OXYNTOMODULIN PEPTIDE ANALOGUE

The present invention relates to Oxyntomodulin peptide analogues and to PEGylated derivatives thereof for use in treating diabetes and /or obesity.

Oxyntomodulin (OXM) is a 37 amino acid peptide hormone that is released along with Glucagon-Like-Peptide 1 (GLP-1) from the L-cells of the small intestine in proportion to nutrient ingestion. It is composed of the full 29 residue sequence of glucagon (Gcg) with an octapeptide extension at the C-terminus as a result of tissue-specific alternate processing of preproglucagon. Endogenous OXM is quickly degraded *in vivo* by dipeptidyl peptidase IV and other peptidases.

Distinct receptors for OXM have not yet been identified. OXM binds to and fully activates both the GLP-1 receptor (GLP-1R) and the glucagon receptor (GcgR) *in vitro* with similar potencies at the two receptors.

OXM is involved in regulation of food intake and body weight. Acute administration of OXM to normal-weight human subjects reduced hunger and decreased meal size by 19 %. In a 4-week study with overweight and obese subjects, three times daily preprandial subcutaneous administration of OXM produced a weight loss of 2.3 kg compared with 0.5 kg in the placebo group. In this trial, nausea, the most common side effect associated with GLP-1 based therapy (such as exenatide and liraglutide), was significantly less prevalent. OXM increased energy usage through promotion of increased physical activity in overweight and obese humans, although the mechanism of the effect is unclear.

OXM presents several challenges for development into a commercially-viable therapeutic agent. As mentioned above, it is rapidly degraded *in vivo* as well as being subjected to rapid renal clearance due to its small size. It is therefore desirable to identify OXM peptide analogues with improved metabolic stability and reduced rate of clearance. Furthermore, the GcgR agonist activity inherent in OXM presents a risk of negatively impacting glycemic control. Thus, it is also desirable to optimize the potency of an OXM peptide analogue designed for therapeutic use while maintaining an appropriate balance between activities at the GLP-1R and GcgR. Activation of GLP-1R is responsible for an insulinotropic effect while activation of both GLP-1R and GcgR may play a role in the weight loss effects. It is therefore desirable to produce an OXM peptide analogue which

has potent insulinotropic activity and promotes weight loss such that it can be used for the treatment of non-insulin dependent diabetes and/or obesity.

OXM peptides with amino acid substitutions to improve stability and with additional modifications to slow clearance, such as PEGylation or lipidation are disclosed in WO 2008101017, WO2006134340, WO2007100535, and Pocai et al. *Diabetes* 58:2258-2266, 2009. While these OXM-derived peptides may represent a potential improvement over the wild type peptide, the doses required to achieve a sizable weight reduction in a diet-induced obese (DIO) mouse model are typically higher than may be considered feasible for pharmaceutical commercialization. For example, Pocai *et al* (2009) reported an average 11 g (~25 %) weight loss after 13 days of dosing with 1900 nmol/kg (~8 mg/kg) every other day (QOD).

Despite the availability of various OXM peptides and analogues thereof, there is still a need for more potent, stable, long-acting, and well-tolerated OXM peptide analogues having a ratio of GcgR/GLP-1R activity which has been optimized such that the potency and insulinotropic activity of the peptide provides effective treatments for diabetes, preferably type 2 diabetes and related disorders. It is also desirable to provide OXM peptide analogues thereof which provide effective treatments to reduce body weight. Accordingly, the present invention seeks to provide effective treatments for diabetes and/or obesity.

Summary

In a first aspect of the present disclosure, there is provided an Oxyntomodulin peptide analogue comprising the amino acid sequence:

His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala-Xaa_{38}-Xaa_{39}

(SEQ ID NO: 5) wherein Xaa_{38} is Cys, Cys-PEG, or is absent; Xaa_{39} is Cys, Cys-PEG, or is absent; and wherein the C-terminal amino acid is optionally amidated.

In a second aspect of the present disclosure, there is provided a pharmaceutical composition comprising the Oxyntomodulin peptide analogue as defined herein, and a pharmaceutically acceptable carrier, diluent, or excipient.

In a third aspect of the present disclosure, there is provided a pharmaceutical composition comprising the Oxyntomodulin peptide analogue as defined herein, together with a pharmaceutically acceptable carrier, diluent, or excipient and optionally other therapeutic ingredients.

In a fourth aspect of the present disclosure, there is provided the use of an Oxyntomodulin peptide analogue as defined herein in the manufacture of a medicament for treating non-insulin-dependent diabetes.

In a fifth aspect of the present disclosure, there is provided the use of an Oxyntomodulin peptide analogue as defined herein in the manufacture of a medicament for treating obesity.

In a sixth aspect of the present disclosure, there is provided the use of an Oxyntomodulin peptide analogue as defined herein in the manufacture of a medicament for treating non-insulin-dependent diabetes or obesity.

In a seventh aspect of the present disclosure, there is provided the Oxyntomodulin peptide analogue as defined herein for use as a medicament.

In an eighth aspect of the present disclosure, there is provided the Oxyntomodulin peptide analogue as defined herein for use in the treatment of non-insulin-dependent diabetes.

In a ninth aspect of the present disclosure, there is provided the Oxyntomodulin peptide analogue as defined herein for use in the treatment of obesity.

In a tenth aspect of the present disclosure, there is provided the Oxyntomodulin peptide analogue as defined herein for use in the treatment of non-insulin-dependent diabetes or obesity.

Description

The present invention comprises an OXM peptide analogue with amino acid substitutions introduced to optimize metabolic stability and modulate the relative GcgR/GLP-1R activities while optimizing overall potency. In addition, the OXM peptide analogue of the present invention is PEGylated at selected positions for enhancement of time action thereby allowing for less frequent dosing.

The present invention provides an Oxyntomodulin peptide analogue comprising the amino acid sequence:

1 5 10

His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-

15 20 25

Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-

30 35

(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala-Xaa_{38}-Xaa_{39} (SEQ ID NO: 5)

wherein Xaa_{38} is Cys, Cys-PEG, or is absent, Xaa_{39} is Cys, Cys-PEG, or is absent, and wherein the C-terminal amino acid is optionally amidated.

The present invention provides an Oxyntomodulin peptide analogue comprising the amino acid sequence:

```
1               5                   10
His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-
     15                  20                  25
Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-
       30                  35
(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala (SEQ ID NO: 1).
```

Furthermore, the present invention provides an Oxyntomodulin peptide analogue comprising the amino acid sequence:

```
1               5                   10
His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-
     15                  20                  25
Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-
       30                  35
(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala-Cys-Cys (SEQ ID NO: 2)
```

wherein the Cys residue at position 38 is optionally PEGylated, and wherein the Cys residue at position 39 is optionally PEGylated, and the carboxyl group of the Cys at position 39 is optionally amidated.

Preferably, the Oxyntomodulin peptide analogue of SEQ ID NO: 2 is PEGylated on either the Cys residue at position 38 or the Cys at position 39 or both with a 40 kDa PEG molecule covalently linked to the thiol group of the Cys residue at these positions. More preferably the Oxyntomodulin peptide analogue is PEGylated on each Cys residue at position 38 and position 39 with a 20 kDa PEG molecule covalently linked to each thiol group of each Cys residue at these positions. Optionally, the Cys residue at position 39 may be absent from SEQ ID NO: 2, leaving a single site for PEGylation at position 38.

The more preferred Oxyntomodulin peptide analogue comprises the amino acid sequence:

```
1               5                   10
His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-
```

15 20 25

Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-

30 35

(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala-Cys(20kDa PEG)-Cys

(20kDa PEG) (SEQ ID NO: 3)

wherein the carboxyl group of the PEGylated Cys at position 39 is optionally amidated.

The most preferred Oxyntomodulin peptide analogue comprises the amino acid sequence of SEQ ID NO: 3, wherein the carboxyl group of the PEGylated Cys at position 39 is amidated.

The PEG molecule used in the present invention may be linear or branched and is preferably a linear PEG molecule.

The present invention provides a pharmaceutical composition comprising the Oxyntomodulin peptide analogue as defined above, and a pharmaceutically acceptable carrier, diluent, or excipient. Additionally, the present invention provides a pharmaceutical composition comprising the Oxyntomodulin peptide analogue as defined above, together with a pharmaceutically acceptable carrier, diluent, or excipient and optionally other therapeutic ingredients.

Furthermore, the present invention provides a method of treating non-insulin-dependent (type 2) diabetes in a subject in need thereof, comprising administering to the subject in need thereof an effective amount of an Oxyntomodulin peptide analogue as defined above.

Additionally, the present invention provides a method of treating insulin-dependent (type 1) diabetes in a subject in need thereof, comprising administering to the subject in need thereof an effective amount of an Oxyntomodulin peptide analogue as defined above.

The present invention includes a method of treating obesity in a subject in need thereof, comprising administering to the subject in need thereof an effective amount of an Oxyntomodulin peptide analogue as defined above.

Furthermore, the present invention includes a method of treating non-insulin-dependent diabetes and obesity in a subject in need thereof, comprising administering to the subject in need thereof an effective amount of an Oxyntomodulin peptide analogue as defined above.

The present invention provides an Oxyntomodulin peptide analogue as defined above for use as a medicament.

Additionally, the present invention provides an Oxyntomodulin peptide analogue as defined above for use in the treatment of non-insulin-dependent diabetes.

Furthermore, the present invention provides an Oxyntomodulin peptide analogue as defined above for use in the treatment of insulin-dependent diabetes.

Furthermore, the present invention provides an Oxyntomodulin peptide analogue as defined above for use in the treatment of obesity.

The present invention includes an Oxyntomodulin peptide analogue as defined above for use in the treatment of non-insulin-dependent diabetes and obesity.

The present invention provides the use of an Oxyntomodulin peptide analogue as defined above in the manufacture of a medicament for the treatment of non-insulin-dependent diabetes.

Additionally, the present invention includes the use of an Oxyntomodulin peptide analogue as defined above in the manufacture of a medicament for the treatment of insulin-dependent diabetes.

Furthermore, the present invention provides the use of an Oxyntomodulin peptide analogue as defined above in the manufacture of a medicament for the treatment of obesity.

Furthermore, the present invention provides the use of an Oxyntomodulin peptide analogue as defined above in the manufacture of a medicament for the treatment of non-insulin-dependent diabetes and obesity.

The OXM peptide analogues of the present invention effectively bind to and activate both the GLP-1 receptor (GLP-1R) and glucagon receptor (GcgR).

It has also been found that the OXM peptide analogues of the present invention are more resistant to degradation by peptidases, in particular dipeptidyl peptidase IV than native human OXM. As a result, the OXM peptide analogues of the present invention possess improved *in vivo* stability versus native human OXM.

Various embodiments according to the present invention are capable of causing a reduction in food intake in overweight and obese subjects.

A particular advantage of the present invention is that the frequency of side-effects, such as nausea, which is commonly associated with GLP-1 based therapy, such as

exenatide and liraglutide, is reduced or eliminated. The present invention therefore has reduced side-effects compared to GLP-1 based therapy.

The OXM peptide analogues of the present invention have superior weight loss effect *versus* wild type human OXM.

According to one embodiment of the present invention, the Oxyntomodulin peptide analogues possess improved glucose tolerance and lipid profile on subjects with type 2 diabetes and/or related metabolic disturbances and do so more effectively than wild type human OXM.

Oxyntomodulin (OXM) is a weak co-agonist with full efficacy and balanced potency at the hGLP-1R and hGcgR, with EC_{50} values of 6.7 $\pm$ 2.7 nM and 4.1 $\pm$ 1.7 nM, respectively in HEK293 cells stably overexpressing the respective receptors. The sequence of native human OXM is given below:
His-Ser-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Arg-Arg-Ala-Gln-Asp-Phe-Val-Gln-Trp-Leu-Met-Asn-Thr-Lys-Arg-Asn-Arg-Asn-Asn-Ile-Ala (SEQ ID NO: 4)

The OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated is a fully efficacious and potent Oxyntomodulin peptide analogue with an EC_{50} of 59.9 $\pm$ 4.14 nM and 2.75 $\pm$ 0.55 nM against the hGcgR and hGLP-1R, respectively. Therefore, the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated has a balance of *in vitro* functional activities that is ~22-fold more selective for the hGLP-1R as compared to hGcgR. Comparable results are observed for the binding affinity, Ki, where the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated is 28-fold more selective for the hGLP-1R as compared to the hGcgR, with Ki values of 73 $\pm$ 23 nM and 2050 $\pm$ 70 nM, respectively.

The covalent attachment of one or more molecules of PEG to particular residues of the OXM peptide analogue results in a PEGylated OXM peptide analogue with an extended half-life and reduced rate of clearance, when compared to that of the non-PEGylated OXM peptide analogue, and *in vitro* potency at the GLP-1R similar to that of native human OXM. Given the small size of the OXM peptide analogue and the relatively large size of the PEG molecule(s), it would be expected that the OXM peptide analogue, once PEGylated, would lose activity as a result of steric hindrance. It has been

found, however, that if placed at the end of the Oxyntomodulin peptide analogue rather than in the middle, the activity of the peptide analogue is retained to a greater extent. Several substitutions in the sequence enhance potency thereby offsetting the potency loss due to PEGylation while maintaining an appropriate ratio of activities at the GLP-1R and GcgR. Furthermore, it has been found that the presence of two PEG molecules at the C-terminal end of the Oxyntomodulin peptide analogue is preferable to a single PEG.

The sequences of the present invention contain the standard single letter or three letter codes for the twenty naturally occurring amino acids. The other codes used are defined as follows:

Aib = alpha amino isobutyric acid

PEG = polyethylene glycol

PEG20K = PEG molecule with average molecular weight of 20,000 Da

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 $HO\text{-}CH_2CH_2\text{-}(CH_2CH_2O)n\text{-}CH_2CH_2\text{-}OH$, where n is from about 8 to about 4000. Typically, n is not a discrete value but constitutes a range with approximately Gaussian distribution around an average value. The terminal hydrogen may be substituted with a capping group such as an alkyl or alkanol group. Preferably, PEG has at least one hydroxy group, more preferably it is a terminal hydroxy group. This hydroxy group is preferably attached to a linker moiety which can react with the peptide to form a covalent linkage. Numerous derivatives of PEG exist in the art. (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 the OXM peptide of the present invention may be approximately 10,000, 20,000, 30,000, or 40,000 daltons average molecular weight. The PEG molecule is preferably 18,000 to 22,000 daltons. More preferably, it is 19,000 to 21,000 Daltons. Most preferably it is 20,000 to 21,000 daltons. It is even more preferably approximately 20,000 daltons. PEGylation reagents may be linear or branched molecules and may be present singularly or in tandem. The PEGylated OXM peptide analogues of the present invention preferably have tandem PEG molecules attached to the C-terminus of the peptide. The PEG molecules are preferably attached to the two cysteine residues at the C-terminal end of the peptide by an mPEG-20kDa maleimide

(Figure 1) or an mPEG-20kDa iodoacetamide (Figure 2). In Figure 1 and Figure 2, n is 10 to 2500. Preferably, n is 350 to 600. More preferably, n is 425 to 475.

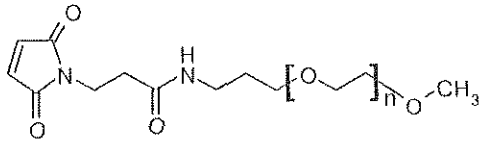


Figure 1

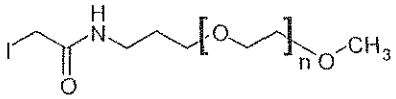


Figure 2

In particular, the PEG molecules are preferably mPEG-20kDa maleimide ($CH_3O(CH_2CH_2O)_n$-$(CH_2)_3NHCO(CH_2)_2$-maleimide) (NOF Sunbright ME-200MA) and are attached to the two cysteine residues at the C terminus of the peptide. The most preferred Oxyntomodulin peptide analogue comprises the amino acid sequence of SEQ ID NO: 3, wherein the PEG molecules are mPEG-20kDa maleimide ($CH_3O(CH_2CH_2O)_n$-$(CH_2)_3NHCO(CH_2)_2$-maleimide) (NOF Sunbright ME-200MA), and wherein the carboxyl group of the PEGylated Cys at position 39 is amidated (Figure 3). Figure 3 contains the standard single letter amino acid code with exception of the box areas where the structures for these amino acid residues have been expanded.

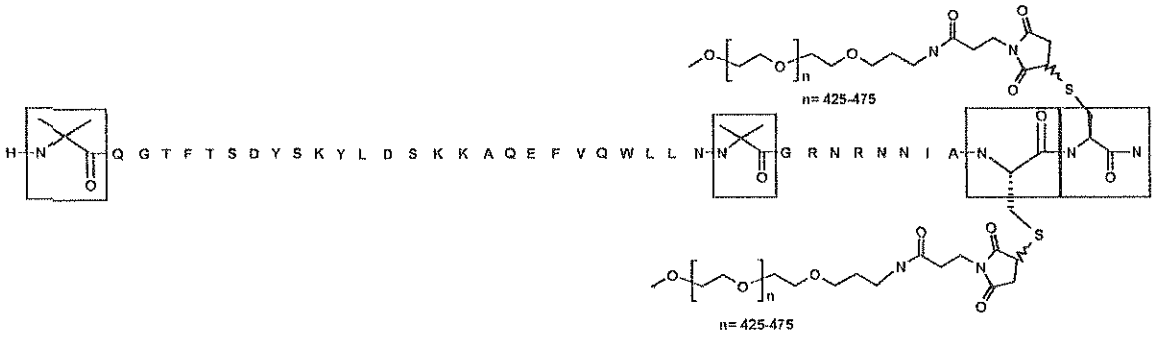


Figure 3

The term "PEGylation" as used herein means the covalent attachment of one or more PEG molecules, as described above, to a molecule such as the OXM peptide analogues of the present invention.

"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 *in vitro* experiments that measure insulin secretion by

insulinoma cell lines or islets, or *in vivo* experiments such as 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. The OXM peptide analogues of the present invention possess robust insulinotropic activity.

"*In vitro* potency" as used herein is the measure of the ability of the OXM peptide analogue to activate the GLP-1R or the GcgR 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 half maximal increase in the measured response (in this case, cyclic AMP production) in a dose-response experiment.

The term "plasma half-life" refers to the time required for half of the relevant molecules to be cleared from the plasma. 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 significant increase in the half-life of a PEGylated OXM peptide analogue 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 of native OXM in monkeys, for example, is expected to be less than 1 hr. The PEGylated OXM peptide analogues of the present invention have an elimination half-life of at least 24 hr in monkey and most preferably at least 48 hr. The half-life reported herein is the elimination half-life, 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.

The term "long-acting GLP-1R agonist" as used herein, refers to a GLP-1 peptide analogue covalently attached to one or more molecules of polyethylene glycol (PEG). PEGylated GLP-1 compounds are disclosed in U.S. Patent 7,557,183.

Clearance is the measure of the body's ability to eliminate a drug from circulation. 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. The PEGylated OXM peptide analogues of the present invention preferably have a clearance value of 200 ml/h/kg or less in monkeys, more preferably 180, 150, 120, 100, 80, 60 ml/h/kg or less and most preferably 50, 40 or 20 ml/h/kg or less.

The OXM peptide analogues of the present invention typically will be administered parenterally. Parenteral administration includes, for example, systemic administration, such as by intramuscular, intravenous, subcutaneous, intradermal, or intraperitoneal injection. The OXM peptide analogue is administered to the subject in conjunction with an acceptable pharmaceutical carrier, diluent, or excipient as part of a pharmaceutical composition for treating non-insulin dependent (type 2) diabetes mellitus, NIDDM, or the disorders discussed below. The pharmaceutical composition can be a solution or a suspension such as one in which the OXM peptide analogue is complexed with a divalent metal cation such as zinc. The peptide analogue may also be formulated in a solid formulation such as by lyophilisation or spray drying, which is then reconstituted in a suitable diluent solution prior to administration. 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 and preservatives such as phenol and m-cresol.

Standard pharmaceutical formulation techniques, such as those described in Remington's Pharmaceutical Sciences (Mack Publishing Company, Easton, PA), may be employed. The OXM peptide analogues of the present invention may alternatively be formulated for administration through the buccal, oral, transdermal, nasal, or pulmonary route. The OXM peptide analogues of the invention may be formulated for extended release such that blood plasma levels are maintained in the efficacious range for extended time periods after administration.

The OXM peptide analogues of the present invention may be employed to treat diabetes, specifically type 2 diabetes (non-insulin dependent diabetes mellitus, NIDDM).

Additional subjects who may benefit from treatment with the OXM peptide analogues of the present invention, include those with impaired glucose tolerance or impaired fasting glucose, subjects whose body weight is about 25% or more 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 OXM peptide analogue may be used to prevent subjects with impaired glucose tolerance from proceeding to develop type 2 diabetes, prevent pancreatic β-cell deterioration, induce β-cell proliferation, improve β-cell function, activate dormant β-cells, promote differentiation of cells into β-cells, stimulate β-cell replication, and inhibit β-cell apoptosis. Other diseases and conditions that may be treated or prevented using compounds 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); impaired glucose tolerance (IGT) (Expert Committee on Classification of Diabetes Mellitus, *Diabetes Care* 22 (Supp. 1):S5, 1999); impaired fasting glucose (IFG) (Charles, et al., *Diabetes* 40:796, 1991); gestational diabetes (Metzger, *Diabetes*, 40:197, 1991); metabolic syndrome X, dyslipidemia, hyperglycemia, hyperinsulinemia, hypertriglyceridemia, and insulin resistance.

The OXM peptide analogues of the invention may also be used in methods of the invention to treat secondary causes of diabetes (Expert Committee on Classification of Diabetes Mellitus, *Diabetes Care* 22 (Supp. 1):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 OXM peptide analogues of the present invention may be effective in the suppression of food intake and the treatment of obesity.

An "effective amount" of an OXM peptide analogue is the quantity that results in a desired therapeutic and/or prophylactic effect without causing unacceptable side effects when administered to a subject. 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 an OXM peptide analogue 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 an OXM peptide analogue for the prevention of NIDDM, for example in subjects with impaired glucose tolerance or impaired fasting glucose, is the quantity that would delay, compared with the absence of treatment, the onset of elevated blood glucose levels that require treatment with anti-hyperglycemic drugs such as sulfonylureas, thiazolidinediones, insulin, and/or bisguanidines.

An "effective amount" of an OXM peptide analogue 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 OXM peptide analogue effective to normalize a subject'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 once weekly dose for the PEGylated OXM peptide analogues of the present invention preferably will range from about 0.1 mg to about 1000 mg (total weight of the conjugate). More preferably, the once weekly dose will range from about 1 mg to about 100 mg, or about 1 mg to about 30 mg. Most preferably, the once weekly dose will range from about 5 mg to about 30 mg, or about 1 mg to about 5 mg.

A "subject" is a mammal, preferably a human, but can also be an animal, including 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).

Various preferred features and embodiments of the present invention will now be described only by way of the examples.

Example 1: Peptide Synthesis

The peptide analogue according to *SEQ ID NO: 1* and *SEQ ID NO: 2* of the present invention is generated by solid-phase peptide synthesis on a Protein Technologies Inc. Symphony or Applied Biosystems 433A automated peptide synthesizer. Synthesis is performed on Fmoc-Rink amide polystyrene resin (Rapp Polymere Tubingen, Germany) with substitution approximately 0.7 mmol/g. The synthesis is performed using the Fmoc main-chain protecting group strategy. Amino acid side-chain derivatives used are: Arg(Pbf), Asn(Trt), Asp(OtBu), Cys(Trt), Gln(Trt), Glu(OtBu), His(Trt), Lys(Boc), Ser(OtBu), Thr(OtBu), Trp(Boc), and Tyr(OtBu). Coupling is carried out with approximately 10 equivalents of amino acid activated with diisopropylcarbodiimide (DIC) and hydroxybenzotriazole (HOBt) (1:1:1 molar ratio) in dimethylformamide (DMF) or N-methyl pyrrolidinone (NMP). Coupling is carried out for 45 to 90 minutes at room temperature.

Concomitant cleavage from the resin and side chain protecting group removal are carried out in a solution containing trifluoroacetic acid (TFA) : triisopropylsilane : 3,6-dioxa-1,8-octane-dithiol : methanol : anisole 90:4:2:2:2 (v/v) for 1.5 to 2 hr at room temperature. The solution is filtered and concentrated to < 2 mL, and peptides are precipitated with cold diethyl ether, redissolved in 30-40 mL of 10 % acetonitrile and purified on a C_{18} reversed-phase high performance liquid chromatography (HPLC) *column (typically a Waters SymmetryPrep 7 um, 19 x 300 mm) at a flow rate of 12-15* mL/min. Samples are eluted with a two-stage linear AB gradient of 0 to 25 % B over 20 minutes followed by 25 to 75 % B over 100 minutes where A = 0.05% TFA/water and B = 0.05 % TFA/acetonitrile. Product generally elutes at 30-35 % acetonitrile. Peptide purity and molecular weight is confirmed on an Agilent 1100 Series liquid chromatography-mass spectrometry (LC-MS) system with a single quadrupole MS detector. Analytical HPLC separation is done on a Zorbax Eclipse XDB-C8, 5 micron, 4.6 mm i.d. x 15 cm column with a linear AB gradient of 6 to 60 % B over 15 minutes in which A = 0.05 % TFA/H_2O and B = 0.05 % TFA/acetonitrile and the flow rate is 1 ml/min. The peptide analogue is purified to > 95 % purity and is confirmed to have molecular weight corresponding to the calculated value within 1 atomic mass unit (amu).

Example 2: PEGylation of peptide containing two Cys residues with mPEG-MAL-20kDa

The lyophilized peptide analogue (SEQ ID NO:2) generated according to Example 1 is weighed out (typically 30-50 mg). A 2.1 fold molar equivalent of mPEG-20kDa maleimide ($CH_3O(CH_2CH_2O)_n$-$(CH_2)_3NHCO(CH_2)_2$-maleimide) (NOF Sunbright ME-200MA) is weighed out and combined with the peptide. The reactants are dissolved in a 50/50 (v/v) water/acetonitrile mixture to a peptide concentration of approximately 20 mg/mL. The peptide analogue solution is diluted two-fold with 100 mM ammonium acetate, 10 mM ethylenediaminetetraacetic acid (EDTA), pH 7. The resultant mixture is then stirred at room temperature. The reaction mixture is monitored by analytical reversed phase HPLC (analytical HPLC separation is done on a Waters SymmetryShield C18, 3.5 micron, 4.6 mm i.d. x 10 cm column at 50 °C with a two-stage linear AB gradient of 0 to 30 % B over 5 minutes and 30 to 90 % B over the subsequent 30 min in which A = 0.05 % TFA/H_2O and B = 0.05 % TFA/acetonitrile and the flow rate is 1 ml/min), and typically after 1-2 hour reaction time, shows almost complete disappearance of the peptide peak. Two peaks due to mono- and di-PEGylated peptide appear with the di-PEGylated peptide typically constituting 90-95 % of the total peak area. The sample is then diluted to about 20 mL with water and purified as in Example 1 with a two-stage linear AB gradient of 0 to 30 % B over 20 min followed by 30 to 80 % B over 100 min. Product generally elutes at 35 – 40 % acetonitrile. The purified peptide is quantitated by ultraviolet (UV) absorbance at 280 nm using a calculated molar extinction coefficient based on the peptide sequence. Yield after purification is in the range of 70 to 80 % based on the amount of starting peptide.

Example 3: Glucagon Receptor (hGcgR) Binding Assay

The Glucagon receptor binding assay utilizes cloned human glucagon receptor (hGcgR) (Lok S, Kuijper JL, Jelinek LJ, Kramer JM, Whitmore TE, Sprecher CA, Mathewes S, Grant FJ, Biggs SH, Rosenberg GB, et al.Gene 140 (2), 203-209 (1994)) isolated from 293HEK membranes. The hGcgR cDNA is subcloned into the expression plasmid phD (Trans-activated expression of fully gamma-carboxylated recombinant human protein C, an antithrombotic factor. Grinnell, B.W., Berg, D.T., Walls, J. and

Yan, S.B. Bio/Technology 5: 1189-1192 (1987)). This plasmid DNA is transfected into 293HEK cells and selected with 200 µg/ml Hygromycin.

Crude plasma membranes are prepared using cells from suspension culture. The cells are lysed on ice in hypotonic buffer containing 25 mM Tris HCl, pH 7.5, 1 mM $MgCl_2$, DNAse1, 20 ug/ml, and Roche Complete Inhibitors without EDTA. The cell suspension is homogenized with a glass dounce homogenizer using a Teflon pestle for 25 strokes. The homogenate is centrifuged at 4 °C at 1800 x g for 15 min. The supernatant is collected and the pellet is resuspended in hypotonic buffer and rehomogenized. The mixture is centrifuged at 1800 x g for 15 min. The second supernatant is combined with the first supernatant. The combined supernatants are centrifuged at 1800 x g for 15 min to clarify. The clarified supernatant is transferred to high speed tubes and centrifuged at 25000 x g for 30 min at 4 °C. The membrane pellet is resuspended in homogenization buffer and stored as frozen aliquots at -80 °C until use.

Glucagon is radioiodinated by ^{125}I-lactoperoxidase procedure and purified by reversed phase HPLC at Perkin-Elmer/NEN (NEX207). The specific activity is about 2200 Ci/mmol. K_D determination is performed by homologous competition instead of saturation binding due to high propanol content in the ^{125}I-labelled glucagon material. The K_D is estimated to be 2.62 nM and is used to calculate Ki values for all compounds tested.

The receptor binding assay is carried out using a Scintillation Proximity Assay (SPA) with wheat germ agglutinin (WGA) beads previously blocked with 1 % fatty acid free bovine serum albumin (BSA). The binding buffer contains 25 mM 4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid (HEPES), pH 7.4, 2.5 mM $CaCl_2$, 1 mM $MgCl_2$, 0.1 % fatty acid free BSA, 0.003 % Tween20, and Roche Complete Inhibitors without EDTA. Glucagon is dissolved in 0.01 N HCl at 1 mg/ml and immediately frozen at -80 °C in 30 µl aliquots. The Glucagon aliquot is diluted and used in the binding assay within 1 hr. The OXM peptide analogue is dissolved in phosphate buffered saline (PBS) and serially diluted in binding buffer. Next, 10 µl diluted compounds or PBS is transferred into Corning 3632 clear bottom assay plates containing 40 µl assay binding buffer or cold glucagon (non-specific binding (NSB) at 1 µM final). Then, 90 µl membranes (3 µg/well), 50 µl ^{125}I-labelled Glucagon (0.15 nM final concentration in reaction), and 50 µl of WGA beads (150 µg/well) are added. Plates are sealed, mixed end

over end, and read with a MicroBeta scintillation counter after 12 hr of settling time at room temperature.

Results are calculated as a percent of specific ^{125}I-labelled glucagon binding in the presence of compound. The absolute IC_{50} concentration of compound is derived by non-linear regression of percent specific binding of ^{125}I-labelled glucagon vs. the concentration of compound added. The IC_{50} dose is converted to Ki using the Cheng-Prusoff equation (Cheng Y., Prusoff W. H., Biochem. Pharmacol. 22, 3099-3108, 1973). The Ki of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated was 2050 $\pm$ 70 nM for hGcgR binding.

Example 4: Glucagon-Like-Peptide 1 (hGLP-1-R) Receptor Binding Assay

The GLP-1 receptor binding assay uses cloned human glucagon-like peptide 1 receptor (hGLP-1R) (Graziano MP, Hey PJ, Borkowski D, Chicchi GG, Strader CD, Biochem Biophys Res Commun. 1993 Oct 15;196(1):141-6) isolated from 293HEK membranes. The hGLP-1R cDNA is subcloned into the expression plasmid phD (Trans-activated expression of fully gamma-carboxylated recombinant human protein C, an antithrombotic factor. Grinnell, B.W., Berg, D.T., Walls, J. and Yan, S.B. Bio/Technology 5: 1189-1192 (1987)). This plasmid DNA is transfected into 293HEK cells and selected with 200 µg/ml Hygromycin.

Crude plasma membranes are prepared using cells from suspension culture. The cells are lysed on ice in hypotonic buffer containing 25 mM Tris HCl, pH 7.5, 1 mM $MgCl_2$, DNAse1, 20 ug/ml, and Roche Complete Inhibitors without EDTA. The cell suspension is homogenized with a glass dounce homogenizer using a Teflon pestle for 25 strokes. The homogenate is centrifuged at 4 °C at 1800 x g for 15 min. The supernatant is collected and the pellet is resuspended in hypotonic buffer and rehomogenized. The mixture is centrifuged at 1800 x g for 15 min. The second supernatant is combined with the first supernatant. The combined supernatants are centrifuged at 1800 x g for 15 min to clarify. The clarified supernatant is transferred to high speed tubes and centrifuged at 25000 x g for 30 min at 4 °C. The membrane pellet is resuspended in homogenization buffer and stored as frozen aliquots at -80 °C until use.

Glucagon-like peptide 1 (GLP-1) is radioiodinated by the ^{125}I-lactoperoxidase procedure and purified by reversed phase HPLC at Perkin-Elmer/NEN (NEX308). The

specific activity is about 2200 Ci/mmol. K_D determination is performed by homologous competition instead of saturation binding due to high propanol content in the ^{125I}-labelled GLP-1 material. The K_D is estimated to be 0.96 nM and is used to calculate Ki values for all compounds tested.

The receptor binding assay is carried out using a Scintillation Proximity Assay (SPA) with wheat germ agglutinin (WGA) beads previously blocked with 1 % fatty acid free BSA (ICN). The binding buffer contains 25 mM HEPES, pH 7.4, 2.5 mM $CaCl_2$, 1 mM $MgCl_2$, 0.1 % fatty acid free BSA, 0.003 % Tween20, and Roche Complete Inhibitors without EDTA. GLP-1 is dissolved in PBS at 1 mg/ml and immediately frozen at -80 °C in 30 µl aliquots. The GLP-1 aliquots are thawed, diluted and used in binding assays within 1 hr. The OXM peptide analogue is dissolved in PBS and serially diluted in binding buffer. Next, 10 µl diluted compounds or PBS is transferred into Corning 3632 clear bottom assay plates containing 40 µl assay binding buffer or cold GLP-1 (NSB at 1 µM final). Then, 90 µl membranes (1 µg/well), 50 µl ^{125}I-labelled GLP-1 (0.15 nM final concentration in reaction), and 50 µl of WGA beads (150 µg/well) are added. Plates are sealed, mixed end over end, and read with a MicroBeta scintillation counter after 12 hr of settling time at room temperature.

Results are calculated as a percent of specific ^{125}I-labelled GLP-1 binding in the presence of compound. The Absolute IC_{50} concentration of compound is derived by non-linear regression of percent specific binding of ^{125}I-labelled GLP-1 vs. the concentration of compound added. The IC_{50} concentration is converted to Ki using the Cheng-Prusoff equation (Cheng Y., Prusoff W. H., Biochem. Pharmacol. 22, 3099-3108, 1973). The Ki of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated was 73 $\pm$ 23 nM for hGLP-1R binding.

Example 5: Glucagon receptor (hGcgR)-Stimulated cAMP Functional Assay

The Glucagon stimulated cAMP functional assay uses the same cloned hGcgR expressing cell line as used for the hGlucR binding assay described above in Example 3. Cells are stimulated with the OXM peptide analogue, and the cAMP generated within the cell is quantitated using an Amplified Luminescent Proximity Homogeneous Assay (Alpha Screen) from Perkin Elmer (6760625R). Briefly, cAMP induced within the cell competes for binding of biotinylated cAMP from the kit to a coated anti-cAMP antibody

Acceptor bead and a strepavidin coated Donor bead. As the cAMP level within the cell increases, a disruption of the Acceptor bead-biotinylated cAMP -Donor bead complex occurs and decreases the signal which is observed.

The hGcgR-HEK293 cells are harvested from sub-confluent tissue culture dishes with Enzyme-Free Cell Dissociation Solution, (Specialty Media 5-004-B). The cells are pelleted at low speed and washed 3 times with assay buffer [25 mM HEPES in Hank's buffered salt solution (HBSS)-with Mg and Ca (GIBCO, 14025-092) with 0.1 % Fatty Acid Free BSA] then diluted to a final concentration of 125,000 cells per ml. Biotinylated cAMP from the Alpha Screen kit is added to the diluted cells at a final concentration of 1 unit/0.04 ml. A phosphodiesterase inhibitor, IBMX (250 mM in dimethyl sulfoxide (DMSO)), is also added to the diluted cells to a final concentration of 500 uM. Glucagon is initially dissolved in 0.01 N HCl at 1 mg/ml and immediately frozen at -80 °C. Upon thawing, the glucagon should be used within 1 hr. The glucagon, cAMP standard, and OXM peptide analogue are serially diluted into Assay buffer to a 6X final concentration. The functional assay is performed in 96 well, low-volume, white, polystyrene Costar Plates (3688). The reaction starts by adding 0.01 ml of the diluted peptides, glucagon, or cAMP into 0.04 ml of the cell mixture. After one hour at room temperature, the reaction is stopped by the addition of 0.03 ml of Lysis Buffer [10 mM HEPES, pH 7.4, 1 % NP40, and 0.01 % fatty acid free BSA containing 1 unit each/0.03 ml of Acceptor and Donor beads from the Alpha Screen Kit]. Addition of the lysis buffer is performed in the dark to prevent bleaching of the detection beads. The plates are wrapped in foil, gently shaken for 1 min then left to equilibrate overnight at room temperature. The plates are read on a Perkin-Elmer Envision instrument. The Alpha screen units are converted into pmoles cAMP generated per well based upon the cAMP standard curve. The pmoles cAMP generated in each well is converted to a percent of the maximal response observed with the glucagon control. An EC_{50} value is derived by non-linear regression analysis using the percent maximal response vs. the concentration of peptide added. The OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated, like wild type OXM, was fully efficacious and potent at hGcgR with EC_{50} of 59.9 $\pm$ 4.14 nM.

Example 6: Glucagon-Like-Peptide 1 Receptor (hGLP-1R)-Stimulated cAMP Functional Assay.

The GLP-1 stimulated cAMP functional assay uses the same cloned hGLP-1R expressing cell line as used for the hGLP-1R binding assay described above in Example 4. Cells are stimulated with the OXM peptide analogue, and the cAMP generated within the cell is quantitated using an Amplified Luminescent Proximity Homogeneous Assay (Alpha Screen) from Perkin Elmer (6760625R). Briefly, cAMP induced within the cell competes for binding of biotinylated cAMP from the kit to a coated anti-cAMP antibody Acceptor bead and a strepavidin coated Donor bead. As the cAMP level within the cell increases, a disruption of the Acceptor bead-biotinylated cAMP -Donor bead complex occurs and decreases the signal which is observed.

The hGLP-1R-HEK293 cells are harvested from sub-confluent tissue culture dishes with Enzyme-Free Cell Dissociation Solution, (Specialty Media 5-004-B). The cells are pelleted at low speed and washed 3 times with assay buffer [25 mM HEPES in HBSS-with Mg and Ca (GIBCO, 14025-092) with 0.1 % Fatty Acid Free BSA] then diluted to a final concentration of 125,000 cells per ml. Biotinylated cAMP from the Alpha Screen kit is added to the diluted cells at a final concentration of 1 unit/0.04 ml. A phosphodiesterase inhibitor, IBMX (250 mM in DMSO), is also added to the diluted cells to a final concentration of 500 μM. GLP-1 is stored at 1 mg/ml in PBS as frozen aliquots at -80 °C. The GLP-1, cAMP standard, and OXM peptide analogue are serially diluted into Assay buffer to a 6X final concentration. The functional assay is performed in 96 well, low volume, white, polystyrene Costar Plates (3688). The reaction starts by adding 0.01 ml of the diluted OXM peptide analogue, GLP-1, or cAMP into 0.04 ml of the cell mixture. After 1 hr at room temperature, the reaction is stopped by the addition of 0.03 ml of Lysis Buffer [10 mM HEPES, pH 7.4, 1 % NP40, and 0.01 % fatty acid free BSA containing 1 unit each/0.03 ml of Acceptor and Donor beads from the Alpha Screen Kit]. Addition of the lysis buffer is performed in the dark to prevent bleaching of the detection beads. The plates are wrapped in foil, gently shaken for 1 min then left to equilibrate overnight at room temperature. The plates are read on a Perkin-Elmer Envision instrument. The Alpha screen units are converted into pmoles cAMP generated per well based upon the cAMP standard curve. The pmoles cAMP generated in each well is converted to a percent of the maximal response observed with the GLP-1 control. An

EC_{50} value is derived by non-linear regression analysis using the percent maximal response vs. the concentration of peptide added. The OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated, like wild type OXM, was fully efficacious and potent at hGLP-1R with EC_{50} of 2.75 $\pm$ 0.55 nM.

Example 7: Effects on food intake, body weight and body composition in diet-induced obese (DIO) mice

Three to four months old male diet-induced obese (DIO) C57BL/6 mice are used. Animals are individually housed in a temperature-controlled (24°C) facility with a 12 hour light/dark cycle (lights on 22:00), and have free access to food and water. After 2 weeks acclimation to the facility, mice are randomized to treatment groups (n= 8-10/group), each group having similar mean body weight and fat mass. Before the experiment, mice are subcutaneously (sc) injected with vehicle solution and weighed for 2 days to acclimate them to the procedures.

Vehicle or OXM peptide analogue (dose range 6.7-20 nmole/kg) dissolved in vehicle is administered by sc injection to ad libitum fed DIO mice 30-90 minutes prior to the onset of the dark cycle every 3 days for 2 to 4 weeks. Body weight and the weight of food plus the hopper are measured at the same time. Food consumed in the preceding 24 hours is calculated by subtracting current weight of food plus the hopper from that of the previous day. Absolute changes in body weight are calculated by subtracting the body weight of the animal prior to the first injection. On days 1, 14 and 28 total fat mass is measured by nuclear magnetic resonance (NMR) using an Echo Medical System (Houston, TX) instrument. Fat free mass is calculated by subtracting fat mass from total body weight.

Study 1: Two week treatment

The OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated *in vivo*, is administered by subcutaneous injection to 4 months old male diet-induced obese (DIO) C57BL/6. The OXM peptide analogue is injected once every 3 days for 2 weeks at doses of 7.5 and 15 nmole/kg and compared to vehicle treated mice and positive control (7.5 nmole/kg of a long-acting GLP-1R agonist injected every 3 days) treated animals.

Treatment with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated produced a dose-dependent reduction in food intake and body weight. At the end of the 2-week study period, cumulative food intake in the 15 nmole/kg group was reduced by 27 % when compared to the vehicle group. Cumulative weight loss of the 7.5 nmole/kg treated group was similar to that observed with the positive control, which was about 9 % reduction when compared to the vehicle group. Vehicle controlled cumulative weight loss of the 15 nmole/kg treated group was 18 %. Body composition analysis showed that the weight loss was primarily due to loss of fat mass (Table 1).

Table 1

Weight change in DIO mice over a 14-day treatment period

(mean ± SEM; n = 8)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	**Overall weight loss** (g weight change for 14 days)	**Total food intake** (g total for 14 days)	**Fat mass loss** (g fat weight change for 14 days)
0 (Vehicle)	1.0 ± 0.5	40.7 ± 1.3	0.3 ± 0.3
7.5	-3.1 ± 0.4*	35.0 ± 0.8*	-2.2 ± 0.3*
15	-6.1 ± 0.9*	29.8 ± 1.5*	-3.9 ± 0.7*

These data show that the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated decreased cumulative food intake and body weight in the 14 day DIO mouse studies, compared to vehicle-treated mice. Reduced body weight was primarily due to reduction in fat mass. *$p<0.05$ versus vehicle (Dunnett's test)

Study 2: Four week treatment

The OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (6.7 or 20 nmole/kg) and positive control (7.5 or 22.5 nmole/kg of

a long-acting GLP-1R agonist) are administered every 3 days by subcutaneous injection to 4 months old male diet-induced obese (DIO) C57BL/6 for 4 weeks.

Treatment with high doses of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly decreased cumulative food intake. At lower doses, the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated decreased body weight to a similar degree as seen in the positive control group. At the 20 nmole/kg dose, the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated caused significantly greater weight loss when compared with 22.5 nmole/kg dose of the positive control. Maximal weight reduction (about 25 % of the initial body weight) was achieved after 15 days of treatment. Body composition analysis confirmed that weight loss associated with the OXM peptide analogue and the positive control was primarily due to loss of fat mass (Table 2).

The effect of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated is further assessed with indirect calorimetry on days 21 to 23. The animals treated with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (20 nmole/kg) had significantly higher energy expenditure than vehicle treated controls (averaged 24-hour energy expenditure on day 21 was increased by 18 %). The OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated did not result in a significant change in the level of motor activity relative to vehicle control.

At the completion of the study, plasma insulin and cholesterol levels were significantly lower in all treated groups than in vehicle treated controls while only the group treated with the high dose of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated had significantly reduced leptin levels. All peptide treated groups had higher plasma adiponectin levels than vehicle treated controls, but only the group treated with the high dose of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated had a statistically significantly difference.

Table 2

Weight change in DIO mice over a 28-day treatment period

(mean ± SEM; n = 9)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	**Overall weight loss** (g weight change for 28 days)	**Total food intake** (g total for the first 14 days)	**Fat mass loss** (g fat weight change for 28 days)
0 (Vehicle)	0.8 ± 0.2	39.2 ± 0.8	0.5 ± 0.1
6.7	-2.0 ± 0.4*	36.0 ± 1.1	-0.7 ± 0.2*
20.0	-11.1 ± 0.9*	26.1 ± 1.4*	-7.5 ± 0.7*

These data show that the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated decreased cumulative food intake and body weight in the 28 day DIO mouse studies, compared to vehicle-treated mice. Reduced body weight was primarily due to reduction in fat mass. *p<0.05 versus vehicle (Dunnett's test)

Example 8: Effects on blood glucose excursion during an oral glucose tolerance test or an intraperitoneal glucose tolerance test after 2-week or 4 week treatment in DIO mice, respectively

Fifty-six hours after the last injection as described in Example 7 (Study 1) in DIO mice, mice are fasted for 16 hours prior to the start of the glucose tolerance test. At time 0, animals are given 2 g/kg dextrose by oral gavage or intraperitoneal (IP) injection. Blood is collected by tail vein bleeding at 0, 15, 30, 60 and 120 minutes after glucose challenge. Glucose concentration is measured by glucometer. All doses of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated as well as the positive control significantly lowered the blood glucose at all time points measured before and after the oral glucose challenge when compared to the vehicle-treated controls (Table 3).

An intraperitoneal glucose tolerance test (IPGTT) is performed on day 29, 3 days after the last injection as described in Example 7 (Study 2) in DIO mice. The low dose of

the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated decreased fasting blood glucose relative to that of vehicle treated controls but had little effect on glucose levels after IP glucose challenge. The high dose of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated and both doses of the positive control significantly lowered blood glucose at all time points measured before and after IP glucose challenge when compared to the vehicle-treated controls (Table 4).

Table 3

Effects of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated on the blood glucose excursion following administration of an oral glucose load

Data given as area under the glucose curve

(= integrated values from t + 0 to 120 min) (n = 8)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	Glucose AUC (mg*min/dL)	
	MEAN	SEM
0 (Vehicle)	27771	1434
7.5	17722*	1009
15	17518*	1686

These data show that after 2 week treatment in DIO mice with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated, there was significant reduction of the blood glucose excursion following an oral glucose load. Statistical significance evaluated by Dunnett's test. (* $p<0.05$ vs. vehicle)

Table 4

Effects of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated on the blood glucose excursion following an intraperitoneal (ip) glucose load

Data given as area under the glucose curve

(= integrated values from t + 0 to 120 min) (n = 6)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	Glucose AUC (mg*min/dL)	
	MEAN	SEM
0 (Vehicle)	35518	1969
6.7	30073	3389
20.0	19264*	1894

These data show that after 4 week treatment in DIO mice with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated, there was a significant reduction of the blood glucose excursion following an intraperitoneal (ip) glucose load. Statistical significance evaluated by Dunnett's test. (* $p<0.05$ vs. vehicle)

Example 9: Effects on blood glucose excursion during an intraperitoneal glucose tolerance test in lean mice

Nine week old male C57BL/6 mice are used in the study. Animals are randomized into groups based on fed body weight. Animals are injected with vehicle or OXM peptide analogue (dose 5.0-15.0 nmole/kg) 16 hours prior to the start of the test. Food is removed at the time of injection of peptide or vehicle. At time 0, animals are given 2 g/kg dextrose by IP injection. Blood is collected by tail vein bleeding at 0, 3, 6, 12 and 30 minutes after glucose challenge. Glucose concentration is measured by glucometer. Insulin is measure by Mesoscale.

The high dose of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly lowered blood glucose excursion

when compared to the vehicle-treated controls (Table 5). Both doses of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly increased plasma insulin concentrations when compared to the vehicle-treated controls (Table 6).

Table 5

Effects of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated on blood glucose excursion following an intraperitoneal (ip) glucose tolerance test in lean mice

Data given as area under the glucose curve

(= integrated values from t + 0 to 30 min) (n = 6)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	Glucose AUC (mg*min/dL)	
	MEAN	SEM
Vehicle	8718	496
5	7059	476
15	6103*	530

These data show that the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly reduced the blood glucose excursion following an intraperitoneal (ip) glucose tolerance test in lean mice. Statistical significance evaluated by Dunnett's test. (* $p<0.05$ vs. vehicle)

Table 6

Effects of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated on plasma insulin level following an intraperitoneal (ip) glucose tolerance test in lean mice

Data given as area under the insulin curve

(=integrated plasma insulin values from t+0 to 30 min) (n = 6)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	Insulin AUC (ng*min/mL)	
	MEAN	SEM
0 (Vehicle)	8.14	1.13
5	30.67*	4.76
15	45.26*	6.78

These data show that the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly increased plasma insulin AUC following an intraperitoneal (ip) glucose tolerance test in lean mice. Statistical significance evaluated by Dunnett's test. (* $p<0.05$ vs. vehicle)

Example 10: Effects on blood glucose excursion during an oral glucose tolerance test (OGTT) or an intraperitoneal (ip) glucose tolerance test (IPGTT) in ob/ob mice

Two to three months old male ob/ob mice are individually housed in a temperature-controlled (24 °C) facility with a 12 hour light/dark cycle (lights on 2200 hours), and have free access to the standard chow and water. After at least 2 weeks of acclimation to the facility, 3-hours fasting blood glucose is measured by tail vein bleeding at 9 AM. Mice with blood glucose under 180 mg/dL are not used. Remaining animals are randomized to treatment groups (N= 6-7/group), each group having similar average blood glucose level. The mice are given access to food until the time of injection. Animals are injected with vehicle or 7.5 nmole/kg OXM peptide analogue at 4 PM of the

same day. Food is removed at the time of injection. An OGTT (Table 7) or IPGTT (Table 8) is performed 16 hours after the peptide injection. At time 0, animals are given 2 g/kg dextrose by oral gavage (Table 7) or intraperitoneal injection (Table 8). Blood is collected by tail vein bleeding at 0, 15, 30, 60 and 120 minutes after glucose challenge. Glucose concentration is measured by glucometer.

A single injection of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated normalized blood glucose in ob/ob mice. Blood glucose levels at all time points measured after glucose challenge were significantly lower than that in the vehicle control group.

Table 7

Effects of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated on blood glucose excursion following an oral glucose tolerance test in ob/ob mice

Data given as area under the glucose curve

(= integrated values from t + 0 to 120 min) (n = 7)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	Glucose AUC (mg*min/dL)	
	MEAN	SEM
0 (Vehicle)	23938	1629
7.5	12266*	1215

These data show that the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly reduced the blood glucose excursion following an oral glucose tolerance test in ob/ob mice. Statistical significance evaluated by Dunnett's test. (*$p<0.05$ vs. vehicle)

Table 8

Effects of the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated on blood glucose excursion following an intraperitoneal (ip) glucose tolerance test in ob/ob mice

Data given as area under the glucose curve

(= integrated values from t + 0 to 120 min) (n = 6)

Dose of OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated (nmole/kg)	Glucose AUC (mg*min/dL)	
	MEAN	SEM
0 (Vehicle)	37894	1482
7.5	18878*	3224

These data show that the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated significantly reduced the blood glucose excursion following an intraperitoneal (ip) glucose tolerance test in ob/ob mice. Statistical significance evaluated by Dunnett's test. (*$p<0.05$ vs. vehicle)

Example 11: Acute Effects on plasma FGF21, triglyceride levels, and hepatic gene expression in male diet-induced obese C57BL/6 mice

In order to investigate metabolic pathways that are modulated by treatment with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated independent of weight loss, the OXM peptide analogue and a positive control (a long acting GLP-1R agonist) are administered by subcutaneous injection to 3 month old male diet-induced obese (DIO) mice. The day before the study, mice are randomized to treatment groups (N= 7/group), each group having similar mean body weight. That same night (approximately 10 PM), animals are placed into clean cages and dosed with vehicle or the OXM peptide analogue by subcutaneous injection. The OXM peptide analogue and the controls are administered at 22.5 nmole/kg. Food is removed at the time of

injection of peptide or vehicle. The following morning (approximately 10 AM), the animals are sacrificed to collect plasma and liver tissue. Glucose and triglyceride concentrations are measured using a Hitachi blood chemistry analyzer. Gene expression is determined by RT-PCR. Malonyl-CoA and acetyl-CoA levels are measured by HPLC.

After a single injection, plasma glucose was significantly decreased relative to vehicle control in all treatment groups. Plasma triglyceride level was decreased relative to vehicle control only in mice treated with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated but not in those treated with the long-acting GLP-1R agonist. Liver malonyl-CoA and acetyl-CoA concentrations were significantly decreased by 63 % and 39 %, respectively versus vehicle control, following treatment with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated. Treatment with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated altered the expression of several hepatic genes including an increase of pgc-1α gene expression by 7-fold and decrease of ChREBP and PCSK9 gene expression by 52 % and 61 %, respectively. In addition, hepatic FGF21 gene expression was induced 17-fold, corresponding to a 6-fold increase in circulating FGF21 after acute treatment with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated. All these changes were specific to the mice treated with the OXM peptide analogue of SEQ ID NO: 3 wherein the Cys(PEG20k) at position 39 is amidated.

WE CLAIM:

1. An Oxyntomodulin peptide analogue comprising the amino acid sequence:
His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala- Xaa_{38}-Xaa_{39} (SEQ ID NO: 5)
wherein Xaa_{38} is Cys, Cys-PEG, or is absent; Xaa_{39} is Cys, Cys-PEG, or is absent; and wherein the C-terminal amino acid is optionally amidated.

2. An Oxyntomodulin peptide analogue according to Claim 1, comprising the amino acid sequence:
His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala-Cys-Cys (SEQ ID NO: 2)
wherein the Cys residue at position 38 is optionally PEGylated; and wherein the Cys residue at position 39 is optionally PEGylated; and the carboxyl group of the Cys at position 39 is optionally amidated.

3. The Oxyntomodulin peptide analogue according to Claim 2, wherein the analogue is PEGylated with an approximately 40 kDa PEG molecule attached to the thiol group of the Cys residue at either position 38 or position 39.

4. The Oxyntomodulin peptide analogue according to either Claim 1 or 2, wherein the analogue is PEGylated on the thiol of both Cys residues at positions 38 and 39 with an approximately 20 kDa PEG molecule in each case and comprises the amino acid sequence:
His-(Aib)-Gln-Gly-Thr-Phe-Thr-Ser-Asp-Tyr-Ser-Lys-Tyr-Leu-Asp-Ser-Lys-Lys-Ala-Gln-Glu-Phe-Val-Gln-Trp-Leu-Leu-Asn-(Aib)-Gly-Arg-Asn-Arg-Asn-Asn-Ile-Ala-Cys(PEG20K)-Cys(PEG20K) (SEQ ID NO: 3)
wherein the carboxyl group of the PEGylated Cys at position 39 is optionally amidated.

5. The Oxyntomodulin peptide analogue according to any one of Claims 1 to 4, wherein the PEG molecule is linear.

6. The Oxyntomodulin peptide analogue according to any one of Claims 1 to 5, wherein the carboxyl group of the Cys residue at position 39 is amidated.

7. The Oxyntomodulin peptide analogue according to Claim 1, wherein the Cys residue at position 39 is absent, and the Cys residue at position 38 is PEGylated with an approximately 40 kDa PEG molecule and is optionally amidated.

8. A pharmaceutical composition comprising the Oxyntomodulin peptide analogue of any one of Claims 1 to 7, and a pharmaceutically acceptable carrier, diluent, or excipient.

9. A pharmaceutical composition comprising the Oxyntomodulin peptide analogue of any one of Claims 1 to 7, together with a pharmaceutically acceptable carrier, diluent, or excipient and optionally other therapeutic ingredients.

10. Use of an Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 in the manufacture of a medicament for treating non-insulin-dependent diabetes.

11. Use of an Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 in the manufacture of a medicament for treating obesity.

12. Use of an Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 in the manufacture of a medicament for treating non-insulin-dependent diabetes or obesity.

13. The Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 for use as a medicament.

14. The Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 for use in the treatment of non-insulin-dependent diabetes.

15. The Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 for use in the treatment of obesity.

16. The Oxyntomodulin peptide analogue according to any one of Claims 1 to 7 for use in the treatment of non-insulin-dependent diabetes or obesity.