an amino acid sequence of Formula 4 (SEQ ID NO: 4) and a C-terminal extension selected from: SEQ ID NO: 5, 6, 7, 8, 9, 10, 11 and 12, and wherein the PEGylated VPAC2 receptor peptide agonist further comprises a N-terminal modification, which modification is the addition of acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid (6-aminocaproic acid), and –

$C(=NH)-NH_2$. In this embodiment, it is more preferred that the N-terminal modification is the addition of acetyl or hexanoyl.

According to a more preferred embodiment of the present invention, there is provided a PEGylated VPAC2 receptor peptide agonist comprising an amino acid sequence of Formula 4 (SEQ ID NO: 4), wherein Xaa_{15} is Aib, Xaa_{20} is Aib, and Xaa_{12}, Xaa_{21}, Xaa_{27} and Xaa_{28} are all Orn, and a C-terminal extension selected from: SEQ ID NO: 5, 6, 7, 8, 9, 10, 11 and 12, and wherein the PEGylated VPAC2 receptor peptide agonist further comprises a N-terminal modification, which modification is the addition of acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid (6-aminocaproic acid), and –$C(=NH)-NH_2$. In this embodiment, it is more preferred that Xaa_{15} is Aib, Xaa_{20} is Aib, Xaa_{12}, Xaa_{21}, Xaa_{27} and Xaa_{28} are all Orn, Xaa_8 is Glu, Xaa_9 is Gln, and Xaa_{10} is Tyr(OMe). It is especially preferred that Xaa_{15} is Aib, Xaa_{20} is Aib, Xaa_{12}, Xaa_{21}, Xaa_{27} and Xaa_{28} are all Orn, Xaa_8 is Glu, Xaa_9 is Gln, Xaa_{10} is Tyr(OMe), and Xaa_{23} and/or Xaa_{25} is Aib

PEGylation of proteins may overcome many of the pharmacological and toxicological/immunological problems associated with using peptides or proteins as therapeutics. However, for any individual peptide it is uncertain whether the PEGylated form of the peptide will have significant loss in bioactivity as compared to the unPEGylated form of the peptide.

The bioactivity of PEGylated proteins can be affected by factors such as: i) the size of the PEG molecule; ii) the particular sites of attachment; iii) the degree of modification; iv) adverse coupling conditions; v) whether a linker is used for attachment or whether the polymer is directly attached; vi) generation of harmful co-products; vii) damage inflicted by the activated polymer; or viii) retention of charge. Work performed on the PEGylation of cytokines, for example, shows the effect PEGylation may have. Depending on the coupling reaction used, polymer modification of cytokines has resulted in dramatic reductions in bioactivity [Francis, G.E., *et al.*, (1998) PEGylation of cytokines and other therapeutic proteins and peptides: the importance of biological optimization of coupling techniques, *Intl. J. Hem.* 68:1-18]. Maintaining the bioactivity of PEGylated peptides is even more problematic than for proteins. As peptides are smaller

than proteins, modification by PEGylation may potentially have a greater effect on bioactivity.

The VPAC2 receptor peptide agonists of the present invention are modified by the covalent attachment of one or more molecules of a PEG and generally have improved pharmacokinetic profiles due to slower proteolytic degradation and renal clearance. PEGylation will increase the apparent size of the VPAC2 receptor peptide agonists, thus reducing renal filtration and altering biodistribution. PEGylation can shield antigenic epitopes of the VPAC2 receptor peptide agonists, thus reducing reticuloendothelial clearance and recognition by the immune system and also reducing degradation by proteolytic enzymes, such as DPP-IV.

Covalent attachment of one or more molecules of PEG to a small, biologically active VPAC2 receptor peptide agonist poses the risk of adversely affecting the agonist, for example, by destabilising the inherent secondary structure and bioactive conformation and reducing bioactivity, so as to make the agonist unsuitable for use as a therapeutic. The present invention, however, is based on the finding that covalent attachment of one or more molecules of PEG to particular residues of a VPAC2 receptor peptide agonist surprisingly results in a biologically active, PEGylated VPAC2 receptor peptide agonist with an extended half-life and reduced clearance when compared to that of non-PEGylated VPAC2 receptor peptide agonists. The compounds of the present invention include selective PEGylated VPAC2 receptor peptide agonists.

In order to determine the potential PEGylation sites in a VPAC2 receptor peptide agonist, serine scanning may be conducted. A Ser residue is substituted at a particular position in the peptide and the Ser-modified peptide is tested for potency and selectivity. If the Ser substitution has minimal impact on potency and the Ser-modified peptide is selective for the VPAC2 receptor, the Ser residue is then substituted for a Cys or Lys residue, which serves as a direct or indirect PEGylation site. Indirect PEGylation of a residue is the PEGylation of a chemical group or residue which is bonded to the PEGylation site residue. Indirect PEGylation of Lys includes PEGylation of K(W) and $K(CO(CH_2)_2SH)$.

The invention described herein provides PEGylated VPAC2 receptor peptide agonists. PEGylation can enhance the half-life of the selective VPAC2 receptor peptide agonists, resulting in PEGylated VPAC2 receptor peptide agonists with an elimination

half-life of at least one hour, preferably at least 3, 5, 7, 10, 15, 20, or 24 hours and most preferably at least 48 hours. The PEGylated VPAC2 receptor peptide agonists of the present invention preferably have a clearance value of 200 ml/h/kg or less, more preferably 180, 150, 120, 100, 80, 60 ml/h/kg or less and most preferably less than 50, 40 or 20 ml/h/kg.

The present invention encompasses the discovery that specific amino acids added to the C-terminus of a peptide sequence for a VPAC2 receptor peptide agonist may protect the peptide as well as may enhance activity, selectivity, and/or potency. For example, these C-terminal extensions may stabilize the helical structure of the peptide and stabilize sites located near to the C-terminus, which are prone to enzymatic cleavage. Furthermore, many of the C-terminally extended peptides disclosed herein may be more selective for the VPAC2 receptor and can be more potent than VIP, PACAP, and other known VPAC2 receptor peptide agonists. An example of a preferred C-terminal extension is the extension peptide of Exendin-4 as the C-capping sequence. Exendin-4 is found in the salivary excretions from the Gila Monster, *Heloderma Suspectum*, (Eng *et al., J.Biol.Chem.*, 267(11):7402-7405 (1992)). Other examples of C-terminal extensions are the C-terminal sequences of helodermin and helospectin. Helodermin and helospectin are also found in the salivary excretions of the Gila Monster.

It has furthermore been discovered that modification of the N-terminus of the VPAC2 receptor peptide agonist may enhance potency and/or provide stability against DPP-IV cleavage.

VIP and some known VPAC2 receptor peptide agonists are susceptible to cleavage by various enzymes and, thus, have a short *in vivo* half-life. Various enzymatic cleavage sites in the VPAC2 receptor peptide agonists are discussed below. The cleavage sites are discussed relative to the amino acid positions in VIP (SEQ ID NO: 14), and are applicable to the sequences noted herein.

Cleavage of the peptide agonist by the enzyme dipeptidyl-peptidase-IV (DPP-IV) occurs between position 2 (serine in VIP) and position 3 (aspartic acid in VIP). The agonists of the present invention may be rendered more stable to DPP-IV cleavage in this region by the addition of a N-terminal modification. Examples of N-terminal modifications that may improve stability against DPP-IV cleavage include the addition of acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-

phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid, or $-C(=NH_2)-NH_2$. Preferably, the N-terminal modification is the addition of acetyl or hexanoyl.

There are chymotrypsin cleavage sites in wild-type VIP between the amino acids 10 and 11 (tyrosine and threonine) and those at 22 and 23 (tyrosine and leucine). Making substitutions at position 10 and/or 11 and position 22 and/or 23 may increase the stability of the peptide at these sites. For example, substitution of tyrosine at position 10 and/or position 22 with Tyr(OMe) may increase stability.

There is a trypsin cleavage site between the amino acids at positions 12 and 13 of wild-type VIP. Certain amino acids render the peptide less susceptible to cleavage at this site, for example, ornithine at position 12 and amino isobutyric acid at position 13.

In wild-type VIP, and in numerous VPAC2 receptor peptide agonists known in the art, there are cleavage sites between the basic amino acids at positions 14 and 15 and between those at positions 20 and 21. The selective PEGylated VPAC2 receptor peptide agonists of the present invention may have improved proteolytic stability *in-vivo* due to substitutions at these sites. The preferred substitutions at these sites are those which render the peptide less susceptible to cleavage by trypsin-like enzymes, including trypsin. For example, amino isobutyric acid at position 15, amino isobutyric acid at position 20, and ornithine at position 21 are all preferred substitutions which may lead to improved stability. The improved stability of a representative number of selective PEGylated VPAC2 receptor peptide agonists with resistance to peptidase cleavage and encompassed by the present invention is demonstrated in Example 7.

There is also a cleavage site between the amino acids at positions 25 and 26 of wild type VIP.

The region of the VPAC2 receptor peptide agonist encompassing the amino acids at positions 27, 28, 29, 30 and 31 is also susceptible to enzyme cleavage. The addition of a C-terminal extension may render the peptide agonist more stable against neuroendopeptidase (NEP), it may also increase selectivity for the VPAC2 receptor. This region may also be attacked by trypsin-like enzymes. If that occurs, the peptide agonist may lose its C-terminal extension with the additional carboxypeptidase activity leading to an inactive form of the peptide. Preferred substitutions which may increase resistance to

cleavage in this region include ornithine at position 27, ornithine, or amino isobutyric acid at position 28 and ornithine at position 29.

In addition to selective PEGylated VPAC2 receptor peptide agonists with resistance to cleavage by various peptidases, the selective PEGylated VPAC2 peptide receptor agonists of the present invention may also encompass peptides with enhanced selectivity for the VPAC2 receptor, increased potency, and/or increased stability compared with some peptides known in the art. The increased potency and selectivity for various PEGylated VPAC2 receptor peptide agonists of the present invention is demonstrated in Examples 3, 4 and 5.

Table 1 in Example 3 provides a list of selective PEGylated VPAC2 receptor peptide agonists and their corresponding *in vitro* potency results. Preferably, the selective PEGylated VPAC2 receptor peptide agonists of the present invention have an EC_{50} value less than 200 nM. More preferably, the EC_{50} value is less than 100 nM. Even more preferably, the EC_{50} value is less than 50 nM. Still more preferably, the EC_{50} value is less than 30 nM.

Table 2 in Example 4 provides a list of PEGylated VPAC2 receptor peptide agonists and their corresponding receptor binding results for human VPAC2, VPAC1 and PAC1. See Example 4 for further details of these assays. The degree of selectivity is determined by a ratio of VPAC2 receptor binding affinity to VPAC1 receptor binding affinity and by a ratio of VPAC2 receptor binding affinity to PAC1 receptor binding affinity. Preferably, the agonists of the present invention have a selectivity ratio where the affinity for the VPAC2 receptor is at least 50 times greater than for the VPAC1 and/or for PAC1 receptors. More preferably, this affinity is at least 100 times greater for VPAC2 than for VPAC1 and/or for PAC1. Even more preferably, the affinity is at least 200 times greater for VPAC2 than for VPAC1 and/or for PAC1. Still more preferably, the affinity is at least 500 times greater for VPAC2 than for VPAC1 and/or for PAC1. Yet more preferably, the ratio is at least 1000 times greater for VPAC2 than for VPAC1 and/or for PAC1.

As used herein, "selective VPAC2 receptor peptide agonists" also include pharmaceutically acceptable salts of the agonists described herein. A selective VPAC2 receptor peptide agonist of this invention can possess a sufficiently acidic, a sufficiently basic, or both functional groups, and accordingly react with any of a number of inorganic

bases, and inorganic and organic acids, to form a salt. Acids commonly employed to form acid addition salts are inorganic acids such as hydrochloric acid, hydrobromic acid, hydroiodic acid, sulfuric acid, phosphoric acid, and the like, and organic acids such as *p*-toluenesulfonic acid, methanesulfonic acid, oxalic acid, *p*-bromophenyl-sulfonic acid, carbonic acid, succinic acid, citric acid, benzoic acid, acetic acid, trifluoroacetic acid, and the like. Examples of such salts include the sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate, chloride, bromide, iodide, acetate, propionate, decanoate, caprylate, acrylate, formate, isobutyrate, caproate, heptanoate, propiolate, oxalate, malonate, succinate, suberate, sebacate, fumarate, maleate, butyne-1,4-dioate, hexyne-1,6-dioate, benzoate, chlorobenzoate, methylbenzoate, dinitrobenzoate, hydroxybenzoate, methoxybenzoate, phthalate, sulfonate, xylenesulfonate, phenylacetate, phenylpropionate, phenylbutyrate, citrate, lactate, gamma-hydroxybutyrate, glycolate, tartrate, methanesulfonate, propanesulfonate, naphthalene-1-sulfonate, naphthalene-2-sulfonate, mandelate, and the like.

Base addition salts include those derived from inorganic bases, such as ammonium or alkali or alkaline earth metal hydroxides, carbonates, bicarbonates, and the like. Such bases useful in preparing the salts of this invention thus include sodium hydroxide, potassium hydroxide, ammonium hydroxide, potassium carbonate, and the like.

The selective PEGylated VPAC2 receptor peptide agonists of the present invention are preferably formulated as pharmaceutical compositions. Standard pharmaceutical formulation techniques may be employed such as those described in Remington's Pharmaceutical Sciences, Mack Publishing Company, Easton, PA. The selective PEGylated VPAC2 receptor peptide agonists of the present invention may be formulated for administration through the buccal, topical, oral, transdermal, nasal, or pulmonary route, or for parenteral administration.

Parenteral administration can include, for example, systemic administration, such as by intramuscular, intravenous, subcutaneous, intradermal, or intraperitoneal injection. The selective PEGylated VPAC2 receptor peptide agonists can be administered to the subject in conjunction with an acceptable pharmaceutical carrier, diluent, or excipient as part of a pharmaceutical composition for treating NIDDM, or

the disorders discussed below. The pharmaceutical composition can be a solution or, if administered parenterally, a suspension of the PEGylated VPAC2 receptor peptide agonist or a suspension of the PEGylated VPAC2 receptor peptide agonist complexed with a divalent metal cation such as zinc. Suitable pharmaceutical carriers may contain inert ingredients which do not interact with the peptide or peptide derivative. Suitable pharmaceutical carriers for parenteral administration include, for example, sterile water, physiological saline, bacteriostatic saline (saline containing about 0.9% mg/ml benzyl alcohol), phosphate-buffered saline, Hank's solution, Ringer's-lactate and the like. Some examples of suitable excipients include lactose, dextrose, sucrose, trehalose, sorbitol, and mannitol.

The PEGylated VPAC2 receptor peptide agonists of the invention may be formulated for administration such that blood plasma levels are maintained in the efficacious range for extended time periods. The main barrier to effective oral peptide drug delivery is poor bioavailability due to degradation of peptides by acids and enzymes, poor absorption through epithelial membranes, and transition of peptides to an insoluble form after exposure to the acidic pH environment in the digestive tract. Oral delivery systems for peptides such as those encompassed by the present invention are known in the art. For example, PEGylated VPAC2 receptor peptide agonists can be encapsulated using microspheres and then delivered orally. For example, PEGylated VPAC2 receptor peptide agonists can be encapsulated into microspheres composed of a commercially available, biocompatible, biodegradable polymer, poly(lactide-co-glycolide)-COOH and olive oil as a filler (see Joseph, et al. *Diabetologia* 43:1319-1328 (2000)). Other types of microsphere technology is also available commercially such as Medisorb® and Prolease® biodegradable polymers from Alkermes. Medisorb® polymers can be produced with any of the lactide isomers. Lactide:glycolide ratios can be varied between 0:100 and 100:0 allowing for a broad range of polymer properties. This allows for the design of delivery systems and implantable devices with resorption times ranging from weeks to months. Emisphere has also published numerous articles discussing oral delivery technology for peptides and proteins. For example, see WO 95/28838 by Leone-bay et al. which discloses specific carriers comprised of modified amino acids to facilitate absorption.

The selective PEGylated VPAC2 receptor peptide agonists described herein can be used to treat subjects with a wide variety of diseases and conditions. Agonists encompassed by the present invention exert their biological effects by acting at a receptor referred to as the VPAC2 receptor. Subjects with diseases and/or conditions that respond favourably to VPAC2 receptor stimulation or to the administration of VPAC2 receptor peptide agonists can therefore be treated with the PEGylated VPAC2 agonists of the present invention. These subjects are said to "be in need of treatment with VPAC2 agonists" or "in need of VPAC2 receptor stimulation".

The selective PEGylated VPAC2 receptor peptide agonists of the present invention may be employed to treat diabetes, including both type 1 and type 2 diabetes (non-insulin dependent diabetes mellitus or NIDDM). The agonists may also be used to treat subjects requiring prophylactic treatment with a VPAC2 receptor agonist, e.g., subjects at risk for developing NIDDM. Such treatment may also delay the onset of diabetes and diabetic complications. Additional subjects which may be treated with the agonists of the present invention include those with impaired glucose tolerance (IGT) (Expert Committee on Classification of Diabetes Mellitus, *Diabetes Care* 22 (Supp. 1):S5, 1999), or impaired fasting glucose (IFG) (Charles, et al., *Diabetes* 40:796, 1991), subjects whose body weight is about 25% above normal body weight for the subject's height and body build, subjects having one or more parents with NIDDM, subjects who have had gestational diabetes, and subjects with metabolic disorders such as those resulting from decreased endogenous insulin secretion. The selective PEGylated VPAC2 receptor peptide agonists may be used to prevent subjects with impaired glucose tolerance from proceeding to develop NIDDM, prevent pancreatic β-cell deterioration, induce β-cell proliferation, improve β-cell function, activate dormant β-cells, differentiate cells into β-cells, stimulate β-cell replication, and inhibit β-cell apoptosis. Other diseases and conditions that may be treated or prevented using agonists of the invention in methods of the invention include: Maturity-Onset Diabetes of the Young (MODY) (Herman, et al., *Diabetes* 43:40, 1994); Latent Autoimmune Diabetes Adult (LADA) (Zimmet, et al., *Diabetes Med.* 11:299, 1994); gestational diabetes (Metzger, *Diabetes*, 40:197, 1991); metabolic syndrome X, dyslipidemia, hyperglycemia, hyperinsulinemia, hypertriglyceridemia, and insulin resistance.

The selective PEGylated VPAC2 receptor peptide agonists of the invention may also be used to treat secondary causes of diabetes (Expert Committee on Classification of Diabetes Mellitus, *Diabetes Care* 22 (Supp. l):S5, 1999). Such secondary causes include glucocorticoid excess, growth hormone excess, pheochromocytoma, and drug-induced diabetes. Drugs that may induce diabetes include, but are not limited to, pyriminil, nicotinic acid, glucocorticoids, phenytoin, thyroid hormone, β-adrenergic agents, α-interferon and drugs used to treat HIV infection.

The selective PEGylated VPAC2 receptor peptide agonists of the present invention may be effective in the suppression of food intake and the treatment of obesity.

The selective PEGylated VPAC2 receptor peptide agonists of the present invention may also be effective in the prevention or treatment of such disorders as atherosclerotic disease, hyperlipidemia, hypercholesteremia, low HDL levels, hypertension, primary pulmonary hypertension, cardiovascular disease (including atherosclerosis, coronary heart disease and coronary artery disease), cerebrovascular disease and peripheral vessel disease; and for the treatment of lupus, polycystic ovary syndrome, carcinogenesis, and hyperplasia, male and female reproduction problems, sexual disorders, ulcers, sleep disorders, disorders of lipid and carbohydrate metabolism, circadian dysfunction, growth disorders, disorders of energy homeostasis, immune diseases including autoimmune diseases (e.g., systemic lupus erythematosus), as well as acute and chronic inflammatory diseases, rheumatoid arthritis, and septic shock.

The selective PEGylated VPAC2 receptor peptide agonists of the present invention may also be useful for treating physiological disorders related to, for example, cell differentiation to produce lipid accumulating cells, regulation of insulin sensitivity and blood glucose levels, which are involved in, for example, abnormal pancreatic β-cell function, insulin secreting tumors and/or autoimmune hypoglycemia due to autoantibodies to insulin, autoantibodies to the insulin receptor, or autoantibodies that are stimulatory to pancreatic β -cells, macrophage differentiation which leads to the formation of atherosclerotic plaques, inflammatory response, carcinogenesis, hyperplasia, adipocyte gene expression, adipocyte differentiation, reduction in the pancreatic β -cell mass, insulin secretion, tissue sensitivity to insulin, liposarcoma cell growth, polycystic ovarian disease, chronic anovulation, hyperandrogenism, progesterone production, steroidogenesis, redox potential and oxidative stress in cells, nitric oxide synthase (NOS)

production, increased gamma glutamyl transpeptidase, catalase, plasma triglycerides, HDL, and LDL cholesterol levels, and the like.

In addition, the selective PEGylated VPAC2 receptor peptide agonists of the invention may be used for treatment of asthma (Bolin, et al., *Biopolymer* 37:57-66 (1995); U.S. Patent No. 5,677,419; showing that polypeptide R3PO is active in relaxing guinea pig tracheal smooth muscle); hypotension induction (VIP induces hypotension, tachycardia, and facial flushing in asthmatic patients (Morice, et al., *Peptides* 7:279-280 (1986); Morice, et al., *Lancet* 2:1225-1227 (1983)); for the treatment of male reproduction problems (Siow, et al., *Arch. Androl.* 43(1):67-71 (1999)); as an anti-apoptosis/neuroprotective agent (Brenneman, et al., *Ann. N. Y. Acad. Sci.* 865:207-12 (1998)); for cardioprotection during ischemic events (Kalfin, et al., *J. Pharmacol. Exp. Ther.* 1268(2):952-8 (1994); Das, et al., *Ann. N. Y. Acad. Sci.* 865:297-308 (1998)); for manipulation of the circadian clock and its associated disorders (Hamar, et al., *Cell* 109:497-508 (2002); Shen, et al., *Proc. Natl. Acad. Sci.* 97:11575-80, (2000)); and as an anti-ulcer agent (Tuncel, et al., *Ann. N. Y. Acad. Sci.* 865:309-22, (1998)).

An "effective amount" of a selective PEGylated VPAC2 receptor peptide agonist is the quantity that results in a desired therapeutic and/or prophylactic effect without causing unacceptable side effects when administered to a subject in need of VPAC2 receptor stimulation. A "desired therapeutic effect" includes one or more of the following: 1) an amelioration of the symptom(s) associated with the disease or condition; 2) a delay in the onset of symptoms associated with the disease or condition; 3) increased longevity compared with the absence of the treatment; and 4) greater quality of life compared with the absence of the treatment. For example, an "effective amount" of a PEGylated VPAC2 agonist for the treatment of NIDDM is the quantity that would result in greater control of blood glucose concentration than in the absence of treatment, thereby resulting in a delay in the onset of diabetic complications such as retinopathy, neuropathy, or kidney disease. An "effective amount" of a selective PEGylated VPAC2 receptor peptide agonist for the prevention of NIDDM is the quantity that would delay, compared with the absence of treatment, the onset of elevated blood glucose levels that require treatment with anti-hypoglycemic drugs such as sulfonylureas, thiazolidinediones, insulin, and/or bisguanidines.

An "effective amount" of the selective PEGylated VPAC2 receptor peptide agonist administered to a subject will also depend on the type and severity of the disease and on the characteristics of the subject, such as general health, age, sex, body weight and tolerance to drugs. The dose of selective PEGylated VPAC2 peptide receptor agonist effective to normalize a patient's blood glucose will depend on a number of factors, among which are included, without limitation, the subject's sex, weight and age, the severity of inability to regulate blood glucose, the route of administration and bioavailability, the pharmacokinetic profile of the peptide, the potency, and the formulation.

A typical dose range for the selective PEGylated VPAC2 receptor peptide agonists of the present invention will range from about 1 µg per day to about 5000 µg per day. Preferably, the dose ranges from about 1 µg per day to about 2500 µg per day, more preferably from about 1 µg per day to about 1000 µg per day. Even more preferably, the dose ranges from about 5 µg per day to about 100 µg per day. A further preferred dose range is from about 10 µg per day to about 50 µg per day. Most preferably, the dose is about 20 µg per day.

A "subject" is a mammal, preferably a human, but can also be an animal, e.g., companion animals (e.g., dogs, cats, and the like), farm animals (e.g., cows, sheep, pigs, horses, and the like) and laboratory animals (e.g., rats, mice, guinea pigs, and the like).

The selective PEGylated VPAC2 receptor peptide agonists of the present invention can be prepared by using standard methods of solid-phase peptide synthesis techniques. Peptide synthesizers are commercially available from, for example, Rainin-PTI Symphony Peptide Synthesizer (Tucson, AZ). Reagents for solid phase synthesis are commercially available, for example, from Glycopep (Chicago, IL). Solid phase peptide synthesizers can be used according to manufacturers instructions for blocking interfering groups, protecting the amino acid to be reacted, coupling, decoupling, and capping of unreacted amino acids.

Typically, an α-*N*-protected amino acid and the *N*-terminal amino acid on the growing peptide chain on a resin is coupled at room temperature in an inert solvent such as dimethylformamide, N-methylpyrrolidone or methylene chloride in the presence of coupling agents such as dicyclohexylcarbodiimide and 1-hydroxybenzotriazole and a base

such as diisopropylethylamine. The α-*N*-protecting group is removed from the resulting peptide resin using a reagent such as trifluoroacetic acid or piperidine, and the coupling reaction repeated with the next desired *N*-protected amino acid to be added to the peptide chain. Suitable amine protecting groups are well known in the art and are described, for example, in Green and Wuts, *"Protecting Groups in Organic Synthesis"*, John Wiley and Sons, 1991. Examples include t-butyloxycarbonyl (tBoc) and fluorenylmethoxycarbonyl (Fmoc).

The selective VPAC2 receptor peptide agonists may also be synthesized using standard automated solid-phase synthesis protocols using t-butoxycarbonyl- or fluorenylmethoxycarbonyl-alpha-amino acids with appropriate side-chain protection. After completion of synthesis, modification of the N-terminus may be accomplished by reacting the α-amino group with, for example: (i) active esters (using similar protocols as described above for the introduction of an α-*N*-protected amino acid); (ii) aldehydes in the presence of a reducing agent (reductive amination procedure); and (iii) guanidation reagents. Then, peptides are cleaved from the solid-phase support with simultaneous side-chain deprotection using standard hydrogen fluoride methods or trifluoroacetic acid (TFA). Crude peptides are then further purified using Reversed-Phase Chromatography on VYDAC C18 columns using acetonitrile gradients in 0.1% TFA. To remove acetonitrile, peptides are lyophilized from a solution containing 0.1 % TFA, acetonitrile and water. Purity can be verified by analytical reversed phase chromatography. Identity of peptides can be verified by mass spectrometry. Peptides can be solubilized in aqueous buffers at neutral pH.

The peptide agonists of the present invention may also be made by recombinant methods known in the art using both eukaryotic and prokaryotic cellular hosts.

Once a peptide is prepared and purified, it is modified by covalently linking at least one PEG molecule to Cys or Lys residues, to K(W) or K($CO(CH_2)_2SH$), or to the carboxy-terminal amino acid. A wide variety of methods have been described in the art to produce peptides covalently conjugated to PEG and the specific method used for the present invention is not intended to be limiting (for review article see, Roberts, M. et al. *Advanced Drug Delivery Reviews,* 54:459-476, 2002).

An example of a PEG molecule which may be used is methoxy-PEG2-MAL-40K, a bifurcated PEG maleimide (Nektar, Huntsville, Alabama). Other examples include, but

are not limited to bulk mPEG-SBA-20K (Nektar), mPEG2-ALD-40K (Nektar) and methoxy-PEG-MAL-30K (Dow).

Carboxy-terminal attachment of PEG may be attached via enzymatic coupling using recombinant VPAC2 receptor peptide agonist as a precursor or alternative methods known in the art and described, for example, in U.S. Patent 4,343,898 or *Intl. J. Pept. & Prot. Res.* 43:127-38 (1994).

One method for preparing the PEGylated VPAC2 receptor peptide agonists of the present invention involves the use of PEG-maleimide to directly attach PEG to a thiol group of the peptide. The introduction of a thiol functionality can be achieved by adding or inserting a Cys or hC residue onto or into the peptide at positions described above. A thiol functionality can also be introduced onto the side-chain of the peptide (e.g. acylation of lysine ε-amino group by a thiol-containing acid, such as mercaptopropionic acid). A PEGylation process of the present invention utilizes Michael addition to form a stable thioether linker. The reaction is highly specific and takes place under mild conditions in the presence of other functional groups. PEG maleimide has been used as a reactive polymer for preparing well-defined, bioactive PEG-protein conjugates. It is preferable that the procedure uses a molar excess, preferably from 1 to 10 molar excess, of a thiol-containing VPAC2 receptor peptide agonist relative to PEG maleimide to drive the reaction to completion. The reactions are preferably performed between pH 4.0 and 9.0 at room temperature for 10 minutes to 40 hours. The excess of unPEGylated thiol-containing peptide is readily separated from the PEGylated product by conventional separation methods. The PEGylated VPAC2 receptor peptide agonist is preferably isolated using reverse-phase HPLC or size exclusion chromatography. Specific conditions required for PEGylation of VPAC2 receptor peptide agonists are set forth in Example 8. Cysteine PEGylation may be performed using PEG maleimide or bifurcated PEG maleimide.

An alternative method for preparing the PEGylated VPAC2 receptor peptide agonists of the invention, involves PEGylating a lysine residue using a PEG-succinimidyl derivative. In order to achieve site specific PEGylation, the Lys residues which are not used for PEGylation are substituted for Arg residues.

Another approach for PEGylation is via Pictet-Spengler reaction. A Trp residue with its free amine is needed to incorporate the PEG molecule onto a VPAC2 receptor

selective peptide. One approach to achieve this is to site specifically introduce a Trp residue onto the amine of a Lys sidechain via an amide bond during the solid phase synthesis (see Example 10).

Various preferred features and embodiments of the present invention will now be described only by way of the examples with reference to the following figure in which:-

Figure 1 shows the enhancement of the insulin response to the i.v. glucose challenge in animals treated with P505 or P525 24h prior to the glucose injection. The insulin response in vehicle-treated animals is shown for reference.

Example 1 - Preparation of the Selective VPAC2 Receptor Peptide Agonists by Solid Phase t-Boc Chemistry:

Approximately 0.5-0.6 grams (0.38-0.45 mmole) Boc Ser(Bzl)-PAM resin is placed in a standard 60 mL reaction vessel. Double couplings are run on an Applied Biosystems ABI430A peptide synthesizer.

The following side-chain protected amino acids (2 mmole cartridges of Boc amino acids) are obtained from Midwest Biotech (Fishers, IN) and are used in the synthesis:

Arg-Tosyl (TOS), Asp-δ-cyclohexyl ester (OcHx), Glu-δ-cycohexyl ester (OcHx), His-benzyloxymethyl(BOM), Lys-2-chlorobenzyloxycarbonyl (2Cl-Z), Ser-O-benzyl ether (OBzl), Thr-O-benzyl ether (OBzl), Trp-formyl (CHO) and Tyr-2-bromobenzyloxycarbonyl (2Br-Z).

Trifluoroacetic acid (TFA), di-isopropylethylamine (DIEA), 0.5 M hydroxybenzotriazole (HOBt) in DMF and 0.5 M dicyclohexylcarbodiimide (DCC) in dichloromethane are purchased from PE-Applied Biosystems (Foster City, CA). Dimethylformamide (DMF-Burdick and Jackson) and dichloromethane (DCM-Mallinkrodt) is purchased from Mays Chemical Co. (Indianapolis, IN).

Standard double couplings are run using either symmetric anhydride or HOBt esters, both formed using DCC. At the completion of the syntheses, the N-terminal Boc group is removed and the peptidyl resins are treated with 20% piperidine in DMF to deformylate the Trp side chain if Trp is present in the sequence. For the N-terminal acylation, four-fold excess of symmetric anhydride of the corresponding acid is added onto the peptide resin. The symmetric anhydride is prepared by diisopropylcarbodiimde (DIC) activation in DCM. The reaction is allowed to proceed for 4 hours and monitored

by ninhydrin test. After washing with DCM, the resins are transferred to a TEFLON reaction vessel and are dried *in vacuo*.

Cleavages are done by attaching the reaction vessels to a HF (hydrofluoric acid) apparatus (Penninsula Laboratories). 1 mL m-cresol per gram/resin is added and 10 mL HF (purchased from AGA, Indianapolis, IN) is condensed into the pre-cooled vessel. 1 mL DMS per gram resin is added when methionine is present. The reactions are stirred one hour in an ice bath. The HF is removed *in vacuo*. The residues are suspended in ethyl ether. The solids are filtered and are washed with ether. Each peptide is extracted into aqueous acetic acid and either is freeze dried or is loaded directly onto a reverse-phase column.

Purifications are run on a 2.2 x 25cm VYDAC C18 column in buffer A (0.1% TFA in water). A gradient of 20% to 90% B (0.1% TFA in acetonitrile) is run on an HPLC (Waters) over 120 minutes at 10 mL/minute while monitoring the UV at 280 nm (4.0 A) and collecting one minute fractions. Appropriate fractions are combined, frozen and lyophilized. Dried products are analyzed by HPLC (0.46 x 15 cm METASIL AQ C18) and MALDI mass spectrometry.

Example 2 - Preparation of the Selective VPAC2 Receptor Peptide Agonists by Solid Phase FMoc Chemistry:

Approximately 114 mg (50 mMole) FMOC Ser(tBu) WANG resin (purchased from GlycoPep, Chicago, IL) is placed in each reaction vessel. The synthesis is conducted on a Rainin Symphony Peptide Synthesizer. Analogs with a C-terminal amide are prepared using 75 mg (50 μmole) Rink Amide AM resin (Rapp Polymere. Tuebingen, Germany).

The following FMOC amino acids are purchased from GlycoPep (Chicago, IL), and NovaBiochem (La Jolla, CA): Arg-2,2,4,6,7-pentamethyldihydrobenzofuran-5-sulfonyl (Pbf), Asn-trityl (Trt), Asp-β-t-Butyl ester (tBu), Glu-δ-t-butyl ester (tBu), Gln-trityl (Trt), His-trityl (Trt), Lys-t-butyloxycarbonyl (Boc), Ser-t-butyl ether (OtBu), Thr-t-butyl ether (OtBu), Trp-t-butyloxycarbonyl (Boc), Tyr-t-butyl ether (OtBu).

Solvents dimethylformamide (DMF-Burdick and Jackson), N-methyl pyrrolidone (NMP-Burdick and Jackson), dichloromethane (DCM-Mallinkrodt) are purchased from Mays Chemical Co. (Indianapolis, IN).

Hydroxybenzotrizole (HOBt), di-isopropylcarbodiimde (DIC), di-isopropylethylamine (DIEA), and piperidine (Pip) are purchased from Aldrich Chemical Co (Milwaukee, WI).

All amino acids are dissolved in 0.3 M in DMF. Three hour DIC/HOBt activated couplings are run after 20 minutes deprotection using 20% Pip/DMF. Each resin is washed with DMF after deprotections and couplings. After the last coupling and deprotection, the peptidyl resins are washed with DCM and are dried *in vacuo* in the reaction vessel. For the N-terminal acylation, four-fold excess of symmetric anhydride of the corresponding acid is added onto the peptide resin. The symmetric anhydride is prepared by DIC activation in DCM. The reaction is allowed to proceed for 4 hours and monitored by ninhydrin test. The peptide resin is then washed with DCM and dried *in vacuo*.

The cleavage reaction is mixed for 2 hours with a cleavage cocktail consisting of 0.2 mL thioanisole, 0.2 mL methanol, 0.4 mL triisopropylsilane, per 10 mL TFA, all purchased from Aldrich Chemical Co., Milwaukee, WI. If Cys is present in the sequence, 2% of ethanedithiol is added. The TFA filtrates are added to 40 mL ethyl ether. The precipitants are centrifuged 2 minutes at 2000 rpm. The supernatants are decanted. The pellets are resuspended in 40 mL ether, re-centrifuged, re-decanted, dried under nitrogen and then *in vacuo*.

0.3-0.6 mg of each product is dissolved in 1 mL 0.1% TFA/acetonitrile(ACN), with 20 µL being analyzed on HPLC [0.46 x 15cm METASIL AQ C18, 1mL/min, 45°C, 214 nM (0.2A), A=0.1%TFA, B=0.1%TFA/50%ACN. Gradient = 50% B to 90% B over 30 minutes].

Purifications are run on a 2.2 x 25 cm VYDAC C18 column in buffer A (0.1% TFA in water). A gradient of 20% to 90% B (0.1% TFA in acetonitrile) is run on an HPLC (Waters) over 120 minutes at 10 mL/minute while monitoring the UV at 280 nm (4.0A) and collecting 1 minute fractions. Appropriate fractions are combined, frozen and lyophilized. Dried products are analyzed by HPLC (0.46 x 15 cm METASIL AQ C18) and MALDI mass spectrometry.

Precursor to P521 (C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY AibQSIOrnOrnGGPSSGAPPPCC-NH_2): Synthesis is carried out using the FMoc protocols described above. The peptide is characterised by analytical HPLC: t_R = 10.9 min, HPLC conditions as described above, and MALDI-TOF: calculated m/z = 4290.0, measured m/z = 4290.8 [M+H^+]. After purification using reversed-phase preparative HPLC, pure fractions are combined and lyophilised: 14.8 mg is obtained as a final lyophilised powder.

Precursor to P525 (C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQ AibIOrnOrnGGPSSGAPPPCC-NH_2): As described for the precursor to P521. Analytical HPLC: t_R = 11.0 min. MALDI-TOF: calculated m/z = 4288.0, measured m/z = 4288.8 [M+H^+]. 18.7 mg is obtained as a final lyophilised powder.

Precursor to P574 (C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrn Y(OMe)LQAibIOrnOrnGGPSSGAPPPCC-NH_2): As described for the precursor to P521. Analytical HPLC: t_R = 11.7 min. MALDI-TOF: calculated m/z = 4330.1, measured m/z = 4330.7 [M+H^+]. 46.2 mg is obtained as a final lyophilised powder.

Example 3 – *In-vitro* Potency at Human VPAC2 Receptors:

Alpha screen: Cells are washed in the culture flask once with PBS. Then, the cells are rinsed with enzyme free dissociation buffer. The dissociated cells are removed. The cells are then spun down and washed in stimulation buffer. For each data point, 50,000 cells suspended in stimulation buffer are used. To this buffer, Alpha screen acceptor beads are added along with the stimuli. This mixture is incubated for 60 minutes. Lysis buffer and Alpha screen donor beads are added and are incubated for 60 to 120 minutes. The Alpha screen signal (indicative of intracellular cAMP levels) is read in a suitable instrument (e.g. AlphaQuest from Perkin-Elmer). Steps including Alpha screen donor and acceptor beads are performed in reduced light. The EC_{50} for cAMP generation is calculated from the raw signal or is based on absolute cAMP levels as determined by a standard curve performed on each plate.

Results for each agonist are, at minimum, from two analyses performed in a single run. For some agonists, the results are the mean of more than one run. The tested peptide concentrations are: 10000, 1000, 100, 10, 3, 1, 0.1, 0.01, 0.003, 0.001, 0.0001 and 0.00001 nM.

DiscoveRx: A CHO-S cell line stably expressing human VPAC2 receptor in a 96-well microtiter plate is seeded with 50,000 cells/well the day before the assay. The cells are allowed to attach for 24 hours in 200 µL culture medium. On the day of the experiment, the medium is removed. Also, the cells are washed twice. The cells are incubated in assay buffer plus IBMX for 15 minutes at room temperature. Afterwards, the stimuli are added and are dissolved in assay buffer. The stimuli are present for 30 minutes. Then, the assay buffer is gently removed. The cell lysis reagent of the DiscoveRx cAMP kit is added. Thereafter, the standard protocol for developing the cAMP signal as described by the manufacturer is used (DiscoveRx Inc., USA). EC_{50} values for cAMP generation are calculated from the raw signal or are based on absolute cAMP levels as determined by a standard curve performed on each plate.

Results for each agonist are the mean of two independent runs. The typically tested concentrations of peptide are: 1000, 300, 100, 10, 1, 0.3, 0.1, 0.01, 0.001, 0.0001 and 0 nM.

The activity (EC_{50} (nM)) for the human VPAC2 receptor is reported in Table 1 for the different assay formats.

Table 1. Peptide potency at human VPAC2 receptors

Agonist #	Human VPAC2 Receptor: Alphascreen (EC_{50};nM)	Human VPAC2 Receptor: DiscoveRx (EC_{50};nM)
VIP	1.0	0.7
PACAP-27	2.3	0.8
P410	128.8	
P417	14.7	
P451	68.6	
P454	59.9	
P460	430.2	
P470	83.3	
P472	123.3	
P473	26.5	
P475	109.3	
P478	49.9	
P483	33.5	
P485	44.5	
P490	115.6	
P492	509.6	
P495	116.7	

P497	176.1	
P499	57.7	
P501	130.9	
P503	146.8	
P505	40.5	
P507	27.1	
P509	13.0	
P511	7.6	
P513	28.9	
P517	7.5	
P519	30.3	
P521	22.1	
P523	5.8	
P525	25.0	
P529	170.5	
P531	94.6	
P533	2382.0	
P535	98.4	
P537	32.0	
P541	45.8	
P545	45.0	
P547	62.0	
P539	10.7	47.3
P543	84.2	8.9
P551	15.6	
P553	15.0	
P555	22.5	8.1
P557		108.3
P560	13.8	11.3
P562	30.2	24.2
P566	11.8	7.8
P568	128.6	
P570	13.4	4.5
P572	11.2	
P574	21.2	36.1
P576	55.0	
P578	205.3	
P580	10.9	
P582	20.3	
P584	51.2	
P586	122.4	
P588	54.0	
P590	4.1	
P602	42.1	7.2

Example 4 – Selectivity:

Binding assays: Membrane prepared from a stable VPAC2 cell line (see Example 3) or from cells transiently transfected with human VPAC1 or PAC1 are used. A filter binding assay is performed using 125I-labeled VIP for VPAC1 and VPAC2 and 125I-labeled PACAP-27 for PAC1 as the tracers.

For this assay, the solutions and equipment include:

Presoak solution: 0.5 % Polyethyleneamine in Aqua dest

Buffer for flushing filter plates: 25 mM HEPES pH 7.4

Blocking buffer: 25 mM HEPES pH 7.4; 0.2 % protease free BSA

Assay buffer: 25 mM HEPES pH 7.4; 0.5 % protease free BSA

Dilution and assay plate: PS-Microplate, U form

Filtration Plate: Multiscreen FB Opaque Plate; 1.0 µM Type B Glasfiber filter

In order to prepare the filter plates, the presoak solution is aspirated by vacuum filtration. The plates are flushed twice with 200 µL flush buffer. 200 µL blocking buffer is added to the filter plate. The filter plate is then incubated with 200 µL presoak solution for 1 hour at room temperature.

The assay plate is filled with 25 µL assay buffer, 25 µL membranes (2.5 µg) suspended in assay buffer, 25 µL agonist in assay buffer, and 25 µL tracer (about 40000 cpm) in assay buffer. The filled plate is incubated for 1 hour with shaking.

The transfer from assay plate to filter plate is conducted. The blocking buffer is aspirated by vacuum filtration and washed two times with flush buffer. 90 µL is transferred from the assay plate to the filter plate. The 90 µL transferred from assay plate is aspirated and washed three times with 200 µL flush buffer. The plastic support is removed. It is dried for 1 hour at 60 °C. 30 µL Microscint is added. The count is performed.

The receptor binding (IC_{50}) for human VPAC2, VPAC1 and PAC1 is reported in Table 2.

Table 2.

Agonist #	Human VPAC2	Human VPAC1	Human PAC1

	Receptor Binding (IC50;nM)	Receptor Binding (IC50;nM)	Receptor Binding (IC50;nM)
VIP	5.1	3.3	>1000
PACAP-27	2.6	4.5	10.2
P410	264.4	>25000	
P417	24.1	>25000	
P451	595.7		
P454	36.6	>25000	
P460	914.5	>25000	
P470	262.9		
P473	256.4	>25000	
P475	436.0		
P478	30.0		
P483	37.3	>25000	
P485	17.3		
P490	13.2		
P492	156.0		
P495	142.1		
P497	146.0		
P499	34.0	>25000	
P501	111.0		
P503	41.5		
P505	26.1	>25000	>25000
P509	11.2	>25000	
P511	7.2	>25000	>25000
P513	50.5		
P517	3.7	>25000	
P519	51.6		
P521	67.1		
P523	4.8		
P525	41.8	>25000	>25000
P529	192.4		
P531	69.7		
P533	959.0		
P535	145.4	>25000	
P537	17.2	>25000	>25000
P539	13.5		
P541	59.8	>25000	
P543	56.3		
P545	79.9	>25000	>25000
P547	5.6		
P551	16.6	>25000	>25000
P553	21.7	>25000	>25000
P555	15.4	>25000	>25000
P557	380.0		

P560	11.6		
P562	42.8	>25000	>25000
P566	8.2		
P570	4.1	>25000	>25000
P572	14.9	>25000	>25000
P574	32.3	>25000	>25000
P580	20.7	>25000	>25000
P582	48.3	>25000	>25000
P590	7.4	>25000	>25000
P602	28.0	>25000	>25000

Example 5 - *In vitro* potency at rat VPAC1 and VPAC2 receptors:

DiscoveRx: CHO-PO cells are transiently transfected with rat VPAC1 or VPAC2 receptor DNA using commercially available transfection reagents (Lipofectamine from Invitrogen). The cells are seeded at a density of 10,000/well in a 96-well plate and are allowed to grow for 3 days in 200ml culture medium At day 3, the assay is performed.

On the day of the experiment, the medium is removed. Also, the cells are washed twice. The cells are incubated in assay buffer plus IBMX for 15 minutes at room temperature. Afterwards, the stimuli are added and are dissolved in assay buffer. The stimuli are present for 30 minutes. Then, the assay buffer is gently removed. The cell lysis reagent of the DiscoveRx cAMP kit is added. Thereafter, the standard protocol for developing the cAMP signal as described by the manufacturer is used (DiscoveRx Inc., USA). EC_{50} values for cAMP generation are calculated from the raw signal or are based on absolute cAMP levels as determined by a standard curve performed on each plate.

Results for each agonist are the mean of two independent runs. Rat VPAC1 and VPAC2 results are only generated using the DiscoveRx assay. The typically tested concentrations of peptide are: 1000, 300, 100, 10, 1, 0.3, 0.1, 0.01, 0.001, 0.0001 and 0 nM.

The activity (EC_{50}(nM)) for the rat VPAC2 and VPAC1 receptors is reported in Table 3.

Table 3

Agonist #	Rat VPAC1 Receptor: DiscoveRx: (EC_{50};nM)	Rat VPAC2 Receptor: DiscoveRx: (EC_{50};nM)
VIP	0.01	0.6

P410	>1000	318.5
P417	232.3	8.7
P454	1229.5	79.6
P460	>1000	1163.1
P470	>1000	110.9
P472	>1000	284.6
P473	>1000	25.5
P475	>1000	220.4
P478	2053.8	120.1
P483	223.9	128.4
P485	734.9	42.5
P490	>1000	191.8
P492	>4000	962.7
P497	>1000	344.7
P499	803.8	68.2
P501	>1000	272.1
P503	>4000	520.3
P505	639.4	42.6
P507	>1000	94.9
P509	328.4	28.2
P511	61.9	13.9
P517	92.4	10.0
P521	602.4	33.1
P523	20.4	5.3
P525	1137.3	44.0
P529	1182.9	199.3
P531	300.7	69.9
P535	>1000	317.6
P537	205.8	38.8
P539	32.6	21.0
P541	665.1	101.9
P543	355.0	101.1
P545	380.5	99.5
P547	76.2	149.8
P551	171.9	13.2
P553	261.8	22.0
P555	68.9	32.5
P557	581.1	397.2
P560	155.6	20.4
P562	393.4	52.5
P566	52.7	13.1
P568	>1000	250.3
P570	86.7	21.3
P572	94.5	10.8
P574	162.9	33.8
P576	460.9	67.4

P578	269.4	305.6
P580	1.1	11.9
P582	137.4	31.0
P584	188.1	67.2
P586	501.6	186.8
P588	406.3	311.2
P590	245.0	6.9
P602	209.0	36.9

Example 6 - *In vivo* assays:

Intravenous glucose tolerance test (IVGTT): Normal Wistar rats are fasted overnight and are anesthetized prior to the experiment. A blood sampling catheter is inserted into the rats. The agonist is given subcutaneously, normally 24h prior to the glucose challenge. Blood samples are taken from the carotid artery. A blood sample is drawn immediately prior to the injection of glucose along with the agonist. After the initial blood sample, glucose mixed is injected intravenously (i.v.). A glucose challenge of 0.5 g/kg body weight is given, injecting a total of 1.5 mL vehicle with glucose and agonist per kg body weight. The peptide concentrations are varied to produce the desired dose in μg/kg. Blood samples are drawn at 2, 4, 6 and 10 minutes after giving glucose. The control group of animals receives the same vehicle along with glucose, but with no agonist added. In some instances, 20 and 30 minute post-glucose blood samples were drawn. Aprotinin is added to the blood sample (250-500 kIU/ml blood). The plasma is then analyzed for glucose and insulin using standard methodologies.

The assay uses a formulated and calibrated peptide stock in PBS. Normally, this stock is a prediluted 100 μM stock. However, a more concentrated stock with approximately 1 mg agonist per mL is used. The specific concentration is always known. Variability in the maximal response is mostly due to variability in the vehicle dose. Protocol details are as follows:

SPECIES/STRAIN/WEIGHT	Rat/Wistar Unilever/approximately 275 - 300 g
TREATMENT DURATION	Single dose
DOSE VOLUME/ROUTE	1.5 mL/kg/iv
VEHICLE	8% PEG300, 0.1% BSA in water
FOOD/WATER REGIMEN	Rats are fasted overnight prior to surgery.
LIVE-PHASE PARAMETERS	Animals are sacrificed at the end of the test.
IVGTT: Performed on rats (with two	Glucose IV bolus: 500 mg/kg as 10% solution

catheters, jugular vein and carotid artery) of each group, under pentobarbital anesthesia.	(5 mL/kg) at time = 0. Compound iv: 0 – 240 min prior to glucose Blood samplings (300 µL from carotid artery; EDTA as anticoagulant; aprotinin and PMSF as antiproteolytics; kept on ice): 0, 2, 4, 6, and 10, 20 and 30 minutes. Parameters determined: Insulin + glucose
TOXICOKINETICS	Plasma samples remaining after insulin measurements are kept at –20°C and compound levels are determined.

Table 4a

Agonist #	Time between glucose & compound	% increase AUC: Dose = 0.09 mg/kg	% increase AUC: Dose = 0.1 mg/kg	% increase AUC: Dose = 0.3 mg/kg
P505	24h		12	74
P511	24h		38	59
P525	24h		72	208
P570	24h		36	
P602	24h	73		198

AUC = Area under curve (insulin, 0 - 10 min after glucose)

Pharmacokinetic profiles of PEGylated peptides. Healthy Fisher 344 rats (3 animals per group) were injected with 100 µg agonist/kg (agonist amount based on peptide content and dissolved in PBS buffer). Blood samples were drawn 3, 12, 24, 48, 72, 96 and 168 hour post dosing and the peptide content in plasma was analysed by a radio-immunoassay (RIA) directed against the N-terminus of the peptide. PK parameters were then calculated using a model-independent method (WinNonlin Pro, Pharsight Corp., Mountain View, CA, USA).

Table 4b. PK parameters of PEGylated peptide agonists. Mean and (SD) values for N=3.

Agonist #	Cmax (ng/mL)	Tmax (h)	$AUC_{0\text{-last}}$ (ng*h/mL)	T1/2 (h)	Cl/F (mL/h/kg)	Vd/F (mL/kg)
P499	132 (9)	24 (<1)	6650 (1294)	25 (5)	15 (2)	529 (85)
P505	160 (30)	12 (<1)	7006 (890)	22 (5)	13 (1)	425 (116)

P511	100 (16)	16 (7)	3067 (374)	NC NC	NC NC	NC NC
P521	233 (29)	12 (<1)	7633 (1871)	19 (6)	13 (3)	380 (208)
P525	133 (21)	16 (7)	4740 (486)	22 (3)	20 (2)	642 (126)
P539	102 (16)	24 (<1)	4013 (511)	15 (2)	25 (3)	540 (129)
P545	139 (48)	72 (42)	12737 (2492)	43 (5)	7 (2)	457 (66)
P555	102 (9)	16 (7)	4918 (597)	13 (1)	20 (3)	389 (65)
P562	120 (67)	24 (21)	5456 (2157)	25 (7)	19 (6)	673 (315)
P570	71 (34)	20 (7)	3891 (1309)	25 (4)	25 (7)	877 (326)
P574	70 (6)	20 (7)	3408 (312)	18 (2)	28 (2)	727 (71)

*NC = not calculated due to insufficient data

Example 7 - Rat Serum Stability Studies:

In order to determine the stability of VPAC2 receptor peptide agonists in rat serum, CHO-VPAC2 cells clone #6 (96 well plates/50,000 cells/well and 1 day culture), PBS 1X (Gibco), the peptides for the analysis in a 100 µM stock solution, rat serum from a sacrificed normal Wistar rat, aprotinin, and a DiscoveRx assay kit are obtained. The rat serum is stored at 4°C until use and is used within two weeks.

On Day 0, two 100 µL aliquots of 10 µM peptide in rat serum are prepared by adding 10 µL peptide stock to 90 µL rat serum for each aliquot. 250 kIU aprotinin / mL is added to one of these aliquots. The aliquot is stored with aprotinin at 4°C. The aliquot is stored without aprotinin at 37°C. The aliquots are incubated for 24 or 72 hours.

On Day 1, after incubation of the aliquots prepared on day 0 for 24 or 72 hours, an incubation buffer containing PBS + 1.3 mM $CaCl_2$, 1.2 mM $MgCl_2$, 2 mM glucose, and 0.25 mM IBMX is prepared. A plate with 11 serial 5X dilutions of peptide for the 4°C and 37°C aliquot is prepared for each peptide studied. 2000 nM is used as the maximal concentration if the peptide has an EC_{50} above 1 nM and 1000 nM as maximal concentration if the peptide has an EC_{50} below 1 nM from the primary screen (see Example 3). The plate(s) are washed with cells twice in incubation buffer. The plates are allowed to hold 50 µL incubation media per well for 15 minutes. 50 µL solution per well

is transferred to the cells from the plate prepared with 11 serial 5X dilutions of peptide for the 4°C and 37°C aliquot for each peptide studied, using the maximal concentrations that are indicated by the primary screen, in duplicate. This step dilutes the peptide concentration by a factor of two. The cells are incubated at room temperature for 30 minutes. The supernatant is removed. 40 µL/well of the DiscoveRx antibody/extraction buffer is added. The cells are incubated on the shaker (300 rpm) for 1 hour. Normal procedure with the DiscoveRx kit is followed. cAMP standards are included in column 12. EC_{50} values are determined from the cAMP assay data. The remaining amount of active peptide is estimated by the formula $EC_{50,\ 4°C}/EC_{50,\ 37°C}$ for each condition.

Table 5 Estimated peptide stability after 24h or 72h in rat serum at 37°C

Agonist #	24h stab (%)	72h stab (%)
VIP	0.2	
P417	265	
P472	66	
P473	86	
P475	61	
P478	34	
P483	22	
P485	65	
P492	131	
P503	174	
P505	133	161
P521		294
P523		281
P525	298	353
P529		119
P543	119	
P539	123	
P555	117	
P557	131	
P560	192	
P562	213	
P566	152	
P574	288	
P602	573	

[1]Values >100% may represent release of intact peptide from the PEG conjugate

Example 8 - PEGylation of selective VPAC2 receptor peptide agonists using thiol-based chemistry:

In general, PEGylation reactions are run under conditions that permit the formation of a thioether bond. Specifically, the pH of the solution ranges from about 4 to 9 and the thiol-containing peptide concentrations range from 0.7 to 10 molar excess of PEG maleimide concentration. The PEGylation reactions are normally run at room temperature. The PEGylated VPAC2 receptor peptide agonist is then isolated using reverse-phase HPLC or size exclusion chromatography (SEC). PEGylated peptide agonists are characterized using analytical RP-HPLC, HPLC-SEC, SDS-PAGE, and/or MALDI Mass Spectrometry.

Usually a thiol function is introduced into or onto a selective VPAC2 receptor peptide agonist by adding a cysteine or a homocysteine or a thiol-containing moiety at either or both termini or by inserting a cysteine or a homocysteine or a thiol-containing moiety into the sequence. Thiol-containing VPAC2 receptor peptide agonists are reacted with 40 kDa, 30 kDa or 20 kDa PEG-maleimide to produce derivatives with PEG covalently attached via a thioether bond.

Synthesis of P505

19 mg of the peptide precursor (non-PEGylated P505) and 162 mg of methoxy-PEG-maleimide (NOF, Japan) with an average molecular weight of 20,000 Daltons are dissolved in 2 mL of 100 mM NH_4Ac buffer containing 10 mM EDTA (pH 6.8) and the reaction is allowed to proceed for 4 h. 97 mg of the product is obtained as a lyophilized powder after preparative RP-HPLC purification. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro* activity.

Synthesis of P525

18.7 mg of the peptide precursor (non-PEGylated P525) and 157 mg of methoxy-PEG-maleimide with an average molecular weight of 20,000 Daltons are dissolved in 2 mL of 100 mM NH_4Ac buffer containing 10 mM EDTA (pH 6.8) and the reaction is allowed to proceed for 4 h. 114 mg of the product is obtained as a lyophilized powder after preparative RP-HPLC purification. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro* activity.

Synthesis of P572

22.3 mg of the peptide precursor (non-PEGylated P572), and 177 mg of methoxy-PEG-maleimide with an average molecular weight of 20,000 Daltons are dissolved in 2 mL of 100 mM NH_4Ac buffer containing 10 mM EDTA (pH 6.8) and the reaction is allowed to proceed for 4 h. 137 mg of the product is obtained as a lyophilized powder after preparative RP-HPLC purification. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro* activity.

Synthesis of P574

31.9 mg of the peptide precursor (non-PEGylated P574) and 283 mg of methoxy-PEG-maleimide with an average molecular weight of 20,000 Daltons are dissolved in 3 mL of 100 mM NH_4Ac buffer containing 10 mM EDTA (pH 6.8) and the reaction is allowed to proceed for 4 h. 171 mg of the product is obtained as a lyophilized powder after two runs of preparative RP-HPLC purifications. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro* activity.

Synthesis of P602

20 mg of the peptide precursor (non-PEGylated P602) and 223 mg of methoxy-poly(ethyleneglycol) maleimido-propioaamide (Chirotech Technology Ltd., UK) with an average molecular weight of 30,000 Daltons are dissolved in 2 mL of 100 mM NH_4Ac buffer containing 10 mM EDTA (pH 6.8) and the reaction is allowed to proceed for 4 h. 132 mg of the product is obtained as a lyophilized powder after preparative RP-HPLC purification. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro* activity.

Example 9 - PEGylation via acylation on the sidechain of Lysine:

In order to achieve site-specific PEGylation of selective VPAC2 receptor peptide agonists, all the Lys residues are changed into Arg residues except for Lys residues where PEGylation is intended. A PEG molecule which may be used is mPEG-SBA-20K (Nektar, Lot #: PT-04E-11). The PEGylation reaction is preferably performed at room temperature for 2-3 hours. The peptide is purified by preparative HPLC.

Example 10 - PEGylation via Pictet-Spengler reaction:

For PEGylation via Pictet-Spengler reaction to occur, a Trp residue with its free amine is needed to incorporate the PEG molecule onto the selective VPAC2 receptor peptide agonist. To couple a Trp residue onto the sidechain of Lys residue. The extensive SAR indicates that this modification does not change the properties of the parent peptide in terms of its *in vitro* potency and selectivity.

PEG with a functional aldehyde, for example mPEG2-BUTYRALD-40K (Nektar, USA), is used for the reaction. The site specific PEGylation involves the formation a tetracarboline ring between PEG and the peptide. PEGylation is conducted in glacial acetic acid at room temperature for 1 to 48 hours. A 1 to 10 molar excess of the PEG aldehyde is used in the reaction. After the removal of acetic acid, the PEGylated VPAC2 receptor peptide agonist is isolated by preparative RP-HPLC.

Synthesis of P535

27.7 mg of the peptide precursor (non-PEGylated P535) and 590 mg of mPEG2-BUTYRALD-40K are dissolved in 3 mL acetic acid and the reaction is allowed to proceed for 2 days. The product is isolated by preparative RP-HPLC to yield 94 mg of the PEGylated peptide agonist as a lyophilized powder. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro.*

Synthesis of P557

23 mg of the peptide precursor (non-PEGylated P557) and 460 mg of mPEG2-BUTYRALD-40K are dissolved in 3 mL acetic acid and the reaction is allowed to proceed for 2 days. The product is isolated by preparative RP-HPLC to yield 50 mg of the PEGylated peptide agonist as a lyophilized powder. The PEGylated peptide agonist is characterized by RP-HPLC and size-exclusion HPLC, and tested for *in vitro.*

Other modifications of the present invention will be apparent to those skilled in the art without departing from the scope of the invention.

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CLAIMS

1. A PEGylated VPAC2 receptor peptide agonist comprising a sequence selected from:

SEQ ID NO: 17 HSDAVFTEQY(OMe)TRAibRAibQLAAAibOrnY(OMe)LQSIKAibOrn;

SEQ ID NO: 18 HSDAVFTEK(CO(CH_2)$_2$SH)Y(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 19 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnK(W)Orn;

SEQ ID NO: 20 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(CO(CH_2)$_2$SH)YLQSIOrnOrn;

SEQ ID NO: 21 HSDAVFTEQY(OMe)TOrnLRAibQVAAK(CO(CH_2)$_2$SH)OrnYLQSIOrnOrn;

SEQ ID NO: 22 HSDAVFTEQY(OMe)TOrnLRAibQVCAAibOrnYLQSIOrnOrn;

SEQ ID NO: 23 HSDAVFTEQY(OMe)TOrnLRCQVAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 24 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 25 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYAibQSIOrnOrn;

SEQ ID NO: 26 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQAibIOrnOrn;

SEQ ID NO: 27 HSDAVFTEQY(OMe)TOrnLRAibQVAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 28 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQAibIOrnOrn;

SEQ ID NO: 29 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQAibIOrnOrn;

SEQ ID NO: 30 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQSIOrnOrn;

SEQ ID NO: 31 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrn;

SEQ ID NO: 32 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQAibIOrnOrn;

SEQ ID NO: 33 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQSIOrnOrn;

SEQ ID NO: 34 HSDAVFTEQY(OMe)TOrnLRK(W)QVAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 35 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLK(W)SIOrnOrn;

SEQ ID NO: 36 HSDAVFTEQY(OMe)TOrnLRAibQK(W)AAAibOrnYLQSIOrnOrn;

SEQ ID NO: 37 HSDAVFTEQY(OMe)TOrnLRK(CO$(CH_2)_2$SH)QVAAAibOrnYLQSIOrnOrn;

SEQ ID NO: 38 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(W)YLQSIOrnOrn;

SEQ ID NO: 39 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibCYLQSIOrnOrn;

SEQ ID NO: 40 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 41 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSK(W)OrnOrn;

SEQ ID NO: 42 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnCOrn;

SEQ ID NO: 43 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibCOrnOrn;

SEQ ID NO: 44 HSDAVFTEQY(OMe)TOrnLRAibQCAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 45 HSDAVFTEQY(OMe)TOrnLRCQLAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 94 HSDAVFTEQY(OMe)TOrnLRAibQVK(CO$(CH_2)_2$SH)AAibOrnYLQSIOrnOrn;

SEQ ID NO: 95 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnCOrn;

SEQ ID NO: 96 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSCOrnOrn;

SEQ ID NO: 97 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnK(CO$(CH_2)_2$SH)Orn;

SEQ ID NO: 98 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnK(CO$(CH_2)_2$SH)Orn;

SEQ ID NO: 99 HSDAVFTEQY(OMe)TOrnLRK(W)QLAAbuAibOrnYLQAibIOrnOrn;

SEQ ID NO: 100 HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSIOrnOrnC;

SEQ ID NO: 101 HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnC;

SEQ ID NO: 102 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrnC;

SEQ ID NO: 103 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQAibIOrnOrn;

SEQ ID NO: 104 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQAibIOrnCOrn;

SEQ ID NO: 105 HSDAVFTEQY(OMe)TOrnLRAibQCAAbuAibOrnY(OMe)LQAibIOrnOrn;

SEQ ID NO: 106 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrn

OrnC;

SEQ ID NO: 107 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSI OrnOrn;

SEQ ID NO: 108 HSDAVFTEQY(OMe)TOrnLRAibQCAAbuAibOrnY(OMe)LQSI OrnOrn;

SEQ ID NO: 109 HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSI OrnCOrn;

SEQ ID NO: 110 HSDAVFTEQY(OMe)TOrnLRAibQLAbuAAibOrnYLQSIOrnOrn;

SEQ ID NO: 111 HSDAVFTEQY(OMe)TOrnLRAibQK(CO$(CH_2)_2$SH)AAbu AibOrnYLQAibIOrnOrn; and

SEQ ID NO: 112 HSDAVFTEQY(OMe)TOrnLRAibQK(W)AAbuAibOrnYLQ AibIOrnOrn;

and a C-terminal extension wherein the N-terminus of the C-terminal extension is linked to the C-terminus of the peptide sequence and wherein the C-terminal extension comprises an amino acid sequence of the formula:

Xaa_1-Xaa_2-Xaa_3-Xaa_4-Xaa_5-Xaa_6-Xaa_7-Xaa_8-Xaa_9-Xaa_{10}-Xaa_{11}-Xaa_{12}

Formula 3 (SEQ ID NO: 3)

wherein:

Xaa_1 is: Gly, Cys, or absent;

Xaa_2 is: Gly, Arg, or absent;

Xaa_3 is: Pro, Thr, or absent;

Xaa_4 is: Ser, or absent;

Xaa_5 is: Ser, or absent;

Xaa_6 is: Gly, or absent;

Xaa_7 is: Ala, or absent;

Xaa_8 is: Pro, or absent;

Xaa_9 is: Pro, or absent;

Xaa_{10} is: Pro, or absent;

Xaa_{11} is: Ser, Cys, or absent; and

Xaa_{12} is: Cys, or absent;

wherein at least five of Xaa_1 to Xaa_{12} of the C-terminal extension are present and wherein if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, or Xaa_{11} is

absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated,

and wherein;

the peptide agonist comprises at least one Cys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one Lys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one K(W) which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one $K(CO(CH_2)_2SH)$ which is covalently attached to a PEG molecule, or

the carboxy-terminal amino acid of the peptide agonist is covalently attached to a PEG molecule, or

a combination thereof.

2. A PEGylated VPAC2 receptor peptide agonist according to claim 1 wherein the C-terminal extension is selected from:

SEQ ID NO: 5	GGPSSGAPPPS
SEQ ID NO: 6	GGPSSGAPPPS-NH_2
SEQ ID NO: 7	GGPSSGAPPPC
SEQ ID NO: 8	GGPSSGAPPPC-NH_2
SEQ ID NO: 9	GRPSSGAPPPS
SEQ ID NO: 10	GRPSSGAPPPS-NH_2
SEQ ID NO: 11	GGPSSGAPPPCC
SEQ ID NO: 12	GGPSSGAPPPCC-NH_2

3. A PEGylated VPAC2 receptor peptide agonist according to claim 2 wherein the C-terminal extension is SEQ ID NO: 11 or SEQ ID NO: 12.

4. A PEGylated VPAC2 receptor peptide agonist according to claim 1 wherein there is at least one PEG molecule covalently attached to a residue in the C-terminal extension.

5. A PEGylated VPAC2 receptor peptide agonist according to any one of the preceding claims wherein the PEG molecule is branched.

6. A PEGylated VPAC2 receptor peptide agonist according to any one of claims 1 to 4 wherein the PEG molecule is linear.

7. A PEGylated VPAC2 receptor peptide agonist according to any one of the preceding claims wherein each PEG molecule is 20,000, 30,000, 40,000 or 60,000 daltons in molecular weight.

8. A PEGylated VPAC2 receptor peptide agonist according to any one of the preceding claims further comprising a N-terminal modification at the N-terminus of the peptide agonist wherein the N-terminal modification is selected from:

(a) addition of D-histidine, isoleucine, methionine, or norleucine;

(b) addition of a peptide comprising the sequence Ser-Trp-Cys-Glu-Pro-Gly-Trp-Cys-Arg (SEQ ID NO: 93) wherein the Arg is linked to the N-terminus of the peptide agonist;

(c) addition of C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3;

(d) addition of –$C(O)R^1$ wherein R^1 is a C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen, -SH and -CF_3; an aryl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; an aryl C_1-C_4 alkyl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; -NR^2R^3 wherein R^2 and R^3 are independently hydrogen, C_1-C_6 alkyl, aryl or aryl C_1-C_4 alkyl; -OR^4 wherein R^4 is C_1-C_{16} alkyl optionally substituted with one or more substituents independently selected from aryl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3, aryl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6

alkoxy, -NH_2, -OH, halogen and -CF_3 or aryl C_1-C_4 alkyl optionally substituted with one or more substituents independently selected from C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 alkoxy, -NH_2, -OH, halogen and -CF_3; or 5-pyrrolidin-2-one;

(e) addition of $-SO_2R^5$ wherein R^5 is aryl, aryl C_1-C_4 alkyl or C_1-C_{16} alkyl;

(f) formation of a succinimide group optionally substituted with C_1-C_6 alkyl or $-SR^6$, wherein R^6 is hydrogen or C_1-C_6 alkyl;

(g) addition of methionine sulfoxide;

(h) addition of biotinyl-6-aminohexanoic acid (6-aminocaproic acid); and

(i) addition of $-C(=NH)-NH_2$.

9. A PEGylated VPAC2 receptor peptide agonist according to claim 8 wherein the N-terminal modification is the addition of a group selected from: acetyl, propionyl, butyryl, pentanoyl, hexanoyl, methionine, methionine sulfoxide, 3-phenylpropionyl, phenylacetyl, benzoyl, norleucine, D-histidine, isoleucine, 3-mercaptopropionyl, biotinyl-6-aminohexanoic acid (6-aminocaproic acid), and $-C(=NH)-NH_2$.

10. A PEGylated VPAC2 receptor peptide agonist according to claim 9 wherein the N-terminal modification is the addition of acetyl or hexanoyl.

11. A PEGylated VPAC2 peptide receptor agonist according to claim 1 comprising an amino acid sequence selected from:

Agonist #	**SEQ ID NO**	**Sequence**
P410	46	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(W-PEG40K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P417	47	C6-HSDAVFTEQY(OMe)TRAibRAibQLAAAibOrnY(OMe)LQSIKAibOrnGGPSSGAPPPC(PEG40K)-NH_2
P451	48	C6-HSDAVFTEK($CO(CH_2)_2$SPEG40K)Y(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2

P454	49	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnK(WPEG40K)OrnGGPSSGAPPPS-NH_2
P460	50	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibC(PEG40K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P472	51	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(CO(CH_2)$_2$SPEG40K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P473	52	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibK(CO(CH_2)$_2$SPEG20K)YLQSIOrnOrnGGPSSGAPPPS-NH_2
P475	53	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAK(CO(CH_2)$_2$SPEG40K)OrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P478	54	C6-HSDAVFTEQY(OMe)TOrnLRAibQVC(PEG40K)AAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P483	55	C6-HSDAVFTEQY(OMe)TOrnLRC(PEG40K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P485	56	C6-HSDAVFTEQY(OMe)TOrnLRK(CO(CH_2)$_2$SPEG40K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P507	57	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG40K)-NH_2
P509	58	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG40K)-NH_2
P511	59	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG40K)-NH_2
P513	60	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P515	61	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P517	62	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P519	63	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYAibQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2

P521	64	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P523	65	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P525	66	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P529	67	C6-HSDAVFTEQY(OMe)TOrnLRK(WPEG40K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P531	68	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLK(WPEG40K)SIOrnOrnGGPSSGAPPPS-NH_2
P533	69	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(WPEG40K)AAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P535	70	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSK(WPEG40K)OrnOrnGGPSSGAPPPS-NH_2
P537	71	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P541	72	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibC(PEG40K)OrnOrnGGPSSGAPPPS-NH_2
P545	73	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG40K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P547	74	C6-HSDAVFTEQY(OMe)TOrnLRC(PEG40K)QLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P480	113	C6-HSDAVFTEQY(OMe)TOrnLRAibQVK($CO(CH_2)_2$SPEG40K)AAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P481	114	C6-HSDAVFTEQY(OMe)TOrnLRAibQVK($CO(CH_2)_2$SPEG20K)AAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH_2
P539	115	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P543	116	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSC(PEG40K)OrnOrnGGPSSGAPPPS-NH_2
P549	117	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnK($CO(CH_2)_2$SPEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P551	118	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnK($CO(CH_2)_2$SPEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2

P555	119	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P557	120	C6-HSDAVFTEQY(OMe)TOrnLRK(WPEG40K)QLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH_2
P560	121	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAAibOrnYLQSIOrnOrnC(PEG40K)GGPSSGAPPPS-NH_2
P562	122	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnC(PEG20K)GGPSSGAPPPC(PEG20K)-NH_2
P564	123	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrnC(PEG40K)GGPSSGAPPPS-NH_2
P566	124	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrnC(PEG40K)GGPSSGAPPPS-NH_2
P572	125	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQSIOrnOrnC(PEG20K)GGPSSGAPPPC(PEG20K)-NH_2
P574	126	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQAibIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P576	127	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQAibIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P578	128	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG40K)AAbuAibOrnY(OMe)LQAibIOrnOrnGGPSSGAPPPS-NH_2
P580	129	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrnC(PEG20K)GGPSSGAPPPC(PEG20K)-NH_2
P582	130	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2
P584	131	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSIOrnC(PEG40K)OrnGGPSSGAPPPS-NH_2
P586	132	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG40K)AAbuAibOrnY(OMe)LQSIOrnOrnGGPSSGAPPPS-NH_2
P588	133	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnY(OMe)LQSIOrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH_2
P590	134	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAbuAAibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)C(PEG20K)-NH_2

P597	135	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(CO(CH$_2$)$_2$SPEG20K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P599	136	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(CO(CH$_2$)$_2$SPEG40K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH$_2$
P601	137	C6-HSDAVFTEQY(OMe)TOrnLRAibQK(WPEG40K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPS-NH$_2$
P469	139	C6-HSDAVFTEK(CO(CH$_2$)$_2$SPEG20K)Y(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH$_2$
P486	140	C6-HSDAVFTEQY(OMe)TOrnLRK(CO(CH$_2$)$_2$SPEG20K)QVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH$_2$
P553	141	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnC(PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH$_2$
P570	144	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG30K)C(PEG30K)-NH$_2$
P595	146	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG20K)AAbuAibOrnYLQAibIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P476	147	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAK(CO(CH$_2$)$_2$SPEG20K)OrnYLQSIOrnOrnGGPSSGAPPPS-NH$_2$
P602	148	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQSIOrnOrnGGPSSGAPPPC(PEG30K)C(PEG30K)-NH$_2$

12. A PEGylated VPAC2 peptide receptor agonist comprising an amino acid sequence selected from:

Agonist #	**SEQ ID NO**	**Sequence**
P470	75	C6-HSDAVFTEQY(OMe)TOrnK(CO(CH$_2$)$_2$SPEG20K)RAibQVAAAibOrnYLQSIOrnOrnGGPSSGAPPPS-NH$_2$
P490	76	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLK(CO(CH$_2$)$_2$SPEG20K)SIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P492	77	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAK(CO(CH$_2$)$_2$SPEG20K)AibOrnYLQSIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$

P495	78	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQ K(CO(CH$_2$)$_2$SPEG20K)IOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P497	79	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQS K(CO(CH$_2$)$_2$SPEG20K)OrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P499	80	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrn K(CO(CH$_2$)$_2$SPEG20K)OrnGGPSSGAPPPC(PEG20K)-NH$_2$
P501	81	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLC(PEG 20K)SIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P503	82	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSC (PEG20K)OrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P505	83	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrnC (PEG20K)OrnGGPSSGAPPPC(PEG20K)-NH$_2$
P402	138	C6-HSDAVFTEQY(OMe)TOrnLRAibQVAAAibOrnYLQSIOrn OrnGGPSSGAPPPK(W-PEG40K)-NH$_2$
P558	142	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG20K)AAAibOrnY LQSIOrnOrnGGPSSGAPPPS-NH$_2$
P568	143	C6-HSDAVFTEQY(OMe)TOrnLRAibQC(PEG20K)AAAibOrnY LQSIOrnOrnGGPSSGAPPPC(PEG20K)-NH$_2$
P593	145	C6-HSDAVFTEQY(OMe)TOrnLRAibQLAAbuAibOrnYAibQ AibIOrnOrnGGPSSGAPPPK(WPEG40K)-NH$_2$

13. A PEGylated VPAC2 receptor peptide agonist comprising a sequence of the formula:

Xaa$_1$-Xaa$_2$-Xaa$_3$-Xaa$_4$-Xaa$_5$-Xaa$_6$-Thr-Xaa$_8$-Xaa$_9$-Xaa$_{10}$-Thr-Xaa$_{12}$-Xaa$_{13}$- Xaa$_{14}$-Xaa$_{15}$-Xaa$_{16}$-Xaa$_{17}$-Xaa$_{18}$ -Abu-Xaa$_{20}$-Xaa$_{21}$-Xaa$_{22}$- Xaa$_{23}$-Xaa$_{24}$-Xaa$_{25}$-Xaa$_{26}$-Xaa$_{27}$-Xaa$_{28}$-Xaa$_{29}$-Xaa$_{30}$-Xaa$_{31}$-Xaa$_{32}$-Xaa$_{33}$-Xaa$_{34}$-Xaa$_{35}$-Xaa$_{36}$-Xaa$_{37}$-Xaa$_{38}$-Xaa$_{39}$-Xaa$_{40}$

Formula 4 (SEQ ID NO: 4)

wherein:

Xaa$_1$ is: His, dH, or is absent;

Xaa$_2$ is: dA, Ser, Val, Gly, Thr, Leu, dS, Pro, or Aib;

Xaa_3 is: Asp or Glu;

Xaa_4 is: Ala, Ile, Tyr, Phe, Val, Thr, Leu, Trp, Gly, dA, Aib, or NMeA;

Xaa_5 is: Val, Leu, Phe, Ile, Thr, Trp, Tyr, dV, Aib, or NMeV;

Xaa_6 is: Phe, Ile, Leu, Thr, Val, Trp, or Tyr;

Xaa_8 is: Asp, Glu, Ala, Lys, Leu, Arg, or Tyr;

Xaa_9 is: Asn, Gln, Asp, Glu, Ser, Cys, Lys, or $K(CO(CH_2)_2SH)$;

Xaa_{10} is: Tyr, Trp, Tyr(OMe), Ser, Cys, or Lys;

Xaa_{12} is: Arg, Lys, Glu, hR, Orn, Lys (isopropyl), Aib, Cit, Ala, Leu, Gln, Phe, Ser, or Cys;

Xaa_{13} is: Leu, Phe, Glu, Ala, Aib, Ser, Cys, Lys, or $K(CO(CH_2)_2SH)$;

Xaa_{14} is: Arg, Leu, Lys, Ala, hR, Orn, Lys (isopropyl), Phe, Gln, Aib, Cit, Ser, or Cys;

Xaa_{15} is: Lys, Ala, Arg, Glu, Leu, hR, Orn, Lys (isopropyl), Phe, Gln, Aib, K(Ac), Cit, Ser, Cys, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{16} is: Gln, Lys, Glu, Ala, hR, Orn, Lys (isopropyl), Cit, Ser, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{17} is: Val, Ala, Leu, Ile, Met, Nle, Lys, Aib, Ser, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{18} is: Ala, Ser, Cys, Lys, $K(CO(CH_2)_2SH)$, K(W), Abu, or Nle;

Xaa_{20} is: Lys, Gln, hR, Arg, Ser, His, Orn, Lys (isopropyl), Ala, Aib, Trp, Thr, Leu, Ile, Phe, Tyr, Val, K(Ac), Cit, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{21} is: Lys, His, Arg, Ala, Phe, Aib, Leu, Gln, Orn, hR, K(Ac), Cit, Ser, Cys, Val, Tyr, Ile, Thr, Trp, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{22} is: Tyr, Trp, Phe, Thr, Leu, Ile, Val, Tyr(OMe), Ala, Aib, Ser, Cys, Lys, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{23} is: Leu, Phe, Ile, Ala, Trp, Thr, Val, Aib, Ser, Cys, Lys, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{24} is: Gln, Glu, Asn, Ser, Cys, Lys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{25} is: Ser, Asp, Phe, Ile, Leu, Thr, Val, Trp, Gln, Asn, Tyr, Aib, Glu, Cys, Lys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{26} is: Ile, Leu, Thr, Val, Trp, Tyr, Phe, Aib, Ser, Cys, Lys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{27} is: Lys, hR, Arg, Gln, Ala, Asp, Glu, Phe, Gly, His, Ile, Met, Asn, Pro, Ser, Thr, Val, Trp, Tyr, Lys (isopropyl), Cys, Leu, Orn, dK, K(W), or $K(CO(CH_2)_2SH)$;

Xaa_{28} is: Asn, Asp, Gln, Lys, Arg, Aib, Orn, hR, Cit, Pro, dK, Ser, Cys, $K(CO(CH_2)_2SH)$, or K(W);

Xaa_{29} is: Lys, Ser, Arg, Asn, hR, Ala, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Pro, Gln, Thr, Val, Trp, Tyr, Cys, Orn, Cit, Aib, K(W), $K(CO(CH_2)_2SH)$, or is absent;

Xaa_{30} is: Arg, Lys, Ile, Ala, Asp, Glu, Phe, Gly, His, Leu, Met, Asn, Pro, Gln, Ser, Thr, Val, Trp, Tyr, Cys, hR, Cit, Aib, Orn, K(W), $K(CO(CH_2)_2SH)$, or is absent;

Xaa_{31} is: Tyr, His, Phe, Thr, Cys, Ser, Lys, Gln, K(W), $K(CO(CH_2)_2SH)$, or is absent;

Xaa_{32} is: Ser, Cys, Lys, or is absent;

Xaa_{33} is: Trp or is absent;

Xaa_{34} is: Cys or is absent;

Xaa_{35} is: Glu or is absent;

Xaa_{36} is: Pro or is absent;

Xaa_{37} is: Gly or is absent;

Xaa_{38} is: Trp or is absent;

Xaa_{39} is: Cys or is absent; and

Xaa_{40} is: Arg or is absent

wherein if Xaa_{29}, Xaa_{30}, Xaa_{31}, Xaa_{32}, Xaa_{33}, Xaa_{34}, Xaa_{35}, Xaa_{36}, Xaa_{37}, Xaa_{38}, or Xaa_{39} is absent, the next amino acid present downstream is the next amino acid in the peptide agonist sequence,

and a C-terminal extension wherein the N-terminus of the C-terminal extension is linked to the C-terminus of the peptide of Formula 4 and wherein the C-terminal extension comprises an amino acid sequence of the formula:

$$Xaa_1\text{-}Xaa_2\text{-}Xaa_3\text{-}Xaa_4\text{-}Xaa_5\text{-}Xaa_6\text{-}Xaa_7\text{-}Xaa_8\text{-}Xaa_9\text{-}Xaa_{10}\text{-}Xaa_{11}\text{-}Xaa_{12}$$

Formula 3 (SEQ ID NO: 3)

wherein:

Xaa_1 is: Gly, Cys, or absent;

Xaa_2 is: Gly, Arg, or absent;

Xaa_3 is: Pro, Thr, or absent;

Xaa_4 is: Ser, or absent;

Xaa_5 is: Ser, or absent;

Xaa_6 is: Gly, or absent;

Xaa_7 is: Ala, or absent;

Xaa_8 is: Pro, or absent;

Xaa_9 is: Pro, or absent;

Xaa_{10} is: Pro, or absent;

Xaa_{11} is: Ser, Cys, or absent; and

Xaa_{12} is: Cys, or absent;

wherein at least five of Xaa_1 to Xaa_{12} of the C-terminal extension are present and wherein if Xaa_1, Xaa_2, Xaa_3, Xaa_4, Xaa_5, Xaa_6, Xaa_7, Xaa_8, Xaa_9, Xaa_{10}, or Xaa_{11} is absent, the next amino acid present downstream is the next amino acid in the C-terminal extension and wherein the C-terminal amino acid may be amidated,

and wherein;

the peptide agonist comprises at least one Cys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one Lys residue which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one K(W) which is covalently attached to a PEG molecule, or

the peptide agonist comprises at least one $K(CO(CH_2)_2SH)$ which is covalently attached to a PEG molecule, or

the carboxy-terminal amino acid of the peptide agonist is covalently attached to a PEG molecule, or

a combination thereof.

14. A pharmaceutical composition comprising a PEGylated VPAC2 receptor peptide agonist according to any one of claims 1 to 13 and one or more pharmaceutically acceptable diluents, carriers and excipients.

15. A PEGylated VPAC2 receptor peptide agonist according to any one of claims 1 to 13 for use as a medicament.

16. The use of a PEGylated VPAC2 receptor peptide agonist according to any one of claims 1 to 13 for the manufacture of a medicament for the treatment non-insulin-dependent diabetes.

17. The use of a PEGylated VPAC2 receptor peptide agonist according to any one of claims 1 to 13 for the manufacture of a medicament for the treatment of insulin-dependent diabetes.

18. A method of treating diabetes in a patient in need thereof comprising administering a PEGylated VPAC2 receptor peptide agonist according to any one of claims 1 to 13.

19. The method of claim 18, wherein the diabetes in non-insulin dependent diabetes.

20. The method of claim 18, wherein the diabetes is insulin dependent diabetes.

21. A PEGylated VPAC2 receptor peptide agonist substantially as hereinbefore described with reference to the examples.

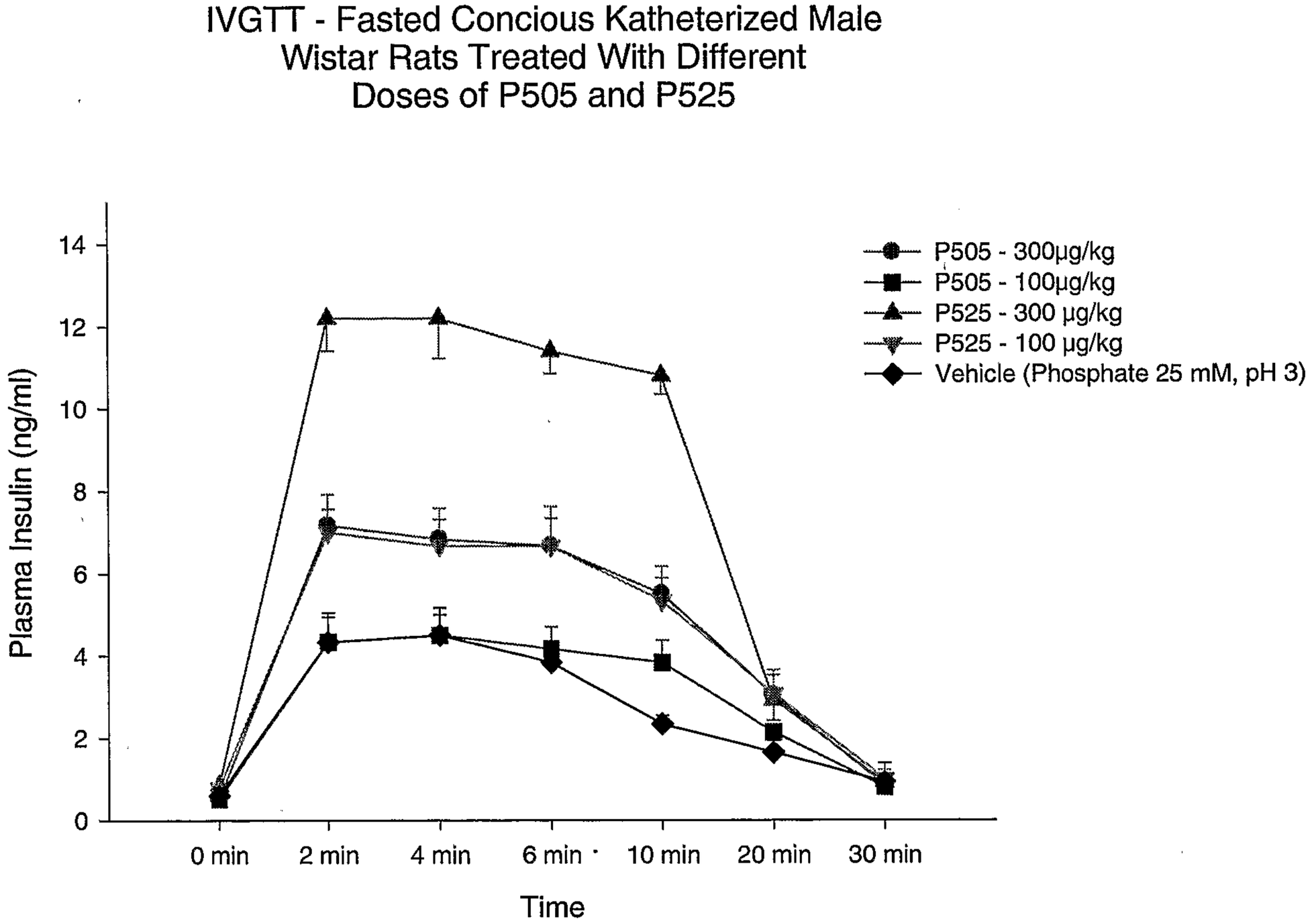

Figure 1. Insulinotrophic activity of P505 and P525 in normal Wistar rats. Compound was injected 24h prior to the i.v. glucose challenge.