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(54) **Title**: METHOD OF TREATING MELANOCORTIN-4 RECEPTOR PATHWAY-ASSOCIATED DISORDERS

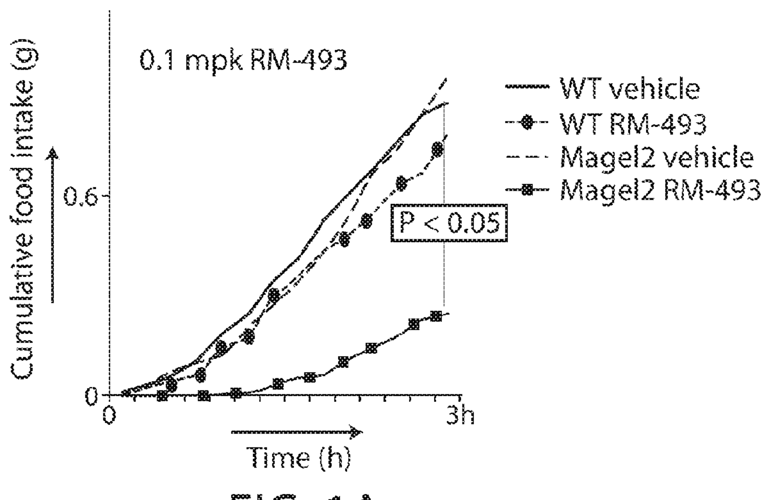

FIG. 1A

(57) **Abstract**: The disclosure is related to a method of treating a disorder, such as Prader Willi Syndrome (PWS), obesity or hyperphagia, in a subject using a melanocortin-4 receptor (MC4R) agonist. Also described is method of treating a subject having a deficiency in the pro-opiomelanocortin (POMC)-MC4R pathway, such as a POMC-null or a PCSK-null subject, using a MC4R agonist.

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METHOD OF TREATING MELANOCORTIN-4 RECEPTOR PATHWAY-ASSOCIATED DISORDERS

BACKGROUND OF THE INVENTION

Melanocortin 4 receptor (MC4R) is a heterotrimeric G-protein-coupled receptor, which transduces signals by activating adenylate cyclase. Expressed in hypothalamic nuclei and other neuronal and non-neuronal tissues, controlling feeding behavior and enegy homeostasis, MC4R integrates an agonist (anorexigenic) signal provided by the α-melanocyte stimulating hormone (α-MSH), and an antagonist (orexigenic) signal provided by the agouti-related peptide (AGPR).

MC4R is a part of the leptin-melanocortin pathway, or POMC-MC4R pathway, which includes a number of proteins such as leptin, leptin receptors, pro-opiomelanocortin (POMC), prohormone convertases including PCSK1, and α-MSH, among others. AGPR binding to MC4R suppresses MC4R activity, while α-MSH binding stimulates the MC4R. Suppressed receptor activity generates an orexigenic signal, whereas stimulated receptor activity generates an anorexigenic signal. Signals from MC4R modulate feeding behavior through secondary effector neurons.

In humans, the hypothalamic POMC-MC4R pathway is part of the regulatory network of appetite and body weight. Monogenic defects in the pathway have been described to lead to severe early onset obesity. For example, patients with POMC loss of function mutations suffer from severe early onset obesity, hyperphagia, and adrenocorticotropic hormone (ACTH) deficiency. They also have low-pigmented skin and body hair. Prader Willi Syndrome (PWS) is thought to be caused by a loss of function of several genes on chromosome 15 in humans, in particular, at 15q11-q13, including one or more genes in the POMC-MC4R pathway. Patients with PWS suffer from severe hyperphagia that leads to severe obesity and other complications. There are currently no approved treatments for the obesity and hyperphagia associated with POMC-MC4R pathway genetic defect disorders such as PWS and POMC-null obesity. Deficiency of MSH, a cleavage product of POMC and the ligand of MC4R, is responsible for the early onset obesity and hyperphagia in these disorders associated with defects in the POMC-MC4R pathway. There is a need for a therapy, such as a MSH replacement therapy, that effectively treats the obesity and hyperphagia associated with POMC-MC4R pathway genetic defect disorders with fewer safety issues.

SUMMARY OF THE INVENTION

In an aspect, provided herein is a method of treating Prader Willi Syndrome (PWS) in a subject in need thereof, comprising:

administering an agonist of the melanocortin-4 receptor (MC4R) at a daily dosage of about 0.1 mg (e.g., 0.1 mg +/- 5%) to about 10 mg (e.g., 10 mg +/- 5%),

wherein the agonist is a MC4R agonist described herein, e.g., the agonist is

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \qquad \text{(I)},$$

wherein:

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl, and substituted aryl(C_1-C_{30})acyl;

each of R^4 and R^5 is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted (C_2-

C_{40})alkenyl, substituted (C_2-C_{40})alkynyl, substituted aryl(C_1-C_{40})alkyl, substituted aryl(C_1-C_{40})acyl, (C_1-C_{40})alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, (C_{1-10})alkyl, substituted (C_{1-10})alkyl, (C_{2-10})alkenyl, substituted (C_{2-10})alkenyl, (C_{2-10})alkynyl, substituted (C_{2-10})alkynyl, aryl, substituted aryl, OH, NH_2, NO_2, or CN,

thereby treating PWS.

In embodiments, the subject has or is identified as having a loss of function mutation in the 15q11-q13 region of chromosome 15.

In embodiments, the subject has or is identified as having a mutation (e.g., loss of function mutation) in the MAGEL2 gene.

In embodiments, the daily dosage is 0.1 mg to 10 mg. In embodiments, the daily dosage is about 0.1 mg to about 7.5 mg. In embodiments, the daily dosage is about 0.1 mg to about 5 mg. In embodiments, the daily dosage is about 0.1 mg to about 2.5 mg. In embodiments, the daily dosage is about 0.1 mg to about 2 mg. In embodiments, the daily dosage is about 0.1 mg to about 1 mg. In embodiments, the daily dosage is about 0.2 mg to about 10 mg. In embodiments, the daily dosage is about 0.2 mg to about 7.5 mg. In embodiments, the daily dosage is about 0.2 mg to about 5 mg. In embodiments, the daily dosage is about 0.2 mg to about 2.5 mg. In embodiments, the daily dosage is about 0.2 mg to about 2 mg. In embodiments, the daily dosage is about 0.2 mg to about 1.5 mg. In embodiments, the daily dosage is about 0.2 mg to about 1 mg. In embodiments, the daily dosage is about 0.3 mg to about 10 mg. In embodiments, the daily dosage is about 0.3 mg to about 7.5 mg. In embodiments, the daily dosage is about 0.3 mg to about 5 mg. In embodiments, the daily dosage is about 0.3 mg to about 2.5 mg. In embodiments, the daily dosage is about 0.3 mg to about 2 mg. In embodiments, the daily dosage is about 0.3 mg to about 1.5 mg. In embodiments, the daily dosage is about 0.3 mg to about 1 mg. In embodiments, the daily dosage is about 0.25 mg (e.g., 0.25 mg) to about 0.5 mg (e.g., 0.5 mg). In embodiments, the daily dosage is about 0.5 mg (e.g., 0.5 mg) to about 0.75 mg (e.g., 0.75 mg). In embodiments, the daily dosage is about 0.25 mg (e.g., 0.25 mg). In embodiments, the daily dosage is about 0.5 mg (e.g., 0.5 mg). In embodiments, the daily dosage is about 0.75 mg (e.g., 0.75 mg) to about 1.25 mg (1.25 mg). In embodiments, the daily dosage is about 1 mg (e.g., 1 mg). In embodiments, the daily dosage is about 1.25 mg (e.g., 1.25 mg) to about 2 mg (e.g., 2 mg). In embodiments, the daily dosage is about 1.5 mg (e.g., 1.5 mg). In embodiments, the daily dosage is about 2 mg (e.g., 2 mg).

In embodiments, the method comprises administering the agonist in a unit dosage suitable for injection, e.g., subcutaneous injection, to the subject.

In embodiments, the unit dosage comprises about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

In embodiments, the unit dosage is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe),an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

In embodiments, the agonist is administered subcutaneously, e.g., by subcutaneous injection.

In embodiments, the agonist is administered daily over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more.

In embodiments, the subject is obese, e.g., severely obese.

In embodiments, the subject has early onset severe obesity.

In embodiments, the subject is hyperphagic.

In embodiments, the subject has a body mass index (BMI) greater than 25 kg/m^2 (e.g., ≥25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 35 kg/m^2 (e.g., ≥36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 40 kg/m^2 (e.g., ≥41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 45 kg/m^2 (e.g., ≥46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a BMI higher than the 85-95th percentile prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has failed one or more previous therapies, e.g., exercise, diet, or behavioral therapies, prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a lower body weight after administration of the agonist than before administration of the agonist.

In embodiments, administration of the agonist results in a reduction of weight in the subject compared to the weight of the subject before treatment of about 1 kg to 3 kg after 1 week of treatment, or about 1 kg to 6 kg after 2 weeks of treatment, or about 2 kg to 12 kg after 4 weeks of treatment, or about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment.

In embodiments, administration of the agonist results in weight loss in the subject at a rate of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment or longer, 16-32 weeks or longer, or 32-64 weeks or longer.

In embodiments, administration of the agonist results in a reduction in hunger level (e.g., a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points) in the subject compared to the hunger level of the subject before treatment, e.g., results in abolishment of hunger (e.g., a score of 0 on the Likert hunger scale) in the subject, e.g., after 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

In embodiments, administration of the agonist results in no detectable/significant decrease in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days or longer, e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass).

In embodiments, administration of the agonist results in an increase in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days, or longer e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or compared to a predetermined REE, e.g., in subjects of similar pre-treatment BMI, when expressed as REE per kg of lean body mass, e.g., after a similar level of weight loss has been attained by fasting).

In embodiments, administration of the agonist results in a reduction in food intake by the subject compared to a control (e.g., the food intake of the subject prior to treatment), e.g., wherein the food intake is daily food intake or food intake over a period of 24 hours, or one week.

In embodiments, administration of the agonist results in a reduction in food intake of at least 100 kilocalories, e.g., at least 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, compared to a control (e.g., the food intake of the subject prior to treatment or a predetermined food intake level), e.g., wherein the food intake is daily food intake or food intake over a period of 24, hours, or one week.

In embodiments, administration of the agonist results in a reduction in food intake of at least 5 kcal/kg/day, e.g., 5, 10, 20, 30, 40, 50, 60, 70, 80, or 90 or more kcal/kg/day. In embodiments, the reduction in food intake is relative to the food intake at baseline. In embodiments, the baseline food intake is at least 100 kcal/kg/day, e.g., for a pediatric subject at about 1 year of age. In embodiments, the baseline food intake is at least 40 kcal/kg/day, e.g., for a pediatric subject, e.g., in late adolescence.

In embodiments, administration of the agonist results in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the

subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in waist circumference of at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in systolic blood of the subject of at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in diastolic blood pressure of the subject of at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the subject is a mammal, e.g., a human.

In embodiments, the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

In embodiments, the method further comprises acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype the 15q11-q13 region of chromosome 15 or of the MAGEL2 gene.

In embodiments, the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in 15q11-q13 region of chromosome 15 or in the MAGEL2 gene.

In embodiments, the knowledge is acquired directly, e.g., from a sample (e.g., a blood, serum, urine, or tissue (e.g., biopsy) sample) from the subject.

In embodiments, the predetermined sequence, e.g., mutation, is detected in a nucleic acid by a method chosen from one or more of: a nucleic acid hybridization assay, an amplification-based assay, a PCR-RFLP assay, real-time PCR, sequencing, screening analysis, FISH, spectral karyotyping or MFISH, comparative genomic hybridization, *in situ* hybridization, SSP, HPLC or mass-spectrometric genotyping.

In embodiments, the predetermined sequence, e.g., mutation, is detected in the subject.

In embodiments, the predetermined sequence, e.g., mutation, is detected in a nucleic acid molecule or a polypeptide in a sample from the subject.

In embodiments, the sample comprises cells from a blood, serum, urine, or tissue (e.g., biopsy) from the subject.

In embodiments, the knowledge is acquired from another party, e.g., wherein the party is the subject, a caregiver, a physician, an endocrinologist, a hospital, clinic, third-party payor, insurance company or government office.

In embodiments, the method comprises:

responsive to a determination of the presence or absence the predetermined sequence, e.g., mutation, in the subject, one or more of:

(1) identifying or selecting the subject as having Prader Willi Syndrome (PWS); and/or

(2) identifying or selecting the subject as likely or unlikely to respond to the agonist.

In embodiments, the presence of the predetermined sequence, e.g., mutation, is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having Prader Willi Syndrome (PWS).

In embodiments, the presence of the predetermined sequence, e.g., mutation, is detected in the subject, and responsive to that determination, the method comprises identifying the subject as likely to respond to the agonist.

In embodiments, the subject has or is identified as having PWS.

In an aspect, provided herein is a method of treating a disorder in a subject in need thereof, comprising:

administering an agonist of the melanocortin-4 receptor (MC4R) at a daily dosage of about 0.1 mg (e.g., 0.1 mg +/- 5%) to about 10 mg (e.g., 10 mg +/- 5%), wherein the disorder is chosen from:

(i) Prader Willi Syndrome (PWS);

(ii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the POMC gene;

(iii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene;

(iv) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the MAGEL2 gene;

(v) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin receptor gene;

(vi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin gene;

(vii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene;

(viii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene;

(ix) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the pro-hormone convertase gene;

(x) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene;

(xi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene;

(xii) a disorder characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising one or more methylated cytosines, e.g., a 5'methyl cytosine); or

(xiii) a disorder characterized by a defect in the POMC-MC4R pathway other than:

(a) a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,

(b) a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,

(c) a melanocortin-4 receptor (MC4R) mutation (e.g., loss of function mutation), or

(d) a pro-hormone convertase mutation (e.g., loss of function mutation);

wherein the agonist is a MC4R agonist described herein, e.g., the agonist is

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \qquad \text{(I)},$$

wherein:

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl, and substituted aryl(C_1-C_{30})acyl;

each of R^4 and R^5 is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted (C_2-

C_{40})alkenyl, substituted (C_2-C_{40})alkynyl, substituted aryl(C_1-C_{40})alkyl, substituted aryl(C_1-C_{40})acyl, (C_1-C_{40})alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, (C_{1-10})alkyl, substituted (C_{1-10})alkyl, (C_{2-10})alkenyl, substituted (C_{2-10})alkenyl, (C_{2-10})alkynyl, substituted (C_{2-10})alkynyl, aryl, substituted aryl, OH, NH_2, NO_2, or CN.

In embodiments, the subject comprises one or more mutations, e.g., from one or more genes described herein.

In embodiments, the disorder is Prader Willi Syndrome (PWS).

In embodiments, the subject has or is identified as having a loss of function mutation in the paternal allele of the 15q11-q13 region of chromosome 15.

In embodiments, the subject has or is identified as having a mutation, e.g., loss of function mutation, in the MAGEL2 gene.

In embodiments, the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the POMC gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional POMC allele and one non-functional POMC allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two distinct non-functional POMC alleles, e.g., having a POMC null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a homozygous POMC null genotype.

In embodiments, the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional PCSK1 allele and one non-functional PCSK1 allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional PCSK1 alleles, e.g., having a PCSK1 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a homozygous PCSK1 null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the MAGEL2 gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional MAGEL2 allele and one non-functional MAGEL2 allele, including the subjects where the remainingfunctional allele is silenced by maternal imprinting, as result of which the subject is a functional MAGEL2 null patient.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two mutated non-functional MAGEL2 alleles, e.g., having a MAGEL2 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a MAGEL2 null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the leptin receptor gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional leptin receptor allele and one non-functional leptin receptor allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional leptin receptor alleles, e.g., having a leptin receptor null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a leptin receptor null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the leptin gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional leptin allele and one non-functional leptin allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional leptin alleles, e.g., having a leptin null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a leptin null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional 5-HT2c receptor allele and one non-functional 5-HT2c receptor allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional 5-HT2c receptor alleles, e.g., having a 5-HT2c receptor null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a 5-HT2c receptor null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional NhHL2 allele and one non-functional NhHL2 receptor allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional NhHL2 alleles, e.g., having a NhHL2 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a NhHL2 null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the pro-hormone convertase gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional pro-hormone convertase allele and one non-functional pro-hormone convertase allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional pro-hormone convertase alleles, e.g., having a pro-hormone convertase null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a pro-hormone convertase null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional CPE allele and one non-functional CPE allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional CPE alleles, e.g., having a CPE null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a CPE null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional SIM1 allele and one non-functional SIM1 allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional SIM1 alleles, e.g., having a SIM1 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a SIM1 null genotype.

In embodiments, the disorder is characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

In embodiments, the disorder is characterized by a defect in the POMC-MC4R pathway other than:

(a) a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,
(b) a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,
(c) a heterozygous melanocortin-4 receptor (MC4R) mutation characterized by the presence of one functional MC4R allele and one non-functional MC4R allele, or
(d) a pro-hormone convertase mutation (e.g., loss of function mutation).

In embodiments, the daily dosage is 0.1 mg to 10 mg. In embodiments, the daily dosage is about 0.1 mg to about 7.5 mg. In embodiments, the daily dosage is about 0.1 mg to about 5 mg. In embodiments, the daily dosage is about 0.1 mg to about 2.5 mg. In embodiments, the daily dosage is about 0.1 mg to about 2 mg. In embodiments, the daily dosage is about 0.1 mg to about 1 mg. In embodiments, the daily dosage is about 0.2 mg to about 10 mg. In embodiments, the daily dosage is about 0.2 mg to about 7.5 mg. In embodiments, the daily dosage is about 0.2 mg to about 5 mg. In embodiments, the daily dosage is about 0.2 mg to about 2.5 mg. In embodiments, the daily dosage is about 0.2 mg to about 2 mg. In embodiments, the daily dosage is about 0.2 mg to about 1.5 mg. In embodiments, the daily dosage is about 0.2 mg to about 1 mg. In embodiments, the daily dosage is about 0.3 mg to about 10 mg. In embodiments, the daily dosage is about 0.3 mg to about 7.5 mg. In embodiments, the daily dosage is about 0.3 mg to about 5 mg. In embodiments, the daily dosage is about 0.3 mg to about 2.5 mg. In embodiments, the daily dosage is about 0.3 mg to about 2 mg. In embodiments, the daily dosage is about 0.3 mg to about 1.5 mg. In embodiments, the daily dosage is about 0.3 mg to about 1 mg. In embodiments, the daily dosage is about 0.25 mg (e.g., 0.25 mg) to about 0.5 mg (e.g., 0.5 mg). In embodiments, the daily dosage is about 0.5 mg (e.g., 0.5 mg) to about 0.75 mg (e.g., 0.75 mg). In embodiments, the daily dosage is about 0.25 mg (e.g., 0.25 mg). In embodiments, the daily dosage is about 0.5 mg (e.g., 0.5 mg). In embodiments, the daily dosage is about 0.75 mg (e.g., 0.75 mg) to about 1.25 mg (1.25 mg). In embodiments, the daily dosage is about 1 mg (e.g., 1 mg). In embodiments, the daily dosage is about 1.25 mg (e.g., 1.25 mg) to about 2 mg (e.g., 2 mg). In embodiments, the daily dosage is about 1.5 mg (e.g., 1.5 mg). In embodiments, the daily dosage is about 2 mg (e.g., 2 mg).

In embodiments, the method comprises administering the agonist in a unit dosage suitable for injection, e.g., subcutaneous injection, to the subject.

In embodiments, the unit dosage comprises about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

In embodiments, the unit dosage is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe),an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

In embodiments, the agonist is administered subcutaneously, e.g., by subcutaneous injection.

In embodiments, the agonist is administered daily over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more.

In embodiments, the subject is obese, e.g., severely obese.

In embodiments, the subject has early onset severe obesity.

In embodiments, the subject is hyperphagic.

In embodiments, the subject has a body mass index (BMI) greater than 25 kg/m^2 (e.g., ≥25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 35 kg/m^2 (e.g., ≥36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 40 kg/m^2 (e.g., ≥41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 45 kg/m^2 (e.g., ≥46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a BMI higher than the 85-95th percentile prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has failed one or more previous therapies, e.g., exercise, diet, or behavioral therapies, prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a lower body weight after administration of the agonist than before administration of the agonist.

In embodiments, administration of the agonist results in a reduction of weight in the subject compared to the weight of the subject before treatment of about 1 kg to 3 kg after 1 week of treatment, or about 1 kg to 6 kg after 2 weeks of treatment, or about 2 kg to 12 kg after 4 weeks of treatment, or about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment.

In embodiments, administration of the agonist results in weight loss in the subject at a rate of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment or longer, 16-32 weeks or longer, or 32-64 weeks or longer.

In embodiments, administration of the agonist results in a reduction in hunger level (e.g., a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points) in the subject compared to the hunger level of the subject before treatment, e.g., results in abolishment of hunger (e.g., a score of 0 on the Likert hunger scale) in the subject, e.g., after 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

In embodiments, administration of the agonist results in no detectable/significant decrease in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days or longer, e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass).

In embodiments, administration of the agonist results in an increase in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days, or longer e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or compared to a predetermined REE, e.g., in subjects of similar pre-treatment BMI, when expressed as REE per kg of lean body mass, e.g., after a similar level of weight loss has been attained by fasting).

In embodiments, administration of the agonist results in a reduction in food intake by the subject compared to a control (e.g., the food intake of the subject prior to treatment), e.g., wherein the food intake is daily food intake or food intake over a period of 24 hours, or one week.

In embodiments, administration of the agonist results in a reduction in food intake of at least 100 kilocalories, e.g., at least 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, compared to a control (e.g., the food intake of the subject prior to treatment or a predetermined food intake level), e.g., wherein the food intake is daily food intake or food intake over a period of 24, hours, or one week.

In embodiments, administration of the agonist results in a reduction in food intake of at least 5 kcal/kg/day, e.g., 5, 10, 20, 30, 40, 50, 60, 70, 80, or 90 or more kcal/kg/day. In embodiments, the reduction in food intake is relative to the food intake at baseline. In embodiments, the baseline food intake is at least 100 kcal/kg/day, e.g., for a pediatric subject at about 1 year of age. In embodiments, the baseline food intake is at least 40 kcal/kg/day, e.g., for a pediatric subject, e.g., in late adolescence.

In embodiments, administration of the agonist results in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the

subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in waist circumference of at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in systolic blood of the subject of at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in diastolic blood pressure of the subject of at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the subject is a mammal, e.g., a human.

In embodiments, the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

In embodiments, the method comprises acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype of, e.g., of a mutation in:

the POMC gene;

the PCSK1 gene;

the MAGEL2 gene;
the leptin receptor gene;
the leptin gene;
the 5-HT2c receptor gene;
the nescient helix loop helix 2 (NhHL2) gene;
the pro-hormone convertase gene;
the carboxypeptidase E (CPE) gene;
the single-minded 1 (SIM1) gene; or
a POMC-MC4R pathway gene.

In embodiments, the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in a gene described herein.

In embodiments, the method comprises acquiring knowledge of the state of methylation of the POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

In embodiments, the agonist is administered in response to the detection of hypermethylation.

In embodiments, the knowledge is acquired directly, e.g., from a sample (e.g., a blood, serum, urine, or tissue (e.g., biopsy) sample) from the subject.

In embodiments, the predetermined sequence, e.g., mutation, is detected in a nucleic acid by a method chosen from one or more of: a nucleic acid hybridization assay, an amplification-based assay, a PCR-RFLP assay, real-time PCR, sequencing, screening analysis, FISH, spectral karyotyping or MFISH, comparative genomic hybridization, *in situ* hybridization, SSP, HPLC or mass-spectrometric genotyping.

In embodiments, the predetermined sequence, e.g., mutation, is detected in the subject.

In embodiments, the predetermined sequence, e.g., mutation, is detected in a nucleic acid molecule or a polypeptide in a sample from the subject.

In embodiments, the state of methylation, e.g., hypermethylation, e.g., methylated cytosine, is detected by a method chosen from one or more of: mass spectrometry, methylation-specific PCR, sequencing of bisulfite treated DNA, HpaII tiny fragment Enrichment by Ligation-mediated PCR Assay, ChIP-on-chip assay, restriction landmark genomic scanning, methylated DNA immunoprecipitation, molecular break light assay for DNA adenine methyltransferase activity, methyl sensitive Southern blotting, or high resolution melt analysis.

In embodiments, the hypermethylation, e.g., methylated cytosine, is detected in the subject.

In embodiments, the hypermethylation, e.g., methylated cytosine, is detected in a nucleic acid molecule in a sample from the subject.

In embodiments, the sample comprises cells from a blood, serum, urine, or tissue (e.g., biopsy) from the subject.

In embodiments, the knowledge is acquired from another party, e.g., wherein the party is the subject, a caregiver, a physician, an endocrinologist, a hospital, clinic, third-party payor, insurance company or government office.

In embodiments, the detection of the predetermined sequence arises from a collaboration with another party.

In embodiments, the method comprises:

responsive to a determination of the presence or absence of (a) the predetermined sequence, e.g., mutation, and/or (b) hypermethylation in the subject, one or more of:

(1) identifying or selecting the subject as having Prader Willi Syndrome (PWS);
(2) identifying or selecting the subject as having a disorder characterized by one or more mutations in the POMC gene, e.g., POMC deficiency;
(3) identifying or selecting the subject as having a disorder characterized by one or more mutations in the PCSK1 gene, e.g., PCSK1 deficiency;
(4) identifying or selecting the subject as having a disorder characterized by one or more mutations in the MAGEL2 gene, e.g., MAGEL2 deficiency;
(5) identifying or selecting the subject as having a disorder characterized by one or more mutations in the leptin receptor gene, e.g., leptin receptor deficiency;
(6) identifying or selecting the subject as having a disorder characterized by one or more mutations in the leptin gene, e.g., leptin deficiency;

(7) identifying or selecting the subject as having a disorder characterized by one or more mutations in the 5-HT2c receptor gene, e.g., 5-HT2c receptor deficiency;

(8) identifying or selecting the subject as having a disorder characterized by one or more mutations in the NhHL2 gene, e.g., NhHL2 deficiency;

(9) identifying or selecting the subject as having a disorder characterized by one or more mutations in the pro-hormone convertase gene, e.g., pro-hormone convertase deficiency;

(10) identifying or selecting the subject as having a disorder characterized by one or more mutations in the CPE gene, e.g., CPE deficiency;

(11) identifying or selecting the subject as having a disorder characterized by one or more mutations in the SIM1 gene, e.g., SIM1 deficiency;

(12) identifying or selecting the subject as having a disorder characterized by a hypermethylated POMC gene, e.g., POMC deficiency;

(13) identifying or selecting the subject has having a disorder characterized by one or more mutations in a POMC-MC4R pathway gene, e.g., POMC-MC4R pathway deficiency; and/or

(14) identifying or selecting the subject as likely or unlikely to respond to the agonist.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in MAGEL2 and/or mutation in the paternal allele of the 15q11-q13 region of chromosome 15) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having Prader Willi Syndrome (PWS).

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the POMC gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the POMC gene, e.g., POMC deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the PCSK1 gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the PCSK1 gene, e.g., PCSK1 deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the leptin receptor gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the leptin receptor gene, e.g., leptin receptor deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the leptin gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the leptin gene, e.g., leptin deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the 5-HT2c receptor gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the 5-HT2c receptor gene, e.g., 5-HT2c receptor deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the NhHL2 gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the NhHL2 gene, e.g., NhHL2 deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the pro-hormone convertase gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the pro-hormone convertase gene, e.g., pro-hormone convertase deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the CPE gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the CPE gene, e.g., CPE deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the SIM1 gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the SIM1 gene, e.g., SIM1 deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in a gene described herein) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in a POMC-MC4R pathway gene, e.g., POMC-MC4R pathway deficiency.

In embodiments, the presence of the hypermethylation in the POMC gene is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by a hypermethylated POMC gene, e.g., POMC deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation, or the hypermethylation, is detected in the subject, and responsive to that determination, the method comprises identifying the subject as likely to respond to the agonist.

In embodiments, the subject has or is identified as having PWS or a disorder characterized by one or more mutations in the POMC, PCSK1, MAGEL2, leptin receptor, leptin, 5-HT2c receptor, NhHL2, pro-hormone convertase, CPE, SIM1, or other POMC-MC4R pathway gene, e.g., POMC-MC4R pathway deficiency.

In an aspect, provided herein is a method of treating a disorder chosen from:

(i) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene;

(ii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the MAGEL2 gene;

(iii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin receptor gene;

(iv) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene;

(v) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene;

(vi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene;

(vii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene;

(viii) a disorder characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine);

(ix) a disorder characterized by a defect in the POMC-MC4R pathway other than:

(a) a POMC mutation, e.g., a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,

(b) a leptin mutation, e.g., a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,

(c) a melanocortin-4 receptor (MC4R) mutation, or

(d) a prohormone convertase mutation;

(x) a disorder characterized by a homozygous POMC mutation (e.g., loss of function mutation), e.g., characterized by a POMC null genotype;

(xi) a disorder characterized by a compound heterozygous POMC mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a POMC null genotype;

(xii) a disorder characterized by a homozygous leptin mutation (e.g., loss of function mutation), e.g., characterized by a leptin null genotype;

(xiii) a disorder characterized by a compound heterozygous leptin mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a leptin null genotype,

in a subject in need thereof, comprising administering an agonist of the melanocortin-4 receptor (MC4R),

wherein the agonist is a MC4R agonist described herein, e.g., the agonist is

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \qquad \text{(I)},$$

wherein:

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl, and substituted aryl(C_1-C_{30})acyl;

each of R^4 and R^5 is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted (C_2-C_{40})alkenyl, substituted (C_2-C_{40})alkynyl, substituted aryl(C_1-C_{40})alkyl, substituted aryl(C_1-C_{40})acyl, (C_1-C_{40})alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, (C_{1-10})alkyl, substituted (C_{1-10})alkyl, (C_{2-10})alkenyl, substituted (C_{2-10})alkenyl, (C_{2-10})alkynyl, substituted (C_{2-10})alkynyl, aryl, substituted aryl, OH, NH_2, NO_2, or CN.

In embodiments, the disorder is characterized by a homozygous POMC mutation (e.g., loss of mutation), e.g., characterized by a POMC null genotype.

In embodiments, the disorder is characterized by a compound heterozygous POMC mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a POMC null genotype.

In embodiments, the mutations are mutations described herein, e.g., p.Lys51Term g.A6851>T and p.Arg145ProfsX12 g.7134delG.

In embodiments, the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional PCSK1 allele and one non-functional PCSK1 allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional PCSK1 alleles, e.g., having a PCSK1 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a PCSK1 null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the MAGEL2 gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional MAGEL2 allele and one non-functional MAGEL2 allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional MAGEL2 alleles, e.g., having a MAGEL2 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a MAGEL2 null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the leptin receptor gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional leptin receptor allele and one non-functional leptin receptor allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional leptin receptor alleles, e.g., having a leptin receptor null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a leptin receptor null genotype.

In embodiments, the disorder is characterized by a homozygous leptin mutation (e.g., loss of mutation), e.g., characterized by a leptin null genotype.

In embodiments, the disorder is characterized by a compound heterozygous leptin mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a leptin null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional 5-HT2c receptor allele and one non-functional 5-HT2c receptor allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional 5-HT2c receptor alleles, e.g., having a 5-HT2c receptor null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a 5-HT2c receptor null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional NhHL2 allele and one non-functional NhHL2 receptor allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional NhHL2 alleles, e.g., having a NhHL2 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a NhHL2 null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional CPE allele and one non-functional CPE allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional CPE alleles, e.g., having a CPE null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a CPE null genotype.

In embodiments, the disorder is characterized by one or mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene.

In embodiments, the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional SIM1 allele and one non-functional SIM1 allele.

In embodiments, the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional SIM1 alleles, e.g., having a SIM1 null genotype.

In embodiments, the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a SIM1 null genotype.

In embodiments, the disorder is characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

In embodiments, the subject has or is identified as having a hypermethylated CpG island in the POMC gene, e.g., at the intron2-exon3 boundary of the POMC gene.

In embodiments, the disorder is characterized by a defect in the POMC-MC4R pathway other than a POMC mutation, e.g., a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele.

In embodiments, the disorder is characterized by a defect in the POMC-MC4R pathway other than a leptin mutation, e.g, a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele.

In embodiments, the disorder is characterized by a defect in the POMC-MC4R pathway other than a MC4R mutation, e.g., a heterozygous melanocortin-4 receptor (MC4R) mutation characterized by the presence of one functional MC4R allele and one non-functional MC4R allele.

In embodiments, the disorder is characterized by a defect in the POMC-MC4R pathway other than a pro-hormone convertase mutation.

In embodiments, the method comprises administering the agonist in a unit dosage suitable for injection, e.g., subcutaneous injection, to the subject.

In embodiments, the unit dosage comprises about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

In embodiments, the unit dosage is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe),an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

In embodiments, the agonist is administered subcutaneously, e.g., by subcutaneous injection.

In embodiments, the agonist is administered daily over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more.

In embodiments, the subject is obese, e.g., severely obese.

In embodiments, the subject has early onset severe obesity.

In embodiments, the subject is hyperphagic.

In embodiments, the subject has a body mass index (BMI) greater than 25 kg/m^2 (e.g., ≥25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 35 kg/m^2 (e.g., ≥36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 40 kg/m^2 (e.g., ≥41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body mass index (BMI) greater than 45 kg/m^2 (e.g., ≥46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a BMI higher than the 85-95th percentile prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has failed one or more previous therapies, e.g., exercise, diet, or behavioral therapies, prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a lower body weight after administration of the agonist than before administration of the agonist.

In embodiments, administration of the agonist results in a reduction of weight in the subject compared to the weight of the subject before treatment of about 1 kg to 3 kg after 1 week of treatment, or about 1 kg to 6 kg after 2 weeks of treatment, or about 2 kg to 12 kg after 4 weeks of treatment, or about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment.

In embodiments, administration of the agonist results in weight loss in the subject at a rate of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment or longer, 16-32 weeks or longer, or 32-64 weeks or longer.

In embodiments, administration of the agonist results in a reduction in hunger level (e.g., a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points) in the subject compared to the hunger level of the subject before treatment, e.g., results in abolishment of hunger (e.g., a score of 0 on the Likert hunger scale) in the subject, e.g., after 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

In embodiments, administration of the agonist results in no detectable/significant decrease in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days or longer, e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass).

In embodiments, administration of the agonist results in an increase in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days, or longer e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or compared to a predetermined REE, e.g., in subjects of similar pre-treatment BMI, when expressed as REE per kg of lean body mass, e.g., after a similar level of weight loss has been attained by fasting).

In embodiments, administration of the agonist results in a reduction in food intake by the subject compared to a control (e.g., the food intake of the subject prior to treatment), e.g., wherein the food intake is daily food intake or food intake over a period of 24 hours, or one week.

In embodiments, administration of the agonist results in a reduction in food intake of at least 100 kilocalories, e.g., at least 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, compared to a control (e.g., the food intake of the subject prior to treatment or a predetermined food intake level), e.g., wherein the food intake is daily food intake or food intake over a period of 24, hours, or one week.

In embodiments, administration of the agonist results in a reduction in food intake of at least 5 kcal/kg/day, e.g., 5, 10, 20, 30, 40, 50, 60, 70, 80, or 90 or more kcal/kg/day. In embodiments, the reduction in food intake is relative to the food intake at baseline. In embodiments, the baseline food intake is at least 100 kcal/kg/day, e.g., for a pediatric subject at about 1 year of age. In embodiments, the baseline food intake is at least 40 kcal/kg/day, e.g., for a pediatric subject, e.g., in late adolescence.

In embodiments, administration of the agonist results in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the

subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in waist circumference of at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in systolic blood of the subject of at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, administration of the agonist results in a reduction in diastolic blood pressure of the subject of at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the subject is a mammal, e.g., a human.

In embodiments, the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

In embodiments, the method comprises acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype of, e.g., of a mutation in:

the POMC gene;
the PCSK1 gene;

the MAGEL2 gene;

the leptin receptor gene;

the leptin gene;

the 5-HT2c receptor gene;

the nescient helix loop helix 2 (NhHL2) gene;

the carboxypeptidase E (CPE) gene; or

the single-minded 1 (SIM1) gene.

In embodiments, the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in a gene described herein.

In embodiments, the method comprises acquiring knowledge of the state of methylation of the POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

In embodiments, the agonist is administered in response to the detection of hypermethylation.

In embodiments, the knowledge is acquired directly, e.g., from a sample (e.g., a blood, serum, urine, or tissue (e.g., biopsy) sample) from the subject.

In embodiments, the predetermined sequence, e.g., mutation, is detected in a nucleic acid by a method chosen from one or more of: a nucleic acid hybridization assay, an amplification-based assay, a PCR-RFLP assay, real-time PCR, sequencing, screening analysis, FISH, spectral karyotyping or MFISH, comparative genomic hybridization, *in situ* hybridization, SSP, HPLC or mass-spectrometric genotyping.

In embodiments, the predetermined sequence, e.g., mutation, is detected in the subject.

In embodiments, the predetermined sequence, e.g., mutation, is detected in a nucleic acid molecule or a polypeptide in a sample from the subject.

In embodiments, the state of methylation, e.g., hypermethylation, e.g., methylated cytosine, is detected by a method chosen from one or more of: mass spectrometry, methylation-specific PCR, sequencing of bisulfite treated DNA, HpaII tiny fragment Enrichment by Ligation-mediated PCR Assay, ChIP-on-chip assay, restriction landmark genomic scanning, methylated DNA immunoprecipitation, molecular break light assay for DNA adenine methyltransferase activity, methyl sensitive Southern blotting, or high resolution melt analysis.

In embodiments, the hypermethylation, e.g., methylated cytosine, is detected in the subject.

In embodiments, the hypermethylation, e.g., methylated cytosine, is detected in a nucleic acid molecule in a sample from the subject.

In embodiments, the sample comprises cells from a blood, serum, urine, or tissue (e.g., biopsy) from the subject.

In embodiments, the knowledge is acquired from another party, e.g., wherein the party is the subject, a caregiver, a physician, an endocrinologist, a hospital, clinic, third-party payor, insurance company or government office.

In embodiments, the detection of the predetermined sequence arises from a collaboration with another party.

In embodiments, the detection of the hypermethylation arises from a collaboration with another party.

In embodiments, the method comprises:

responsive to a determination of the presence or absence of (a) the predetermined sequence, e.g., mutation, and/or (b) hypermethylation in the subject, one or more of:

(1) identifying or selecting the subject as having a disorder characterized by one or more mutations in the PCSK1 gene, e.g., PCSK1 deficiency;
(2) identifying or selecting the subject as having a disorder characterized by one or more mutations in the MAGEL2 gene, e.g., MAGEL2 deficiency;
(3) identifying or selecting the subject as having a disorder characterized by one or more mutations in the leptin receptor gene, e.g., leptin receptor deficiency;
(4) identifying or selecting the subject as having a disorder characterized by one or more mutations in the 5-HT2c receptor gene, e.g., 5-HT2c receptor deficiency;
(5) identifying or selecting the subject as having a disorder characterized by one or more mutations in the NhHL2 gene, e.g., NhHL2 deficiency;

(6) identifying or selecting the subject as having a disorder characterized by one or more mutations in the CPE gene, e.g., CPE deficiency;
(7) identifying or selecting the subject as having a disorder characterized by one or more mutations in the SIM1 gene, e.g., SIM1 deficiency;
(8) identifying or selecting the subject as having a disorder characterized by a hypermethylated POMC gene, e.g., POMC deficiency;
(9) identifying or selecting the subject has having a disorder characterized by one or more mutations in a POMC-MC4R pathway gene, e.g., POMC-MC4R pathway deficiency;
(10) identifying or selecting the subject as having a disorder characterized by a defect in the POMC-MC4R pathway other than a POMC mutation;
(11) identifying or selecting the subject as having a disorder characterized by a defect in the POMC-MC4R pathway other than a leptin mutation;
(12) identifying or selecting the subject as having a disorder characterized by a defect in the POMC-MC4R pathway other than a MC4R mutation;
(13) identifying or selecting the subject as having a disorder characterized by a defect in the POMC-MC4R pathway other than a prohormone convertase mutation;
(14) identifying or selecting the subject as having a disorder characterized by a homozygous POMC mutation;
(15) identifying or selecting the subject as having a disorder characterized by a compound heterozygous POMC mutation;
(16) identifying or selecting the subject as having a disorder characterized by a homozygous leptin mutation;
(17) identifying or selecting the subject as having a disorder characterized by a compound heterozygous leptin mutation; and/or
(18) identifying or selecting the subject as likely or unlikely to respond to the agonist.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in MAGEL2) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having Prader Willi Syndrome (PWS).

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the PCSK1 gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the PCSK1 gene, e.g., PCSK1 deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the leptin receptor gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the leptin receptor gene, e.g., leptin receptor deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the 5-HT2c receptor gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the 5-HT2c receptor gene, e.g., 5-HT2c receptor deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the NhHL2 gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the NhHL2 gene, e.g., NhHL2 deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the CPE gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the CPE gene, e.g., CPE deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in the SIM1 gene) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in the SIM1 gene, e.g., SIM1 deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., mutation in a gene described herein) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by one or more mutations in a POMC-MC4R pathway gene, e.g., POMC-MC4R pathway deficiency.

In embodiments, the presence of the hypermethylation in the POMC gene is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by a hypermethylated POMC gene, e.g., POMC deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., homozygous POMC mutation) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by a homozygous POMC mutation, e.g., POMC deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., compound heterozygous POMC mutation) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by a compound heterozygous POMC mutation, e.g., POMC deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., homozygous leptin mutation) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by a homozygous leptin mutation, e.g., leptin deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation (e.g., compound heterozygous leptin mutation) is detected in the subject, and responsive to that determination, the method comprises identifying the subject as having a disorder characterized by a compound heterozygous leptin mutation, e.g., leptin deficiency.

In embodiments, the presence of the predetermined sequence, e.g., mutation, or the hypermethylation, is detected in the subject, and responsive to that determination, the method comprises identifying the subject as likely to respond to the agonist.

In embodiments, the subject has or is identified as having a disorder characterized by one or more mutations in the PCSK1, MAGEL2, leptin receptor, 5-HT2c receptor, NhHL2, pro-hormone convertase, CPE, SIM1, or other POMC-MC4R pathway gene, e.g., POMC-MC4R pathway deficiency.

In embodiments, the subject has or is identified as having a disorder characterized by a homozygous or compound heterozygous mutation in one or more of the POMC or leptin gene, e.g., POMC deficiency or leptin deficiency.

In as aspect, provided herein is a unit dosage of an agonist described herein, wherein the unit dosage contains 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

In embodiments, the unit dosage contains 0.5 mg of agonist.

In embodiments, the unit dosage contains 1.0 mg of agonist.

In embodiments, the unit dosage contains 1.5 mg of agonist.

In embodiments, the unit dosage is suitable for injection, e.g., subcutaneous injection.

In embodiments, the unit dosage is disposed in a delivery device suitable for injection, e.g., subcutaneous injection.

In embodiments, the unit dosage is disposed in a syringe or pen-type injector suitable for injection, e.g., subcutaneous injection.

In embodiments, the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

In an aspect, provided herein is a method of evaluating a subject, comprising:

acquiring information that identifies the subject as having or not having a predetermined sequence, e.g., mutation, in the 15q11-q13 region of chromosome 15 or in the MAGEL2 gene,

wherein identification of the subject as having the mutation identifies the patient as more likely to have improved symptoms following treatment with a MC4R agonist (e.g., a MC4R agonist described herein), and identification of the subject as not having a mutation in the 15q11-q13 region of chromosome 15 or in the MAGEL2 gene identifies the patient as being less likely to have improved symptoms following treatment with a MC4R agonist, e.g., a MC4R agonist described herein.

In another aspect, provided herein is a method of evaluating a subject, comprising:

acquiring information that identifies the subject as having or not having a predetermined sequence, e.g., mutation, in one or more of:

the POMC gene;

the PCSK1 gene;

the MAGEL2 gene;

the leptin receptor gene;

the leptin gene;

the 5-HT2c receptor gene;

the nescient helix loop helix 2 (NhHL2) gene;

the carboxypeptidase E (CPE) gene; or

the single-minded 1 (SIM1) gene;

wherein identification of the subject as having the predetermined sequence, e.g., mutation, identifies the patient as more likely to have improved symptoms following treatment with a MC4R agonist (e.g., a MC4R agonist described herein), and identification of the subject as not having the predetermined sequence, e.g., mutation, identifies the patient as being less likely to have improved symptoms following treatment with a MC4R agonist, e.g., a MC4R agonist described herein.

In accordance with any method described herein, in embodiments, the improved symptoms comprise one or more of:

(a) a decrease in body weight;

(b) a decrease in waist circumference;

(c) a decrease in hunger level;

(d) a decrease in food intake level; and/or

(e) a lack of decrease or an increase in resting energy expenditure.

In embodiments, the mutation is a loss of function mutation.

In embodiments, the mutation is a homozygous mutation, e.g., homozygous loss of function mutation.

In embodiments, the mutation is a heterozygous mutation.

In embodiments, the heterozygous mutation is a compound heterozygous mutation (e.g., characterized by the presence of two non-functional alleles).

In embodiments, the heterozygous mutation is characterized by the presence of one functional allele and one non-functional allele.

In embodiments, the method further comprises providing a report to another party, e.g., wherein the party is the subject, a caregiver, a physician, an oncologist, a hospital, clinic, third-party payor, insurance company or government office.

In embodiments, said report is in electronic, web-based, or paper form.

In embodiments, the report identifies the presence or absence of the mutation in the subject, and optionally includes an identifier for the subject from which the information was obtained.

In embodiments, the report comprises:

information on the genotype (e.g., presence or absence of the predetermined sequence, e.g., mutation) of the subject;

information on prognosis or suggested therapeutic options, e.g., MC4R agonists;

information on the likely effectiveness of a therapeutic option, e.g., MC4R agonist, the acceptability of a therapeutic option, or the advisability of applying the therapeutic option to the subject; and/or

information, or a recommendation on, the administration of the therapeutic option (e.g., MC4R agonist).

In embodiments, the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

In an aspect, provided herein is a method of selecting a subject having Prader Willi Syndrome (PWS), comprising:

acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype of the paternal allele of the 15q11-q13 region of chromosome 15 or of the MAGEL2 gene;

wherein the acquiring step comprises determining the presence or absence of a predetermined sequence, e.g., mutation in the paternal allele of the 15q11-q13 region of chromosome 15 or in the MAGEL2 gene; and

wherein the presence of the predetermined sequence, e.g., mutation, identifies the subject as having PWS.

In an aspect, provided herein is a method of selecting a subject having a POMC-MC4R pathway deficiency, comprising:

(i) acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype of, e.g., of a mutation in:

the POMC gene;

the PCSK1 gene;

the MAGEL2 gene;

the leptin receptor gene;

the leptin gene;

the 5-HT2c receptor gene;

the nescient helix loop helix 2 (NhHL2) gene;

the carboxypeptidase E (CPE) gene; or

the single-minded 1 (SIM1) gene;

wherein the presence of the mutation identifies the subject as having a POMC-MC4R pathway deficiency; or

(ii) acquiring knowledge of the state of methylation of the POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine),

wherein the presence of the hypermethylation at the POMC intron identifies the subject as having a POMC-MC4R pathway deficiency.

In accordance with any method described herein, in embodiments, the method further comprises administering an agonist of the melanocortin-4 receptor (MC4R) to the subject, e.g., an agonist described herein, e.g., setmelanotide.

In embodiments, the mutation is a loss of function mutation.

In embodiments, the mutation is a homozygous mutation, e.g., homozygous loss of function mutation.

In embodiments, the mutation is a heterozygous mutation.

In embodiments, the heterozygous mutation is a compound heterozygous mutation (e.g., characterized by the presence of two distinct non-functional alleles).

In embodiments, the heterozygous mutation is characterized by the presence of one functional allele and one non-functional allele.

In embodiments, the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

Also provided herein is a use of a MC4R agonist, e.g., a MC4R agonist described herein, in the treatment of or in the manufacture of a medicament for the treatment of Prader Willi Syndrome (PWS), wherein the MC4R agonist is administered at a daily dosage of about 0.1 mg (e.g., 0.1 mg +/- 5%) to about 10 mg (e.g., 10 mg +/- 5%).

Also provided herein is a use of a MC4R agonist, e.g., a MC4R agonist described herein, in the treatment of or in the manufacture of a medicament for the treatment of a disorder chosen from:

(i) Prader Willi Syndrome (PWS);

(ii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the POMC gene;

(iii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene;

(iv) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the MAGEL2 gene;

(v) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin receptor gene;

(vi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin gene;

(vii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene;

(viii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene;

(ix) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the pro-hormone convertase gene;

(x) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene;

(xi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene;

(xii) a disorder characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising one or more methylated cytosines, e.g., a 5'methyl cytosine); or

(xiii) a disorder characterized by a defect in the POMC-MC4R pathway other than:

(a) a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,

(b) a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,

(c) a melanocortin-4 receptor (MC4R) mutation (e.g., loss of function mutation), or

(d) a pro-hormone convertase mutation (e.g., loss of function mutation).

optionally wherein the agonist is administered at a daily dosage of about 0.1 mg (e.g., 0.1 mg +/- 5%) to about 10 mg (e.g., 10 mg +/- 5%).

Additional embodiments in accordance with any method described herein include those that follow.

In embodiments, the MC4R agonist is a compound of Formula I, wherein:

A^1 is A6c, Arg, D-Arg, Cha, D-Cha, hCha, Chg, D-Chg, Gaba, Ile, Leu, hLeu, Met, β-hMet, 2-Nal, D-2-Nal, Nip, Nle, Oic, Phe, D-Phe, hPhe, hPro, Val, or deleted;

A^2 is Asp, Cys, D-Cys, hCys, D-hCys, Glu, Pen, or D-Pen;

A^3 is D-Abu, Aib, Ala, β-Ala, D-Ala, D-Cha, Gaba, D-Glu, Gly, D-Ile, D-Leu, D-Tle, D-Val, or deleted;

A^4 is H is or 3-Pal;

A^5 is D-Bal, D-1-Nal, D-2-Nal, D-Phe, D-Trp, or D-(Et)Tyr;

A^6 is Arg, or hArg;

A^7 is Bal, Bip, 1-Nal, 2-Nal, Trp, D-Trp;

A^8 is A6c, D-Ala, Aha, Ahx, Ala, β-Ala, Apn, Gaba, Gly or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Lys, Pen, or D-Pen;

A^{10} is Thr, or deleted,

wherein at least one of A^3 or A^8 is deleted, but not both, or pharmaceutically acceptable salts thereof.

In embodiments, the MC4R agonist is not an adrenocorticotropic hormone (ACTH).

In embodiments, the MC4R agonist is not melanotan-II (MT-II) (Ac-Nle-cyclo[Asp-His-D-Phe-Arg-Trp-Lys]-NH_2) (SEQ ID NO: 562).

In embodiments, the MC4R agonist comprises 8 amino acids or more.

In embodiments, the MC4R agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(Arg-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 500) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is a tripeptide D-Phe-Arg-Trp (SEQ ID NO: 560) or a pharmaceutical salt thereof.

In embodiments, the MC4R agonist is a peptide that includes D-Phe-Arg-Trp (SEQ ID NO: 560) or a pharmaceutical salt thereof.

In embodiments, the MC4R agonist is a peptide that includes an acetylated tripeptide Ac-D-Phe-Arg-Trp-NH_2 (SEQ ID NO: 561) or a pharmaceutical salt thereof.

In embodiments, the MC4R agonist is c[Hydantoin(C(O)-(Glu-D-Ala))-His-D-Phe-Arg-Trp-Dap]-NH_2 (SEQ ID NO: 496) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(Nle-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 501) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(Gly-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-NH_2 SEQ ID NO: 506) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(Ala-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 507) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(D-Arg-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 515) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(Gly-D-Arg))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 535) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Hydantoin(C(O)-(Gly-Arg))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 531) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-NH_2 (SEQ ID NO: 468) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-NH_2 (SEQ ID NO: 470) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-NH_2 (SEQ ID NO: 471) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-β-Ala-Cys)-$(Pro)_2$ -Lys-Asp-NH_2 (SEQ ID NO: 472) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Aib-Cys)-$(Pro)_2$ -Lys-Asp-NH_2 (SEQ ID NO: 473) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is c[Hydantoin(C(O)-(Asp-Aic))-D-2-Nal-Arg-Trp-Lys]-NH_2 (SEQ ID NO: 492) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is c[Hydantoin(C(O)-(Asp-A6c))-D-2-Nal-Arg-Trp-Lys]-NH_2 (SEQ ID NO: 489) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-Arg-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)- NH_2 (SEQ ID NO: 139) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-NH2 (SEQ ID NO: 36) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is D-Phe-c(Cys-His-D-Phe-Arg-Bip-β-Ala-D-Cys)-Thr-NH2 (SEQ ID NO: 81) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is D-Phe-c(Cys-His-D-Phe-hArg-Bip-β-Ala-D-Cys)-Thr-NH2 (SEQ ID NO: 83) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-NH2 (SEQ ID NO: 84) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-NH2 (SEQ ID NO: 82) or a pharmaceutically acceptable salt thereof.

In embodiments, the MC4R agonist is any MC4R agonist described in US 2014/0329743 A1, incorporated herein by reference.

In embodiments, the MC4R agonist is any MC4R agonist described in WO2014/144260 A1, incorporated herein by reference.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting. Headings, subheadings or numbered or lettered elements, e.g., (a), (b), (i) etc, are presented merely for ease of reading. The use of headings or numbered or lettered elements in this document does not require the steps or elements be performed in alphabetical order or that the steps or elements are necessarily discrete from one another. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description of preferred embodiments of the invention will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there are shown in the drawings embodiments which are presently preferred. It should be understood, however, that the invention is not limited to the precise arrangements and instrumentalities of the embodiments shown in the drawings.

FIGs. 1A and 1B are graphs that show the effects on cumulative food intake suppression following treatment with setmelanotide (RM-493 at 0.1 mg/kg (mpk)) versus vehicle in Magel2-null (Magel2) and wildtype (WT) mice. FIG. 1A is an enlarged version of the inset in FIG. 1B and shows cumulative food intake through 3 hours post-dosing. FIG. 1B shows cumulative food intake through overnight.

FIG. 2 is a set of graphs showing the change in body weight in wild-type obese humans after 2 or 4 weeks of treatment with setmelanotide.

FIGS.3A-D show food intake over time in wild-type and *db/db* mice administred vehicle or setmelanotide.

FIGS.3A and 3D are graphs that show food intake as a function of time in wild-type mice and *db/db* mice at varying concentrations of setmelanotide..

FIGS. 3E-and 3F are graphs that summarize the effects of food intake over time in wild-type (FIG. 3E) or *db/db* mice (FIG. 3F) administered vehicle or 0.0554 mpk, 0.137 mpk, , 0.344 mpk or 1.37 mpk setmelanotide.

DETAILED DESCRIPTION OF THE INVENTION

The present disclosure is based at least in part on the discovery that targeting defects in the POMC-MC4R pathway, e.g., targeting defects upstream of MC4R, by using a MC4R agonist as replacement therapy led to significant weight loss, decrease in hunger, and/or reveal an increase in energy expenditure in obese subjects. The disclosure is also based in part on the discovery that obese subjects having a defect (e.g., genetic defect) in one or more genes upstream of MC4R in the POMC-MC4R pathway are likely to exhibit a significantly greater response (e.g., in decreasing body weight and/or hunger and/or increasing energy expenditure) to an MC4R agonist than obese subjects not having such a defect. For example, as described herein, subjects having a non-functional Magel2 gene (e.g., Magel2-null obesity) may be much more responsive (e.g., in decreasing food intake) following exposure to an MC4R agonist than obese subjects not having such a genetic disorder (e.g., wild-type obese).

Also, as described herein, subjects having a non-functional POMC gene (e.g., POMC null obesity) exhibited a significantly greater response (e.g., in decreasing body weight and/or hunger and/or increasing energy expenditure) to an MC4R agonist than obese subjects not having such a genetic disorder (e.g., wild-type obese). In particular, the MC4R agonist led to a weight loss of about 2-2.5 kg per week over the course of 26 weeks of treatment (a total weight loss of about 36 kg after 26 weeks, corresponding to about 23% of the initial body weight). This weight loss in the POMC deficient subject is over 2-fold greater compared to that observed in wild-type obese subjects (which exhibited a weight loss after MC4R agonist treatment of about 0.6-0.9 kg per week over 2-4 weeks). Also, the greater weight loss seen in the POMC deficient subject persisted over a long period of time and did not appear to desensitize.

The dramatic weight loss and duration of weight loss observed in the POMC deficient subject is not only significantly greater than that observed for wild-type obese subjects treated with the MC4R agonist, but also significantly greater than the weight loss seen in obese subjects treated with currently marketed therapies. In clinical studies, marketed therapies such as Belviq® (Lorcaserin HCl tablets), Qsymia® (Phentermine and Topiramate extended release capsules), Contrave® (Naltrexone HCl and Bupropion HCl extended release tablets), and Saxenda® (Liraglutide injection) at prescribed doses caused less than 5 kg placebo adjusted weight loss in obese subjects after one year of treatment. The hyperresponsiveness of POMC-MC4R pathway deficient subjects (e.g., POMC deficient subjects) to an MC4R agonist, e.g., an MC4R agonist described herein, is surprising, as it is believed that weight loss in obese subjects reaches a limit at around 5% as subjects appear to become desensitized and adapt to the therapy effects, ascribed to physiological and compensatory changes that include a decrease in energy expenditure as the subject loses weight. Surprisingly, this limit in continued weight loss was not observed in the POMC deficient subject, who continued to lose weight well beyond 5% even after 13-26 weeks of treatment.

Without being bound by theory, a MC4R agonist, such as setmelanotide, can act to replace a missing MC4R signaling step in subjects having a genetic defect in the POMC-MC4R pathway (e.g., genetic disorders such as PWS and POMC-null obesity). As such, it is believed that a MC4R agonist, such as setmelanotide, can lead to even greater efficacy in these patient populations than those with general (e.g., wild-type) obesity. Accordingly, the methods and compositions described herein provide an optimized approach to restore MC4R pathway function in subjects with genetic disorders (e.g., genetic deficiencies in one or more genes of the POMC-MC4R pathway) such as PWS, POMC-null, and PCSK-null obesity, thereby decreasing the extreme hyperphagia and obesity seen in these subjects. Provided herein are methods to treat subjects having a genetic defect in one or more genes of the POMC-MC4R pathway as well as methods to identify/select subjects that have such defects and/or that are likely to respond to a MC4R agonist (e.g., more likely to respond to a MC4R agonist than wild-type obese subjects).

Definitions

As used herein “about” and "approximately" generally mean an acceptable degree of error for the quantity measured given the nature or precision of the measurements. Exemplary degrees of error are within 20 percent (%), typically, within 10%, and more typically, within 5% of a given value or range of values.

“Acquire” or “acquiring” as the terms are used herein, refer to obtaining possession of a physical entity, or a value, *e.g.*, a numerical value, or knowledge of (e.g., knowledge of the sequence or mutational state of) a genotype or a nucleic acid or polypeptide, by “directly acquiring" or "indirectly acquiring" the physical entity, value, or knowledge. "Directly acquiring" means performing a physical process (*e.g.*, performing a synthetic or analytical method) to obtain the physical entity, value, or knowledge. "Indirectly acquiring" refers to receiving the physical entity, value, or knowledge from another party or source (*e.g.*, a third party laboratory that directly acquired the physical entity, value, or knowledge). Directly acquiring a physical entity includes performing a process that includes a physical change in a physical substance, *e.g.*, a starting material. Exemplary changes include making a physical entity from two or more starting materials, shearing or fragmenting a substance, separating or purifying a substance, combining two or more separate entities into a mixture, performing a chemical reaction that includes breaking or forming a covalent or non-covalent bond. Directly acquiring a value or knowledge includes performing a process that includes a physical change in a sample or another substance. Examples include performing an analytical process which includes a physical change in a substance, *e.g.*, a sample, analyte, or reagent (sometimes referred to herein as "physical analysis"), performing an analytical method, *e.g.*, a method which includes one or more of the following: separating or purifying a substance, *e.g.*, an analyte, or a fragment or other derivative thereof, from another substance; combining an analyte, or fragment or other derivative thereof, with another substance, *e.g.*, a buffer, solvent, or reactant; or changing the structure of an analyte, or a fragment or other derivative thereof, *e.g.*, by breaking or forming a covalent or non-covalent bond, between a first and a second atom of the analyte; or by changing the structure of a reagent, or a fragment or other derivative thereof, *e.g.*, by breaking or forming a covalent or non-covalent bond, between a first and a second atom of the reagent.

As used herein, the term "obese" refers to a subject having a body mass index (BMI) within the ranges defined as "obese" by the Center for Desease Control (s*ee*, e.g., URL.cdc.gov/obesity/defining.html and www.cdc.gov/obesity/childhood/defining.html, last accessed on August 19, 2015) or as defined by "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults" from the National Institutes of Health. BMI is obtained by dividing a subject's weight, e.g., in kilograms (kg) by the square of the subject's height, e.g., in meter (m). For example, an adult who has a BMI of 30 kg/m^2 or higher is considered obese. For example, an adult with a BMI of 25.0 to 29.9 kg/m^2 is considered overweight; an adult with a BMI of 18.5 to 24.9 kg/m^2 is considered to have a normal or healthy weight range; and an adult with a BMI of less than 18.5 kg/m^2 is considered to be underweight. For example, an adult having a height of 5 feet, 9 inches with a body weight of 203 pounds or more is considered obese. For children and teens, obese refers to a subject having a BMI at or above the 85^{th} to 95^{th} percentile for children and teens of the same age and sex.

A "severely obese" subject or a subject having "severe obesity" refers to a subject having a BMI of 35 kg/m^2 or higher, e.g., 40 kg/m^2 or higher. For example, a severely obese subject is over 100% over the ideal (normal, healthy) body weight.

As used herein "early onset", e.g., as in early onset obesity, refers to an onset (e.g., first occurrence of one or more symptoms of a disorder, e.g., a disorder described herein, e.g., obesity, PWS, POMC-null obesity) that occurs in a subject before adulthood, e.g., during childhood, e.g., when the subject is less 18 years of age or younger (e.g., 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 year of age or younger, or during adolescence, e.g., when the child is younger than 12 years of age or when the child is younger than 6 years of age).

As used herein, the term "metabolic syndrome" refers to a group of symptoms that occur together and increase the risk for coronary artery disease, stroke, and type 2 diabetes. According to the American Heart Association and the National Heart, Lung, and Blood Institute, metabolic syndrome also referred to as Syndrome X) is present if a subject has three or more of the following signs:

1) Blood pressure equal to or higher than 130/85 mmHg;

2) Fasting blood sugar (glucose) equal to or higher than 100 mg/dL;

3) Large waist circumference (length around the waist):

- Men - 40 inches or more;
- Women - 35 inches or more;

4) Low HDL cholesterol:

- Men - under 40 mg/dL;
- Women - under 50 mg/dL;

5) Triglycerides equal to or higher than 150 mg/dL.

Metabolic syndrome can be diagnosed by testing subject's blood pressure, blood glucose level, HDL cholesterol level, LDL cholesterol level, total cholesterol level, and triglyceride level.

As used herein, the term "agonist" refers to any chemical compound, either naturally occurring or synthetic, that, upon interacting with (*e.g.*, binding to) its target, e.g., MC4R, raises the signaling activity of MC4R above its basal level. An agonist can be a superagonist (*i.e.* a compound that is capable of producing a greater maximal response than the endogenous agonist for the target receptor, and thus has an efficacy of more than 100%), a full agonist (*i.e.* a compound that elicits a maximal response following receptor occupation and activation) or a partial agonist (*i.e.* a compounds that can activate receptors but are unable to elicit the maximal response of the receptor system).

As used herein "treating" includes achieving one or more of the following results: reducing the body weight (as measured, for example, by a body mass index (BMI) and/or body weight), e.g., compared to a control (e.g., body weight before treatment or a predetermined body weight); reducing the waist circumference, e.g., compared to a control (e.g., waist circumference before treatment or a predetermined waist circumference); reducing the hunger level, e.g., compared to a control (e.g., hunger level before treatment or a predetermined hunger level); increasing the resting energy expenditure (REE), e.g., compared to a control (e.g., REE before treatment or a predetermined REE); decreasing the food intake, e.g., compared to a control level (e.g., before treatment or a predetermined food intake); ameliorating or improving a clinical symptom or indicators associated with a disorder described herein such as obesity, PWS, POMC-null obesity, e.g., type-II diabetes, pre-diabetic condition, blood level of haemoglobin A1C (Hb1Ac) above 6%, hyperinsulimenia, hyperlipidemia, insulin insensitivity, or glucose intolerance; delaying, inhibiting or preventing the progression of obesity and/or obesity related indications; or partially or totally delaying, inhibiting or preventing the onset or development of obesity or a obesity related indication. Delaying, inhibiting or preventing the progression of the obesity includes for example, delaying, inhibiting or preventing the progression of a subject having normal weight to obesity. In embodiments, a control is a value of a parameter measured before treatment by a MC4R agonist described herein or a predetermined value. The term "treating" further includes partially or totally reducing the risk for coronary artery disease, stroke, and type 2 diabetes associated with the metabolic syndrome as well as ameliorating or improving a clinical symptom or signs of metabolic syndrome associated with metabolic syndrome, such as any one or more of the five indicators listed above. For example, the term “treating” includes delaying, inhibiting or preventing the progression of parameters associated with the metabolic syndrome, including insulin resistance, glucose clearance and parameters of cardiovascular disease including heart rate and blood pressure.

As used herein “inhibition” or “inhibits” can include a reduction in a certain parameter, such as a parameter described herein. For example, inhibition of a parameter, e.g., activity, can be at least 5%, 10%, 20%, 30%, 40%, or more is included by this term. Thus, inhibition need not be 100%.

“Prophylactic treatment” refers to treatment before onset of obesity to prevent, inhibit or reduce its occurrence.

As used herein, the term “subject” refers to a mammal, e.g., a human. Subject can also refer to an animal in need of veterinary treatment, 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).

As used herein, the term “mutation” can refer to an altered nucleic acid sequence of a gene or fragment thereof compared to a wild-type sequence. For example, a mutation can include a point mutation, frame-shift mutation, missense mutation, inversion, deletion, insertion, truncation, chromosomal translocation. In embodiments, a mutation can result in the gene or fragment thereof coding for a non-functional protein, a protein with reduced activity (or a partially functional protein), or a protein with altered activity. For example, a “loss of function” mutation refers to a mutation that results in the gene or fragment thereof coding for a non-functional protein, which has substantially reduced activity compared to its wild-type counterpart (e.g., a non-functional protein has less than 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1% or less activity than its wild-type counterpart). For example, “partial loss of function” mutation refers to a mutation that results in the gene or fragment thereof coding for a partially functional protein, which has reduced activity compared to its wild-type counterpart (e.g., a partially functional protein has less than 50% and greater than 10% of the activity of its wild-type counterpart).

As used herein "heterozygous" refers to the presence of two different alleles (having different nucleic acid sequences) for a given gene in a subject. In some embodiments, "heterozygous mutation" can refer to the presence of a mutation on one allele for a given gene and the lack of a mutation on the other allele of the same gene in a subject (e.g., one mutant allele and one wild type allele for a given gene). In other embodiments, a "heterozygous mutation" can be a "compound heterozygous" mutation, which refers to the presence of a mutation (e.g., loss of function mutation or partial loss of function mutation) on one allele for a given gene and a different (e.g., loss of function mutation or partial loss of function mutation) on the other allele for the same gene (e.g., two different alleles that are both mutated, e.g., non-functional or partially functional). In embodiments, where a compound heterozygous mutation includes two non-functional alleles, the genotype can be a null genotype or functionally deficient genotype.

As used herein "homozygous" refers to the presence of two identical alleles for a given gene. In some embodiments, a "homozygous mutation" refers to the presence of two mutant alleles for a given gene, where the two mutant alleles are identical.

As used herein "null genotype" refers to the presence of two non-functional alleles of a gene in a subject.

As used herein "unit dosage" refers to a physically discrete unit suited as unitary doses for a subject to be treated. Each unit contains a predetermined quantity of active compound calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier.

As used herein "dosage" refers to a quantity or amount of a therapeutic agent. In some embodiments, a dosage is the amount administered to the subject in a single administration, e.g., in a single injection, a single infusion, or single administration of one or more unit dosages. In embodiments, a dosage is the amount administered to the subject in multiple administrations, e.g., multiple injections, multiple infusions, or multiple administrations of one or more unit dosages. In other embodiments, a dosage can refer to the total amount administered to the subject in a certain time period, e.g., per day. In such examples, the dosage is typically referred to as "daily dosage" or dosage in terms of quantity per day.

As used herein "hunger" or "hunger level" refers to a subject's appetite, desire to consume food, or perceived need for food. In embodiments, the hunger or hunger level of a subject can be quantified by using a scale to obtain a hunger score. In embodiments, the scale for hunger assigns a higher score for a subject that more frequently (e.g., often or always) feels unbearable hunger and a lower score for a subject that less frequently (e.g., sometimes or never) feels unbearable hunger. See, e.g., Sibilia. Psychologicol Topics 19 (2010), 2, 341-354. For example, a Likert scale for hunger can be used that assigns scores from 0 to 10 points (0=no hunger; 10=severe hunger). In other examples, a Likert scale for hunger can be used that assigns scores from 1 to 4 points, where a subject who never feels unbearable hunger is assigned a score of 1, where a subject who sometimes feels unbearable hunger is assigned a score of 2, where a subject who often feels unbearable hunger is assigned a score of 3, and where a subject who always feels unbearable hunger is assigned a score of 4. See i.d.

POMC-MC4R Pathway

The melanocortin system, which includes melanocortins (MCs), agouti, agouti-related proteins, and their receptors, integrate hormonal, metabolic, and neural signals in order to control energy homeostasis and regulate appetite, energy expenditure, and body weight. The MCs, which include alpha-melanocyte-stimulating hormone (α-MSH), β-MSH, γ-MSH, and ACTH, are a family of peptide hormones that are derived from a precursor protein called pro-opiomelanocortin (POMC). Activation of MC4 receptor (MC4R) in the POMC-MC4R pathway increases energy expenditure and decreases food intake. See, e.g., Fan et al. Nature 1997;385:165-68. The POMC-MC4R pathway includes a number of proteins, such as melanocortins (MCs), MC4 receptor (MC4R), POMC, Proprotein Convertase Subtilisin/Kexin Type 1 (PCSK1, also called PC1/3), MAGE-like-2 (MAGEL2), leptin receptor (leptin-R), leptin, 5-hydroxytryptamine (serotonin) receptor 2C, G protein-coupled (5-HT2c receptor), nescient helix loop helix 2 (NhHL2, also called NSCL2), pro-hormone convertase, carboxypeptidase E (CPE), and single-minded 1 (Sim1), that together contribute to the regulation of energy homeostasis, e.g., by regulating appetite and energy expenditure. MC4R and other components of the POMC-MC4R pathway have a significant role in weight regulation. A mutation of the MC4R gene was reported to result in early-onset and severe obesity. It is believed that other genetic defects in the POMC-MC4R pathway likely also lead to early-onset and severe obesity.

MC4R

hMC4R is a protein encoded by a genomic sequence having GenBank accession number CH471077.2.

Mutations in the MC4R receptor are an associated cause of severe childhood obesity. The carrier prevalence for MC4R mutations in a juvenile-onset obese population has been noted to be around 2.5% with a highest prevalence of 6% among severely obese children. Humans with MC4R mutations show a more or less similar phenotype as has been described for mice with mutations in the MC4R gene. MC4R deficient patients show hyperphagia, hyperinsulinaemia, increased fat mass, accompanied by lean body mass, bone mineral density and linear growth rate increases, with no changes in cortisol levels, gonadotropin, thyroid and sex steroid levels. In contrast to MC4R deletion, hyperphagia and hyperinsulinaemia tends to subside with age in human subjects. Similar to the MC4R knockout mice, the phenotype in heterozygote carriers is intermediate in comparison to homozygote carriers. The exhibited hyperphagia observed upon a test meal is less severe than that observed in people with a leptin deficiency. The severity of MC4R dysfunction seen in assays in vitro can predict the amount of food ingested at a test meal by the subject harboring that particular mutation and correlates with the onset and severity of the obese phenotype. At east 90 different MC4R mutations have been associated with obesity and additional mutations in the MC4R are likely to be discovered, leading to a similar obesity phenotype.

Examples of the MC4R mutations that cause obesity in humans are described, e.g., in Farooqi *et al.*, *The Journal of Clinical Investigation*, July 2000, vol. 106 (2), pp. 271-279 and Vaisse *et al.*, *The Journal of Clinical Investigation*, July 2000, vol. 106(2), pp. 253-262, the relevant portions of which are incorporated herein by reference).

Additional mutations that potentially casue obesity in humans include, R18H, R18L, S36Y, P48S, V50M, F51L, E61K, I69T, D90N, S94R, G98R, I121T, A154D, Y157S, W174C, G181D, F202L, A219 V, I226T, G231S, G238D, N240S, C271R, S295P, P299L, E308K, I317V, L325F, and 750DelGA, as described in Xiang *et al.*, "Pharmacological characterization of 30 human melanocortin-4 receptor polymorphisms with the endogenous proopiomelanocortin-derived agonists, synthetic agonists, and the endogenous agouti-related protein antagonist." Biochemistry, 2010 Jun 8; 49(22):4583-600, the the relevant portions of which are incorporated herein by reference.

Further examples of mutations that potentially cause obesity in humans are those listed in Online Mendelian Inheritance in Man (OMIM), a database of human genes and genetic disorders, under the accession number 155541 (MC4R) (more precisely, accession nos. 155541.0001-155541.0023) at the URL http://omim.org/entry/155541. Representative examples include 4-BP DEL, NT631; 4-BP INS, NT732; TYR35TER; ASP37VAL; SER58CYS; ILE102SER; ASN274SER; 1-BP INS, 112A; 4-BP DEL, 211CTCT; ILE125LYS; ALA175THR; ILE316SER; TYR287TER; ASN97ASP; 15-BP DEL (delta88-92 codons); and SER127LEU. The relevant portions of the OMIM database are incorporated herein by reference.

Additional exemplary mutations in MC4R are described in Lee. Annals Acad. Med. 38.1(2009):34-44.

In example embodiments, the MC4R mutation results in retention of the MC4R signaling activity.

Mutations in the genomic sequence encoding MC4R can be detected by the methods that are known to a person of ordinary skill in the art. For example, the genomic sequence can be cloned using nucleotide primers, such as *e.g.*, the primers described in Farooqi *et al.*, The Journal of Clinical Investigation, July 2000, vol. 106 (2), pp. 271-279 and Vaisse *et al.*, The Journal of Clinical Investigation, July 2000, vol. 106(2), pp. 253-262, and the cloned sequence analyzed using commercially available sequencers and software.

Activity of MC4R can be measured by the methods known to a person of ordinary skill in the art. For example, cells can be transiently transfected with the cloned MC4R DNA, the transfected cells contacted by an agonist of MC4R (*e.g.* α-MSH), and the intracellular level of cAMP, the secondary messenger of MC4R, measured by an electrochemiluminescence assay described, *e.g.*, in Roubert *et al.*, Journal of Endocrinology (2010) 207, pp. 177-183. A reduction in MC4R signaling can be ascertained by comparing the intracellular level of cAMP produced in response to a given agonist by a wild type MC4R to that produced by a mutant MC4R.

POMC

POMC is a component of the POMC-MC4R pathway that acts upstream of the MC4R. POMC is a precursor protein that is cleaved by pro-hormone convertases to generate multiple peptide hormones (e.g., alpha-MSH, ACTH, beta-endorphin, and enkephalin). Convertases that process POMC polypeptides incude prohormone convertase 1 (PC1, also called PC1/3 or PCSK1), prohormone convertase 2 (PC2), carboxypeptidase E (CPE), peptidyl α-amidating monooxygenase (PAM), N-acetyltransferase (N-AT), and prolylcarboxypeptidase (PRCP).

The POMC gene is located on human chromosome 2p23.3, and the gene sequence is provided in GenBank Accession No. NG_008997.1, incorporated herein by reference. An exemplary nucleic acid sequence of human POMC mRNA transcript variant X1 is provided in GenBank Accession No. XM_011532917.1, incorporated herein by reference. An exemplary amino acid sequence of human POMC isoform X1 is provided in GenBank Accession No. XP_011531219.1, incorporated herein by reference. An exemplary nucleic acid sequence of human POMC mRNA transcript variant 1 is provided in GenBank Accession No. NM_001035256.1, incorporated herein by reference. An exemplary amino acid sequence of human POMC pre-proprotein is provided in GenBank Accession No. NP_001030333.1. An exemplary nucleic acid sequence of human POMC mRNA transcript variant 2 is provided in GenBank Accession No. NM_000939.2, incorporated herein by reference. An exemplary amino acid sequence of human POMC pre-proprotein is provided in GenBank Accession No. NP_000930.1.

POMC neurons, which express POMC, provide an anorexigenic effect, where secretion of POMC neuropeptides from the POMC neurons decreases body weight and food intake. Loss of function mutations of the POMC gene have been reported to result in obesity, red hair, and adrenal insufficiency. For example, defects in POMC (e.g., loss of function mutation(s) or hypermethylation) have been associated with obesity and ACTH deficiency. See, e.g., Mendiratta et al. Intl. J. Ped. Endocrinol. 2011:5; and Kuehnen et al. PLoS Genetics. 8.3(2012):e1002543. A homozygous codon 231 cytosine to adenosine (c.231C > A) change in POMC has been reported to result in a premature termination codon, causing loss of function of POMC, which was associated with extreme weight gain, congenital adrenal insufficienty, and hypoglycemia. See, e.g., Mendiratta et al. Intl. J. Ped. Endocrinol.

2011:5. In embodiments, exemplary mutations in POMC are described in Lee. Annals Acad. Med. 38.1(2009):34-44.

In embodiments, exemplary mutations in POMC are described in Table 1 below. In embodiments, homozygous and/or heterozygous (e.g., compound heterozygous) mutations from Table 1 are contemplated.

Table 1

Examples of loss of function POMC heterozygote (POMC+/-) Variants*	**Reference**	**Function**
Cys28Phe	J Clin Endo 2008; 93; 4494	
Leu37Phe	J Clin Endo 2008; 93; 4494 Cell Met. 2006; 3; 135	
His143GLu	Cell Met. 2006; 3; 135	Alpha-MSH loss of function
Phe144Leu	Ped Res. 2008; 63; 2; 211	Alpha-MSH loss of function
Tyr221Cys	Cell Met. 2006; 3; 135 Cell Met. 2006; 3; 135 Cell met. 2006; 3; 141	Beta-MSH loss of function
Pro231Leu	Clin Chem 2005; 51(8); 1358	Beta-MSH likely loss of function
Arg236Gly	Hum Mol Gen. 2002; 11; 1997 Hum Mol Gen. 2002; 11; 1997	Beta-endorphin loss of function
Glu244X	Clin Chem 2005; 51(8); 1358	
*Amino acid numbering corresponds to that of the protein including the signal peptide, as described in Takahashi, et al. 1981 Febs Letters 135(1)97. X indicates early termination.		

In certain embodiments, e.g., as referred to in Table 1, the POMC amino acid sequence is that described in Takahashi, et al. 1981 Febs Letters 135(1)97, copied below (where the 26-amino acid signal peptide is underlined).

```
MPRSCCSRSG ALLLALLLQA SMEVRG WCLE SSQCQDLTTE SNLLECIRAC
KPDLSAETPM FPGNGDEQPL TENPRKYVMG HFRWDRFGRR NSSSSGSSGA
GQKREDVSAG EDCGPLPEGG PEPRSDGAKP GPREGKRSYS MEHFRWGKPV
GKKRRPVKVY PNGAEDESAE AFPLEFKREL TGQRLREGDG PDGPADDGAG
AQADLEHSLL VAAEKKDEGP YRMEHFRWGS PPKDKRYGGF MTSEKSQTPL
VTLFKNAIIK NAYKKGE  (SEQ ID NO: 563)
```

In certain embodiments, e.g., as referred to in Table 1, the POMC gene nucleotide sequence is that described in Takahashi et al. Nucl Acids Res. 1983, 11(19)6847, e.g., provided in GenBank Accession No. V01510.1 and copied below.

```
   1 ctgctcttca cagcatcacc ctctccccat ttaatggttt aggttaacag gactttttcc
  61 ttgaggcttg ggacacggaa gggagcctcc cctaaaccag gcccttggag agcaggcccc
 121 aggggagcag tgcaactcac cttcacaccc acaagacggc tcctgacttc tgctccctcc
 181 tcccctcccc aaagtggaac agagagaata tgattcccca cgacttccac atcacagttt
 241 ccaaacaatg ggaaatcgg aggcctcccc gtgtgcagac ggtgatattt accgccaaat
 301 gcgaaccagg cagatgccag ccccagcacg cacgcaggta acttcaccct cgcctcaacg
 361 acctcagagg ctgcccggcc tgccccacac gggggtgcta agcctcccgc ccgttctaag
 421 cggagaccca acgccatcca taattaagtt cttcctgagg gcgagcggcc aggtgcgcct
 481 tcggcaggac agtgctaatt ccagcccctt tccagcgcgt ctccccgcgc tcgtcccccg
 541 tctggaagcc cccctcccac gccccgcggc ccccccttccc ctggcccggg gagctgctcc
 601 ttgtgctgcc gggaaggtca aagtcccgcg cccaccagga gagctcggca agtatataag
 661 gacagaggag cgcgggacca agcggcggcg aaggagggga agaagagccg cgaccgagag
 721 aggccgccga gcgtccccgc cctcagagag cagcctcccg agacaggtaa gggcgcagcg
 781 tggggggaccc gtgctctttc cccgggatcc cctgtccccg tcctcgcgat gcagtcggcc
 841 ggctccggct ccgaaggcgg acctgggcgc ctctggctct ccgcggtccc gagttctcga
 901 caaactttct gcgccgactg cggcatgaga agccgccagt agctgagctg gagggcccac
 961 gtccggcccc tgggcggacg gccgcgaagc tgcaggcgct gtctccaggg agccggcggc
1021 ctcctctccc ccagggggctc gcggcggtcc ggaggctccg agagcttgct aggaggtctt
1081 gggacaaccc ggtctttttt tttttttttg agacggagtt tcgctcttgt tgcccatgct
1141 ggagagcaaa ggggtgatct ctgctcaccg caaccttcgc ctcccgggtt caagcgattc
1201 tcctgcttca gcctcccgag tagctgggat tacaggcatg cgccaccacg cccggctaat
1261 ttttgtattt ttagtagtga cggagtttct ccatgttggt caggctggtc tcaaactccc
1321 gacaacaggt gatccgcccg ccttggcccc ccaaagttct ggcattacag gcgcgagcca
1381 ccgcccccgg ccagcccggt cttttagtat ctcttgctcc cagtttccag gataggtgtc
1441 acatcttgaa agtcaaattc catacacgct atcgcaaatt aatgttggaa acggggcagc
1501 agagaaaagg ataaaagtca taatgaacgc cctgccttcc ggattttttc ggattcagac
1561 ccctgaatcc ttgtttcctt gcccacctta gcgcacccga ggtggccgcg ctatgataat
1621 tacatgataa ctgggtcaat tacaatgcag aatagttggg tctcttctct ccaagaccta
1681 gctggggtta aaaacaggtg gccggggcgg gagctgtcct agatcctgaa acgcactgtc
1741 tagtttcgga tgccctcaac agaaccgggg tggacggttt atggcgcaga tcctgggttg
1801 agggcacggg cagccatttg gaatgatcaa ggctcaggta aggggcgttt ccagcgaagg
1861 agagacagtc cacttggcat ttggattccc caaattcttc atgtttaaat ggggcaggga
1921 gggttcttac agaatggctg gaaggagcca aggaaaataa aagtgtgtgt ggattttttt
1981 tgtgtgtgtg tcagtttata aactctgcac agattatggc cactttaatg acttactgtt
2041 cctttgatgc ttttgttata ggactcgatg catgtatgtc atggtgtaag gacaaaactc
2101 ggcccctgtg ctcctctaat ctttacaaaa ggtcatggcc agcgtgcagt tttacagtaa
2161 caagcaaaat gatttgttga gctcatagag agcccctcac acctatgaag ttctaataag
2221 tgtagttcta ctataaagtt aatctcagga tgagcaaatt tcaagtttct atttttccag
2281 agctttccat ttttggatta taatactttc cctacttaaa aaagcacaac atttgatatt
2341 tccccaataa tttgttgctt taaaaatgac acaaaaggta ctatttgttc attgtagaga
2401 actgaaaata cacataagca aatacacata cacataagca aaatatacaa tacaaacaca
2461 agaccatctt tcagggaaga atctgaagtt ttagcaatag cagccatcta accagtttag
2521 caacagaata taagctctga gagggtggga gtgaatatgt taccacattg tacaacacag
2581 cacatagggc ataaggaggg gaaatgctct ctggggcttt ccaggaaggc ctgaagtcat
2641 tgcttctagc aaatggaaat cactccagag tagttatctt tgacaagaat tgaaatataa
2701 ttgagggaac tatcagacct gtaagatttt gttttttcct ttactaatat gttactttac
2761 atttgcattt ggtgacatac gtaactacca tttttctgtg actgtaacat ctgggcattt
2821 ttcagagcta aatgtgctat ggtcaacttg gagctttaat ctaattgcct ggtccaccaa
2881 gttctggctg tgtacttgaa tagatcactg gcagggtaca atgggaacag cctgtccctt
2941 ggagccagga gaggacacca aggttgacca aagctcgttc agttgcccct ttagccgaag
3001 cgcacctggg ccagtcactg gctgccagtg ccatctaatg gctgctctga aaatgctcag
3061 ccttgcccgg caacccttca gaagctagca ccgtgcaggc ccagcgcctg gggaataggg
3121 cgagggtggg gtagagagaa ggaagtggcc tcctgaagta gaaatcagcg cttcagagga
3181 ctttcacttc caaagcctcc cctatataaa aaagatttgg cccacgcctc cccaaatgag
3241 agatttattt taggcaaact tattttaaaa tgccagcgtt cattaggagt gacaagacac
3301 ttagtcatcc acgctttaat gtgaattact tttctcatct aattacattt ctttctagca
3361 gctggctgag aagatcttct gaaatccaaa atgattgtag ggttggcggt gagctgatct
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3421 ccggcctcga ggtggcttca gggggcccac ctggttaagg gaaatttggc agtgcgaggg
3481 tagtgctgga gagaggggtg ggtacagggg gctaggggca ccatggatgc cccctcctta
3541 ctgtcccctg gtgtcttgac ctcagcttct gcccacaggc acttgctgga ttctccaaaa
3601 gtatctgcag tggctgttcc accaggaggt aattcccttc tggtctcttt cccctccaca
3661 tctgcatcct cttcaaatcc tgccatttca gaccacattt gagagctcta gagaacaaga
3721 catctgacac gtgacgtgtc cagaagatga gccagatttc aaagaactga gatctgcttt
3781 aaaaacgaag ctctccaaag ttactggagt ctgggtaata gtgatcacca gagtaatttg
3841 tgtgcaggac atcaaatcag gctgctcgaa atgctgccta aattggccag tggttttatt
3901 tgcttttctg tcaacctaat attcatagga aatagagttt cagaggaatg ataggatcct
3961 ggtggaataa aaagggaaaa gaccatcttg agcaggagtt tcagggtcct ccgtttttcc
4021 caagttactt tcactcctga gatcttgcat gttagaacta cagcttaatg tagtgaaata
4081 ggaaagttct ctgttaggag cttagcctta ccttgtcatg gacattaaag taattgtctc
4141 tctttgggct tcaattttcc catctctcat gggaagggct gaaccaagca atccccaaaa
4201 tagcttccag ccttaacctt tttaggggtc tcgtttaaat agaagataac agggaaatgg
4261 tcacagttta cccaggtcca ttccctcctc cttatcacaa cttataccac cgctgtactg
4321 cacacctcct ttctcagcat tgctgctgtc cttaaaatgc ctttaactcc acaagagagt
4381 gtgttgttaa tgttggctca aggtccttcc tggtgagtgg ccaacattgt tttgctcctt
4441 gcaggggtcc caccaatctt gtttgcttct gcagagcctc agcctgcctg gaagatgccg
4501 agatcgtgct gcagccgctc gggggccctg ttgctggcct tgctgcttca ggcctccatg
4561 gaagtgcgtg gctggtgcct ggagagcagc cagtgtcagg acctcaccac ggaaagcaac
4621 ctgctggtac gtgggccatg actgccatct tggcttagac attagatggg actggagctg
4681 ggaaagctca aaagaaaagg gtgtggggaa agggaaattc attcccagtg ataggcgtga
4741 ttcaatccag ggcaggagca aaactttgca gtgaagtaag aaatgggaga agaaatcagg
4801 gaaggaagca gcttcaggga gaggggttga gtccacaatt tctgcttggt tatccttact
4861 tcttgcccca tcttttatgg agaccttgaa ccctttaagc tagagatggt gctataagag
4921 caataatgga cccctcaatc tattctgtac tttacatctt tagcttccca aactattcct
4981 ttttaagaag ctcatatcac ttgccatttt cattccatat ttcttaccct tttatctact
5041 accggttgca aaaccagcca ggtagttctt caaatcatct ctggaagaag gaaaaaccag
5101 gggccctttt tttttttctc ttaattggtg ccaaatgtct catgtttatt ctggaggact
5161 ggccttctgc tgtgttcctc tacagtcttt ccagagcatg tgaaggcctt tgcatcaggc
5221 aggagctccc tccaggtcac cacagggtgt atgtatctgc ctgtgggggg tgtgtgtgtg
5281 tgtgtgttgg ggggcataaa tgagtaatga tgccaaatcc agagattaaa aggcacactg
5341 agaccaggcg agatggctca tggctgtaat cccagcactt ttagatgcta aggtgggagg
5401 attgcttgag cccagggatt caagacaagc ctgggcaaca tagtgagacc tccacttcta
5461 caaaaaataa aaaagttagc cagatgtggt ggcatgtgcc tgtagtccta gctacttggg
5521 aggttcactt gaggccagga gtctgacgac acagtaagct atgatcacac cattgcactc
5581 cagtctgggt aacagaatga gaccttgtct caaaacaaaa caaaatgaaa caaacaaaca
5641 aacaaacccc catactgtta gtgtcagtga ccggaatttt aatcttgttg ccatcacctg
5701 gcaggtgctg agggtggaat gtacataact acattctgtg tattttgtca atgcagaagc
5761 tgagttaagg tgaagataga atgaggtcct caaagacaca gaccagtttt catgtgtaat
5821 ataaaataga aacaaagagc ccaggggatt ctgtgagttc cagtttggaa agacccaaga
5881 gtctcttgac ttgagacacc cacagcacag ctcaccaggg agggtgcact ggacacagtc
5941 aggacccatg ggttctagac ccagttttga ggtgtgggac cttgaccagg tcctatcacc
6001 tctctgagtc tcctgtttca ctatctgtcc acgggagggg agtgtaaatt agtttttttcc
6061 attgttaacg ttccacagag ttgtaattct gaacacctgg agtaggcaat gtccagctca
6121 acagagtggg taggatcctt ttattttctc ctttgctatt cccaagaaag agagcagcca
6181 gtgagctttt catcttttta tcactgaaaa ctcaaggctg cagcctatgc agccattttc
6241 ctaagctaat atgtaccaca atagagtcct ctagggacaa ggagcagaga cacaggttcc
6301 acagacggtg caatggaaat aacgctagct ttccacccct ccctccagtc agaatgagat
6361 tacagggaaa taagcttgcc ccagagctca ctgggggatc tctcagaaat cagctcagaa
6421 gtcgtgaaag aaccaaggtg cagttttgga ggcttagtgc agagatggag ctggggtagg
6481 gcataaagta ggttttccat cactgaggta aggttgaggc attatttttt attttttgtt
6541 tatttattta tttttttgag acggagtctc gctctatcac ccaggctgga gtgcagtggc
6601 gcgatctccc ctcactgcaa gctccacctc ccaggttcac acaggttgaa gcattattaa
6661 aaatatgttt aaaaatatgg gccctagtag ccagacttct atcacctgga gagattatcc
6721 cccaaatttc agccccactc ccctcctgga cttgaattaa accatatgta tttattcaat
6781 attcttttta tttatttatt tattttttttg agacggagtc ttgctctgtt gccctggctg
6841 gagtgtggag tgcagtggtg tgatcttggc tcactgcaac ctctacctcc caggttcaag
6901 cggttctcct gcctcaggct ccagagtagc tgggattaca ggcgcccgcc accacaccca
6961 gcttatttat ttatttatac tagagatggt atttcaccat agttggccag gctggtcttg
7021 aactcctgac ctcatgtgat ctgcctgcct tggcctccca aagtgctggg attataggtg
7081 tgagccacca tgcccggccc tcaatattca ttaagtgcca acaactacca cccgtctgcc
7141 tttcttggag ccactccttt atgtcaggca tatgacagta agactttggt cctgttcaca
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7201 aaagctaggg gtggctagat ggctagacaa accatggaat gggatgggaa gtgtgttgca
7261 gttgccagca gaagcatgaa ggggatggga caaaagaggc ggtggcaaga tcttagatgc
7321 ccacgagtgc caagaaagca ggtgggcaga cctgctctgt agggaggcct cgacgcttga
7381 cacgcccgac actgtgccct gtgtcctcgg cacgtggcga gggcggccag ggcctaggcg
7441 cagtgacggg cgcggcagcc gggccggggt gcggggcacg ggctgccctc atgccctcgc
7501 gtcttccccc aggagtgcat ccgggcctgc aagcccgacc tctcggccga gactcccatg
7561 ttcccgggaa atggcgacga gcagcctctg accgagaacc cccggaagta cgtcatgggc
7621 cacttccgct gggaccgatt cggccgccgc aacagcagca gcagcggcag cagcggcgca
7681 gggcagaagc gcgaggacgt ctcagcgggc gaagactgcg gcccgctgcc tgagggcggc
7741 cccgagcccc gcagcgatgg tgccaagccg ggcccgcgcg agggcaagcg ctcctactcc
7801 atggagcact tccgctgggg caagccggtg ggcaagaagc ggcgcccagt gaaggtgtac
7861 cctaacggcg ccgaggacga gtcggccgag gccttccccc tggagttcaa gagggagctg
7921 actggccagc gactccggga gggagatggc cccgacggcc ctgccgatga cggcgcaggg
7981 gcccaggccg acctggagca cagcctgctg gtggcggccg agaagaagga cgagggcccc
8041 tacaggatgg agcacttccg ctggggcagc ccgcccaagg acaagcgcta cggcggtttc
8101 atgacctccg agaagagcca gacgcccctg gtgacgctgt tcaaaaacgc catcatcaag
8161 aacgcctaca agaagggcga gtgagggcac agcgggcccc agggctaccc tcccccagga
8221 ggtcgacccc aaagcccctt gctctcccct gccctgctgc cgcctcccag cctggggggt
8281 cgtggcagat aatcagcctc ttaaagctgc ctgtagttag gaaataaaac ctttcaaatt
8341 tcacatccac ctctgacttt gaatgtaaac tgtgtgaata aagtaaaaat acgtagccgt
8401 caaataacag cagcatggat cggaggagca cagtggtttc catgcggtag gatatttcac
8461 aggacttagt gagcgtgaaa ggaaaatgtg cttcctgccc ccacccccaa atggatcttc
8521 gagggatcag atagtttggg tgaaggcaca gggtggctcc agcacctcta ggatggccgt
8581 attttccaca cactccactg agtgggagac tgctcagcta gcacacgtgt aaaggcagga
8641 ttcctgcaag agtgaccc
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(SEQ ID NO: 564)

In some embodiments, exemplary mutations in POMC, e.g., that lead to homozygous POMC deficiency, are described, e.g., in the references in Table 2, each of which are incorporated herein by reference.

Table 2

Reference
Aslan et al. International Journal of Obesity (2014) 38, 148–151
Krude et al. J Clin Endocrinol Metab 88: 4633–4640, 2003)
Krude et al. Nature genetics volume 19 (june) 1998; 155-157.
Darcan S et al. Transient Salt Wasting in POMC-deficiency. Exp Clin Endocrinol Diabetes 2010; 118: 281 – 283
Mendiratta et al. International Journal of Pediatric Endocrinology 2011, 2011:5
Farooqi et al. Diabetes 2006; 55(9): 2549-2553
Clement et al. JCEM 2008; 93(12): 4955-4962.
Krude H, Grüters A: Implications of Proopiomelanocortin (POMC) mutations in humans: the POMC deficiency syndrome. Trends in Endocrinology and Metabolism 2000, 11(1):15-22.
Hung et al. J Ped Endocrinol Metabol 2012; 25 (1-2): 175-179
Ozen et al. J Ped Endocrinol Metabol 2015; 28 (5-6): 691-694
Cirillo G, et al., Br J Dermatol. 2012;167:1393–5
Samuels J Clin End Met, 2013, 98(2); 736-742

Additionally, hypermethylation of the POMC gene has been associated with childhood obesity. See, e.g., Kuehnen et al. PLoS Genetics. 8.3(2012):e1002543. A hypermethylation variant at a CpG island at the intron2-exon3 boundary of the POMC gene was significantly associated with obesity compared to normal-weight children. See i.d. It is believed that exon3 of POMC is involved in binding to the transcription enhancer P300, and hypermethylation in exon3 reduces expression of the POMC transcript. See i.d.

In yet other embodiments, an exemplary mutation in POMC includes one or more mutations described in one or more of the following: Aslan, Int J Obes (Lond). 2014 Jan;38(1):148-51; Krude, Nature 1998; 19; 155-157; Krude, J clin Res Metab 2003,88(10); 4633-4640; Samuels, J Clin Endocrin Metab, 2013; 98(2); 736-742; Clement, J Clin Endocrin Metab., 2008; 93(12); 4955-4962; Creemers, J Clin Endocr Metab, 2008, 93(11); 4494-4499; Cirillo, British Assoc Derm, 2012, 167; 1390-1400; ESPE poster Barcelona 2015, R Marina et al.; Farooqi, Diabetes 2006; 55; 2549-2553; Mendiratta, Int J Pediatr Endocrinol. 2011;2011:5; A Meloni, et al., ESPE Poster Barcelona 2015; Hinney, J Clin Endocrin Metab, 1998, 10; 3737-3741; Lee, Cell Metabol., 2006; 3; 135-140 (PLOF); Dubern, Pediatric Res. 2008; 63(2); 211-216; Philippe et al. Int. J. Obes. 39.2.(2015):295-302; Bieberman, 2006; 3; 141-146; or Buono, Clin Chem, 2005; 51(8); 1358-1364; Challis, Hum. Mol. Genet. 11(17): 1997; Hum. Mol. Genet. 11(17): 1998, each of which is hereby incorporated by reference in its entirety.

PCSK1

Proprotein convertase subtilisin/kexin type 1 (PCSK1, also called PC1/3) is an enzyme that acts upstream of the MC4R in the POMC-MC4R pathway by processing (cleaving) prohormones such as POMC into their mature forms.

A heterozygous nonsense variant in PCSK1 (p.Arg80*), which encodes a propeptide truncated to less than two out of the 14 exons, has been reported to be associated with obesity in humans. See, e.g., Philippe et al. Intl. J. Obesity 39.2(2015):295-302.

The PCSK1 gene is located at cytogenetic location 5q15-q21 in humans. The human PCSK1 gene sequence is provided in GenBank Accession No. NG_021161.1, incorporated herein by reference. An exemplary nucleic acid sequence of human PCSK1 transcript variant 1 is provided in GenBank Accession No. NM_000439.4 (see, e.g., Hsiao et al. Gene 533 (1), 32-37 (2014)), incorporated herein by reference. An exemplary amino acid sequence of human PCSK1 isoform 1 is provided in GenBank Accession No. NP_000430.3, incorporated herein by reference. An exemplary nucleic acid sequence of human PCSK1 transcript variant 2 is provided in GenBank Accession No. NM_001177875.1, incorporated herein by reference. An exemplary amino acid sequence of human PCSK isoform 2 is provided in GenBank Accession No. NP_001171346.1, incorporated herein by reference.

In some embodiments, exemplary mutations in PCSK1, e.g., that lead to homozygous PCSK1 deficiency, are described, e.g., in the references in Table 3, each of which are incorporated herein by reference.

Table 3

Reference
Jackson et al (Cambridge). Nature Genetics 1997: 16 (June): 303-306
O'Rahilly et al. NEJM 1995: 333:1386-1390
Jackson et al. J. Clin. Invest. 112:1550–1560 (2003). doi:10.1172/JCI200318784
Farooqi et al. J Clin Endocrinol Metab. 92: 3369–3373, 2007
Martin et al. Gastroenterology 2013;145:138–148
Yourshaw et al. J Pediatr Gastroenterol Nutr. 2013 December ; 57(6): 759–767
Frank et al (Farooqi). Molecular Genetics and Metabolism 110 (2013) 191–194
Wilschanski et al. PLOS One Oct 2014; DOI: 10.1371/Journal.pone.0108878

In some embodiments, exemplary mutations in PCSK1, e.g., that lead to heterozygous PCSK1 deficiency, are described, e.g., in the references in Table 4, each of which are incorporated herein by reference.

Table 4

Examples of loss of function PCSK1 heterozygote (PCSK1+/-) variants	**Ref**	**Function**
Met125Ile Thr175Met Asn180Ser Tyr181His	Diabetes 2012, Vol 61: 383	All loss of function

Gly262Arg Ser325Asn Thr558Ala		
Asn221Asp Gln665E- S690Thr	Nature genetics 2008, 40(8): 943	Impacts PCSK1 Ca2+ binding

In yet other embodiments, an exemplary mutation in PCSK1 includes one or more mutations described in one or more of the following: Martin, Gastroenterology 145:138-48, 2013; Creemers, Diabetes 61:383, 2012; Jackson, Nature Gen.: July 16, 1997,p. 303; Martin, Gastroenterology 145:138-48, 2013; Blanco et al. Endrocrinology 156:3625-37, 2015; Jackson, J. Clin. Investigation 112:1550-51, 2003; Benzinou, Nat. Genetics 8: 943, 2008; Yourshaw, Gastroenterology 57(6):759, 2013; Faroqi, J. Clin. Endocrinol. and Metab. 92:3369-73, 2007; Pickett, PLoS One 8:e55065,2013; Bohours-Nouet, EXPE Poster at Barcelona 2015 PWS meeting; Graeme et al., Mol. Gen. Metabol. 110:191-94, 2013; Blanco et al. Endrocrinology 155:3434-47, 2014; Wilschansky PLoS ONE 9: 108878, 2014; Frank, Mol.Gen Metabol. 2013; and Harter J. Pediatr. Gastroentrol Nutr. 2015, each of which is hereby incorporated by reference in its entirety.

MAGEL2

MAGEL2 (Melanoma Antigen (MAGE) Family L2, or MAGE-like protein 2) is believed to be involved in ubiquitin ligase activity of zinc finger-containing E3 ubiquitin-protein ligases and possibly in regulation of the circadian clock. MAGEL2 is a member of the MAGE family of proteins that are involved in pathways that modulate protein degradation, protein modification, transcription, and cytoskeletal rearrangements. See, e.g., Mercer et al. PLoS Genetics 9.1(2013):e1003207.

In mice, MAGEL2 is expressed in the hypothalamus, including in the arcuate nucleus, which controls energy homeostasis. Mice lacking expression of the MAGEL2 gene (MAGEL2 null mice) have been reported to have poor weight gain early on followed by increased adiposity and weight gain. See, e.g., Mercer et al. PLoS Genetics 9.1(2013):e1003207. Adult mice lacking MAGEL2 (MAGEL2 null mice) have been reported to exhibit defective anorexigenic responses to leptin and defective responses of POMC neurons to leptin. See, e.g., Pravdivyi et al. Hum. Mol. Genet. 2015, 1-8. Mice lacking MAGEL2 (MAGEL2 null mice) also had lower levels of alpha-MSH in the paraventricular hypothalamic nucleus. See i.d. In embodiments, exemplary MAGEL2 mutations, e.g., loss of function MAGEL2 mutations, are described in Schaaf et al Nat Genet. 2013 Nov;45(11):1405-8. doi: 10.1038/ng.2776. Epub 2013 Sep 29; and Soden et al. Sci Transl Med. 2014 Dec 3;6(265):265ra168, each of which are inforporated herein by reference.

MAGEL2 is one of a number of genes inactivated in Prader Willi Syndrome (PWS). Inactivating mutations in MAGEL2 have been found in children having features of PWS. See i.d. A heterozygous c.1652delT (p.Val551fs) mutation in MAGEL2 (NM_019066.4) was reported in a 13 year old human subject. See, e.g., Schaaf et al. Nat. Genet. 45.11(2013):1405-09. A heterozygous c.1802delC (p.Pro601fs) mutation was also reported in an 8-year old human subject. See i.d. Also, a heterozygous c.3181_3182delAT (p.Ile1061fs) mutation was reported in a 5-year old human subject. See i.d. A c.3124C>T (p.Gln1024*) mutation was also reported in a 19-year old human subject. See i.d. PWS is described in greater detail below.

The human MAGEL2 gene sequence is NG_016776.1, incorporated herein by reference. An exemplary nucleic acid sequence of the human MAGEL2 transcript is NM_019066.4, incorporated herein by reference. An exemplary amino acid sequence of human MAGEL2 is NP_061939.3, incorporated herein by reference.

Leptin and Leptin-R

Leptin is a hormone produced by adipocytes that acts to inhibit hunger in order to regulate energy homeostasis—food intake, body weight, and glucose homeostasis. Leptin acts upstream of the MC4R in the POMC-MC4 pathway by binding to the leptin receptor (leptin-R, also called LEP-R, OB-R, or CD295). POMC neurons are involved in mediated leptin activity in the brain, and one effect of leptin binding to leptin-R is the stimulation of POMC expression. See, e.g., Varela et al. EMBO Reports 13.12(2012):1079-86. It has been reported that deletion of leptin-R in POMC neurons leads to obesity, an effect partly rescuable by overexpression of leptin-R in these leptin-R null mice. See i.d. Mutations of leptin (Lep ob/ob) or leptin-R (Lep db/db) have been reported to be associated with impaired glucose homeostasis and increased body weight in mice. See i.d. In addition, a fa/fa rat has been described to be leptin-R deficient. See, e.g., Cettour-Rose et al. Endocrinology: 2002; 143(6); 2277-2283.

Examples of mutant (e.g., non-functional) versions of leptin in humans have been described that have been associated with obesity. A homozygous frame-shift mutation that deleted a guanine nucleotide in codon 133 of the leptin gene was associated with severe obesity in some severely obese children. See, e.g., Montague et al. Nature 387.6636(1997):903-8. A homozygous transversion (c.298G→T) in leptin led to an aspartate to tyrosine change at amino acid position 100 (p.D100Y) and was associated with early-onset extreme obesity (see, e.g., Wabitsch et al. N. Engl. J. Med. 372.1(2015):47-54). Homozygous Gln223Arg and homozygous Lys656Asn mutations in leptin-R have been associated with obesity in humans. See, e.g., Masuo et al. Hypertens. Res. 31.6(2008):1093-100. Additional exemplary mutations in leptin/leptin-R are described in Lee. Annals Acad. Med. 38.1(2009):34-44.

In some embodiments, exemplary mutations in leptin receptor (LEPR), e.g., that lead to homozygous leptin receptor deficiency, are described, e.g., in the references in Table 5, each of which are incorporated herein by reference.

Table 5

Reference
Farooqi et al., New Engl J Med, 356: 237-247; 2007
Clement et al., Nature 392: 398-401, 1998.
Montague et al., Nature 387: 903-908, 1997
Farooqi et al., J. Clin. Invest. 110: 1093-1103, 2002
Gibson et al., J. Clin. Endocr. Metab. 89: 4821-4826, 2004
Wabitsch et al., New Eng. J. Med. 372: 48-54, 2015.
Saeed et al., Obesity 2014; 22; 1112-1117
Huvenne et al., J Clin Endocrinol Metab. 2015 Vol 100; issue 5: E757-766

In some embodiments, exemplary mutations in leptin receptor, e.g., that lead to homozygous leptin receptor deficiency, are described, e.g., in the references in Table 6, each of which are incorporated herein by reference

Table 6

Examples of loss of function LEPR homozygote (LEPR-/-)	Ref	Function

variants		
c.2396-1 G>T	Obesity 2014; 22(4); 1112	Exon 15 splicing defect
c.1675 G>A	Obesity 2014; 22(4); 1112	Nonsense mutation
p.Cys604Gly p.Leu786Pro p.His800_Asn831del p.Tyr422His p.Thr711NfsX18 P.535-1G>A p.166CfsX7	J Clin Endocrinol Metab; 2015; 100(5): E757	Likely LEPR loss of function
4-bp del codon 22 11-bp del codon 70 66-bp del codon 514 Trp31X Ala409Glu Trp664Arg His684Pro 1-bp del codon 15/ Arg612His	N Eng J Med. 2007; 356(3): 237	Impaired LEPR signaling

Exemplary nucleic acid sequences of human leptin transcript are provided in NM_000230.2 and BC060830.1, incorporated herein by reference. Exemplary amino acid sequences of human leptin precursor are provided in NP_000221.1, AAH69452.1, AAH69527.1, AAH69323.1, AAH60830.1, incorporated herein by reference. Exemplary nucleic acid sequences of human leptin receptor are provided in GenBank Accession Nos. U66497.1, U66496.1, U66495.1, U43168.1, NM_001198689.1, NM_001198688.1, NM_001198687.1, NM_001003679.3, NM_002303.5, NM_001003680.3, incorporated herein by reference. Exemplary amino acid sequences of human leptin receptor are provided in GenBank Accession Nos. P48357.2, AAB09673.1, AAC23650.1, AAB07497.1, AAB07496.1, AAB07495.1, AAA93015.1, incorporated herein by reference.

In yet other embodiments, an exemplary mutation in LEPR includes one or more of the mutations described in one or more of the following: Faroqui et al., N Engl J Med 356:237-24, 2007; Gill et al., Obesity 22:576-84, 2014; Kimber et al., Endocrinol. 149:6043-52, 2008; Huvenne et al. J. Clin. Endo Metab. 100:E757-66, 2015; and Mammes et al., Eur. J. Clin. Inv. 31:398-4004, 2015, each of which is hereby incorporated by reference in its entirety.

5HT2c receptor

The 5-hydroxytryptamine (serotonin) receptor 2C, G protein-coupled (5-HT2c receptor) is a G protein-coupled receptor (GPCR) that binds to the neurotransmitter serotonin. The 5HT2c receptor is involved in regulating feeding, among other physiological functions. The 5HT2c receptor acts upstream of the MC4R in the POMC-MC4R pathway. Stimulation of the 5-HT_{2C} receptor results in an increase in POMC in the anterior pituitary lobe. By binding to serotonin receptors, including 5HT2c receptor, serotonin increases POMC activity and reduces feeding behavior. See, e.g., Roepke et al. Am. J. Physiol. Endocrinol. Metab. 302.11(2012):E1399-406. 5HT2c receptor agonists have been reported to reduce feeding in rats and mice. See, e.g., Bickerdike. Curr. Top. Med. Chem. 3.8(2003):885-97. Alternative splicing of the 5-HT2C receptor is regulated by the snoRNA, SNORD115. SNORD115 is inactivated in PWS. Without wishing to be bound by theory, it is believed that 5HT2c polymorphisms are associated with obesity.

The human 5-HT2c receptor gene sequence is provided in GenBank Accession No. NG_012082.2 (see, e.g., Jahnsen JA et al. Eur. J. Pharmacol. 684 (1-3), 44-50 (2012)), incorporated herein by reference. Exemplary nucleic acid sequences of human 5-HT2c receptor are provided in GenBank Accession Nos. NM_001256761.2, NM_001256760.2, NM_000868.3, incorporated herein by reference. Exemplary amino acid sequences of human 5-HT2c receptor are provided in GenBank Accession Nos. NP_001243690.1, NP_001243689.1, NP_000859.1, incorporated herein by reference.

NhLH2

NhLH2 is a neuronal transcription factor that acts upstream of MC4R in the POMC-MC4R pathway. NhLH2 is a member of the basic helix-loop-helix (bHLH) family of transcription factors. NhLH2 is expressed in a number of differentiated adult neurons, including POMC neurons and MC4R neurons. Expression of NhLH2 can be regulated by food intake and leptin levels. See, e.g., Good et al. Trends Endocrinol. Metab. 24.8(2013):385-90. Based on NhLH2 knockout mouse studies, in which deletion of the gene resulted in adult-onset obesity, NhLH2 has been reported to mediate body weight control and fertility. See, e.g., Good et al. Nat. Genet. 15(1997):397-401. In embodiments, exemplary mutations, e .g., that lead to heterozygous NhLH2 deficiency, are described, e.g., in Rayyan et al. Gene. 2013;512(1):134-42, incorporated herein by reference.

NhLH2 binds to the leptin-regulated transcription factor Signal tranducer and activator-3 (Stat-3) to regulate PCSK1 in response to leptin or food intake. In NhLH2 knockout mice, there are lower levels of PCSK1 than in wild type mice. This results in reduced levels of PCSK1 processed peptide, e.g., mature POMC. See, e.g., Good et al. Trends Endocrinol. Metab. 24.8(2013):385-90.

Exemplary nucleic acid sequences of human NhLH2 are provided in GenBank Accession Nos. XM_006710666.2, XR_946659.1, NM_001111061.1, NM_005599.3 (see, e.g., Al Rayyan et al. Gene 512 (1), 134-142 (2013)), incorporated herein by reference. Exemplary amino acid sequences of human NhLH2 are provided in GenBank Accession Nos. XP_006710729.1, NP_001104531.1, NP_005590.1, incorporated herein by reference.

Pro-hormone convertase

Pro-hormone convertase are serine proteases that process precursors of peptide hormones and neuropeptides. There are multiple types pro-hormone convertases: PCSK1 (also called PC1, PC3, and PC1/3), PCSK2 (also called PC2), PCSK3 (also called furin, pace, and PC1), PCSK4 (also called PC4), PCSK5 (also called PC5, PC6, and PC5/6), PCSK6 (also called PACE4), PCSK7 (also called PC7, PC8), PCSK8 (also called Site 1 protease, S1P, SKI), and PCSK9 (also called NARC-1). Pro-hormone convertases are responsible for cleaving POMC to generate alpha-MSH. For example, PC1 cleaves POMC to generate pro-ACTH, which is then cleaved by PC2 to generate ACTH1-17. See, e.g., Pritchard et al. J. Endocrinol. 172(2002):411-21.

It is believed that defective POMC processing can lead to obesity. A patient having compound heterozygous mutations in the PC1 gene had extreme childhood obesity, abnormal glucose homeostasis, hypocorticolism, and hypogonadotrophic hypogonadism. See i.d. Another obese patient was reported to have defective POMC processing. See i.d.

Exemplary sequences of PCSK1 are described above. Exemplary nucleic acid sequences of human PCSK2 are provided in GenBank Accession Nos. NM_002594.4 (see, e.g., van Wamelen et al. J. Neuropathol. Exp. Neurol. 72 (12), 1126-1134 (2013)), NM_001201529.2, NM_001201528.1, incorporated herein by reference. Exemplary amino acid sequences of human PCSK2 are provided in GenBank Accession Nos.

NP_001188458.1, NP_001188457.1, NP_002585.2, incorporated herein by reference. Exemplary nucleic acid sequences of human PCSK3 are provided in GenBank Accession Nos. NM_001289824.1, NM_001289823.1, NM_002569.3, incorporated herein by reference. Exemplary amino acid sequences of human PCSK3 are provided in GenBank Accession Nos. NP_001276753.1 (see, e.g., Dahms et al. ACS Chem. Biol. 9 (5), 1113-1118 (2014)), NP_001276752.1, NP_002560.1, incorporated herein by reference. An exemplary nucleic acid sequence of human PCSK4 is provided in GenBank Accession No. NM_017573.4 (see, e.g., Seidah et al. J. Biol. Chem. 288 (30), 21473-21481 (2013)), incorporated herein by reference. An exemplary amino acid sequence of human PCSK4 is provided in GenBank Accession No. NP_060043.2, incorporated herein by reference. The human PCSK5 gene sequence is provided in GenBank Accession No. NG_029445.1, incorporated herein by reference. Exemplary nucleic acid sequences of human PCSK5 are provided in GenBank Accession Nos. NR_120409.1, NM_006200.5, NM_001190482.1 (see, e.g., Mbikay et al. Genomics 26 (1), 123-129 (1995)), incorporated herein by reference. Exemplary amino acid sequences of human PCSK5 are provided in GenBank Accession Nos. NP_001177411.1, NP_006191.2, incorporated herein by reference. The human PCSK6 gene sequence is provided in GenBank Accession No. NG_030047.3, incorporated herein by reference. Exemplary nucleic acid sequences of human PCSK6 are provided in GenBank Accession nos. NM_138325.3, NM_001291309.1, NM_138323.2, NM_138324.2, NM_138322.3, NM_138319.3, NM_002570.4 (see, e.g., Tsuji et al. J. Biochem. 122 (2), 438-452 (1997)), incorporated herein by reference. An exemplary nucleic acid sequence of human PCSK7 is provided in GenBank Accession no. NM_004716.3 (see, e.g., Stickel et al. Hum. Mol. Genet. 23 (14), 3883-3890 (2014)), incorporated herein by reference. An exemplary amino acid sequence of human PCSK7 is provided in GenBank Accession No. NP_004707.2, incorporated herein by reference. The human PCSK8 gene sequence is provided in GenBank Accession No. NG_033017.1, incorporated herein by reference. An exemplary nucleic acid sequence of human PCSK8 is provided in GenBank Accession No. NM_003791.3 (see, e.g., Weiss et al. J. Invest. Dermatol. 134 (1), 168-175 (2014)), incorporated herein by reference. An exemplary amino acid sequence of human PCSK8 is provided in GenBank Accession no. NP_003782.1, incorporated herein by reference. The human PCSK9 gene sequence is provided in GenBank Accession No. NG_009061.1, incorporated herein by reference.

Exemplary nucleic acid sequences of human PCSK9 are provided in GenBank Accession No. XM_011541193.1, NR_110451.1, and NM_174936.3 (see, e.g., Brouwers et al. Clin. Sci. 126 (9), 679-684 (2014)), incorporated herein by reference. Exemplary amino acid sequences of human PCSK9 are provided in GenBank Accession no. XP_011539495.1 and NP_777596.2, incorporated herein by reference.

In some embodiments, exemplary mutations in a pro-hormone convertase, e.g., PCSK1, e.g., that lead to homozygous deficiency, are described, e.g., in the references in Table 3, each of which are incorporated herein by reference.

In some embodiments, exemplary mutations in a pro-hormone convertase, e.g., PCSK1, e.g., that lead to heterozygous deficiency, are described, e.g., in the references in Table 4, each of which are incorporated herein by reference.

CPE

Carboxypeptidase E (CPE), also called carboxypeptidase H (CPH) or convertase, is an enzyme that catalyzes the release of C-terminal lysine or arginine residues from polypeptides. CPE is involved in the processing of many neuropeptides and peptide hormones. For example, CPE acts downstream of the pro-hormone convertases, which generate intermediate peptide precursors, to further process polypeptides to remove C-terminal basic residues in order to generate mature peptides. For example, CPE is involved in processing POMC. Mutations in CPE have been associated with obesity. For example, morbidly obese female patient was described to have a truncating mutation of the CPE gene (c.76_98del; p.E26RfsX68). See, e.g., Alsters et al. PloS ONE. 10.6(2015):e0131417. In embodiments, exemplary mutations in CPE, e.g., that lead to homozygous CPE deficiency, are described, e.g., in Alsters et al. PloS One. 10.6(2015):e0131417, incorporated herein by reference.

An exemplary nucleic acid sequence of CPE is provided in GenBank Accesion No. NM_001873.2 (Skalka et al. Oncogene 32 (23), 2836-2847 (2013)), incorporated herein by reference. An exemplary amino acid sequence of CPE is provided in GenBank Accession No. NP_001864.1, incorporated herein by reference.

Sim1

Single-minded 1 (Sim1) is a transcription factor involved in the development of the paraventricular nucleus of the hypothalamus, which regulates body weight, energy expenditure, and appetite. Sim1 acts on the MC4R in the POMC-MC4R pathway. Loss of function of Sim1 (e.g., in Sim1+/- and Sim1-/- mice) have been reported to cause hyperphagia, obesity, and increased susceptibility to diet-induced obesity. See, e.g., Xi et al. PLoS One. 7.4(2012):e36453. Also, Sim1 neuron ablation in mice led to obesity caused by increased food intake and reduced energy expenditure. See i.d. In embodiments, exemplary mutations in Sim1, e.g., that lead to heterozygous Sim1 deficiency, are described, e.g., in Bonnefond et al. J. Clin. Invest. 123.7(2013):3037-41, incorporated herein by reference.

The human SIM1 gene sequence is provided in GenBank Accession No. NG_008230.1, incorporated herein by reference. Exemplary nucleic acid sequences of human SIM1 are provided in GenBank Accession Nos. XM_011536073.1 (see, e.g., Ramachandrappa et al. J. Clin. Invest. 123 (7), 3042-3050 (2013)), XM_011536072.1, XM_005267100.2, NM_005068.2, incorporated herein by reference. Exemplary amino acid sequences of human SIM1 are provided in GenBank Accession no. XP_011534375.1, XP_011534374.1, XP_005267157.1, NP_005059.2, incorporated herein by reference.

BBS1-20

BBS1-BBS20 are 20 genes that are associated with Bardet-Biedl syndrome. Mutation(s) in one or more of the BBS genes have been associated with obesity, blindness and loss of hearing. Mice lacking the BBS1 gene in the nervous system have been shown to develop obesity. See, e.g., Guo et al. PLOS Genetics 12.2(2016):e1005890. Also, heterozygous carriers of mutations in BBS genes have been described to have a greater propensity for obesity than control subjects. See, e.g., Gupta et al. J. Endocrinol. 203(2009):327-36.

In embodiments of any method described herein, the method comprises treating a subject having one or more mutations in one or more of the genes BBS1-BBS20. In embodiments, a method described herein comprises use of a MC4R agonist described herein to treat a subject having one or more mutations in one or more of the genes, BBS1-BBS20. Exemplary mutations include non-coding variants in one or more of the BBS genes, e.g., BBS2, BBS4, and/or BBS6. For example, SNPs in BBS6 and BBS4 have been shown by some reports to be associated with adult and childhood obesity. See, e.g., Gupta et al. J. Endocrinol. 203(2009):327-36.

ALMS1

Alström syndrome (ALMS) is an autosomal recessive disease associated with blindness, deafness, diabetes, and obesity, hyperinsulinemia, and altered glucose metabolism that can lead to the development of type 2 diabetes at a young age in afflicted subjects. ALMS is caused by mutations in *ALMS1*, a gene that has been mapped to chormosome 2p13. The progression from early onset obesity toward the impaired fasting glucose or impaired glucose tolerance and overt diabetes is believed to occur mostly because of a progressive failure of β-cell insulin secretion without any further worsening of insulin resistance with age, even in the presence of weight reduction (Bettini et al. Pediatr. Diabetes 13:59-67, 2012). The identification of ALMS1 as a ciliary protein explains several of the observed phenotypes and their similarity to other ciliopathies including the Bardet-Biedl syndrome.

Nucleic acid sequences linked to Alström syndrome, variants of the nucleic acid sequence, the protein produced by that nucleic acid sequence and screening methods for testing individuals to determine if they are carriers of Alström syndrome, are disclosed in, e.g., US Patent No. 7,196,171.

In embodiments of any method described herein, the method comprises treating a subject having one or more mutations in one or more alleles of the *ALMS1* gene. In embodiments, a method described herein comprises use of a MC4R agonist described herein to treat a subject having one or more mutations in the gene.

Nucleic acid sequences linked to Alstrom syndrome, variants of the nucleic acid sequence, the protein produced by that nucleic acid sequence and screening methods for testing individuals to determine if they are carriers of Alstrom syndrome, are disclosed in, e.g., US Patent No. 7, 196,171.

Pseudo Hypoparathyroidism (GNAS1)

In pseudohypoparathyroidism the body is unable to respond to parathyroid hormone and is among other clinical symptoms associated with obesity and short stature. The principal symptoms are low calcium levels and high blood phosphate levels. Afflicted individuals have cataracts, dental problems, seizures, numbness, and/or tetany (muscle twitches and hand and foot spasms). Symptoms are typically initially observed in childhood. People with this disorder are also resistant to other hormones, such as thyroid-stimulating hormone and gonadotropins. Type 1A is also associated with a group of symptoms referred to as Albright's hereditary osteodystrophy, which includes short stature, a round face, obesity, and short hand bones. Pseudohypoparathyroidism type 1A is caused by a mutation in the *GNAS* gene and is inherited in an autosomal dominant manner. The GNAS1 gene is described in, e.g., US20060147936.

In embodiments of any method described herein, the method comprises treating a subject having one or more mutations in one or more alleles of the *GNAS1* gene. In embodiments, a method described herein comprises use of a MC4R agonist described herein to treat a subject having one or more mutations in the gene.

Additional Genes

Additional genes useful in the methods disclosed herein include BDNF, MCH1R, MCH, NTRK2, SIM1 (*J Clin Invest.* 2013;123(7):3042-3050. doi:10.1172/JCI68016), ENPP1, COH1, CNR1, NPC1, c-MAF, PTER, FTO, TMEM18 (childhood), SDCCAG8, TNKS/MSRA, GNPDA2 (childhood), NEGr1, INSIG2, KCTD15, NROB2, and 16p11.2 deletions (including the SH2B1 gene).

In embodiments of any method described herein, the method comprises treating a subject having one or more mutations in one or more of one or more of these genes. In embodiments, a method described herein comprises use of a MC4R agonist described herein to treat a subject having mutations in one of more of these genes.

Disorders

In accordance with the methods and compositions described herein, in some embodiments, a MC4R agonist, e.g., MC4R agonist described herein, e.g., setmelanotide, is used to treat a disorder, such as a metabolic disorder, e.g., obesity, hyperphagia, or metabolic syndrome.

In embodiments, a MC4R agonist, e.g., MC4R agonist described herein, e.g., setmelanotide, is used to treat a genetic disorder caused by a deficiency in one or more components of the POMC-MC4R pathway. In embodiments, a MC4R agonist, e.g., MC4R agonist described herein, e.g., setmelanotide, is used to treat a genetic disorder such as Prader-Willi Syndrome (PWS) or POMC-null obesity. In embodiments, a MC4R agonist, e.g., MC4R agonist described herein, e.g., setmelanotide, is used to treat a genetic disorder associated with a defect in one or more of the following genes: POMC, PCSK1, MAGEL2, Leptin-R, leptin, 5-HT2c receptor, NhHL2, pro-hormone convertase, CPE, MC4R, or Sim1. In embodiments, a MC4R agonist, e.g., MC4R agonist described herein, e.g., setmelanotide, is used to treat a genetic disorder associated with hypermethylation of the POMC gene, e.g., at a POMC intron.

In embodiments, the genetic disorder is associated with obesity, e.g., severe obesity, and/or hyperphagia.

Prader Willi Syndrome (PWS)

Prader Willi Syndrome (PWS) is a rare genetic disease with a prevalence ranging from approximately one in 8,000 to one in 25,000 patients in the U.S. A hallmark of PWS is severe hyperphagia—an overriding physiological drive to eat—leading to severe obesity and other complications. Obesity is one of the greatest health threats to PWS patients, and hyperphagia impairs the ability of PWS patients to live independently, requiring costly and constant supervision to prevent overeating. Without supervision, these patients are likely to die prematurely as a result of choking, stomach rupture, or from complications caused by morbid obesity. Currently, there are no approved treatments for the obesity and hyperphagia associated with PWS.

Symptoms of PWS include infantile hypotonia with failure to thrive, rapid weight gain and overeating during childhood, as well as intellectual disability, developmental delay, short stature, hypogonadism. Diagnostic criteria for PWS are described, e.g., in Holm et al. Pediatrics 91(1993):398-402.

It is believed that the genetics underlying PWS involve a loss of function of several genes on chromosome 15 in humans, in particular, at 15q11-q13. See, e.g., Schaaf et al. Nat. Genet. 45.11(2013):1405-09. Protein coding genes in this section of the chromosome include MKRN3, MAGEL2, NDN, NPAP1, and SNURF-SNRPN. See i.d. Examples of a MAGEL2 null deficiency are described, e.g., in Schaaf et al.; and in Soden et al. Sci Transl Med. 2014 Dec 3;6(265):265ra168, incorporated herein by reference. About 70% of PWS patients have large deletion (about 4 Mb) in the paternal 15q11-q13 chromosomal region. See, e.g., Bervini et al. Front. Neuroendocrinol. 34(2014):107-119. About 25% of PWS patients have maternal uniparental disomy. See i.d. Mice lacking MAGEL2 gene expression have impaired POMC neurons and develop some of the same symptoms exhibited by humans with PWS. It is believed that a defect in the MAGEL2 gene (which is found on chromosome 15 in humans) may impair the function of pro-opiomelanocortin (POMC) neurons, which are key components of the MC4 pathway that normally promote satiety by activating downstream MC4 receptors. This impairment can create a block in the MC4 pathway.

Without wishing to be bound by theory, it is believed that the MC4R agonists described herein, e.g., setmelanotide, may reestablish weight and appetite control in PWS subjects by bypassing the defective POMC neurons and activating the MC4 pathways below the block in the pathway. For example, the melanocortin receptor agonists described herein, e.g., setmelanotide, can act as a replacement therapy for MSH.

POMC-null obesity

Also described as POMC deficiency syndrome, patients with POMC-null obesity have homozygous loss-of-function in the pro-opiomelanocortin (POMC) genes, which results in early-onset, severe obesity. Patients with POMC-null mutations have severe obesity, with BMIs exceeding 40 and uncontrolled appetite (severe hyperphagia) beginning in childhood. This genetic disorder may also be associated with hormonal deficiencies, such as hypoadrenalism, and red hair and fair skin are common. The disorder may also lead to early death. POMC-null obesity is a very rare genetic disorder, and there are no approved treatments for the obesity and hyperphagia associated with this condition. There are an estimated 50 to 500 POMC null patients worldwide.

Bardet-Biedl syndrome (BBS)

In embodiments, a MC4R agonist described herein is used to treat Bardet-Biedl syndrome (BBS). BBS is a genetically heterogeneous disorder. BBS is a form of Laurence-Moon-Beidl syndrome and is characterized by obesity, retinopathy, learning disability, polydactyly, and hypogenitalism. See, e.g., Green et al. New Engl. J. Med. 321(1989):1002-9. Without wishing to be bound by theory, it is believed that BBS is characterized by one or more mutation(s) in one or more of 20 genes (*BBS1-BBS20*). Most of the BBS genes encode proteins thought to be important for the function, formation, and stability of cilia. It is believed that eight BBS proteins (BBS1, BBS2, BBS4, BBS5, BBS7, BBS8, BBS9, and BBS18) form a complex called the BBSome that mediates trafficking to the ciliary membrane. BBS6, BBS10, and BBS12 are believed to form a complex with the CCT/TRiC family of group II chaperonins.

Mutation(s) in the BBS gene(s) are thought to lead to defective cilia, e.g, neuronal cilia, or dysfunctional ciliary regulation. Ciliary dysfunction is believed to cause impaired leptin signaling and hyperleptinemia. The role of primary cilia and cilia proteins in energy homeostasis and obesity-related disorders is described, e.g., in ., Gupta et al. J. Endocrinol. 203(2009):327-36; and Oh et al. Cell Metab. 21.1(2015):21-31. Patients with BBS have been found to have hyperleptinemia that is suggestive of leptin resistance, with triglycerides, leptin, diastolic BP-Z, and intra-abdominal fat mass signficiantly greater in BBS patients than in controls. See, e.g., Feuillan et al. J. Clin. Endocrinol. Metab. 96.3(2011). Obesity in BBS mutant mice, for example, is thought to be caused by leptin resistance and defects in leptin receptor trafficking. See, e.g., Berbari et al. Proc. Natl. Acad. Sci. USA 110.19(2013):7796-7801. BBS2, BB4, and BB6 mutant mice have been shown to be hyperleptinemic and failed to reduce their food intake in response to leptin. See, e.g., Berbari et al. Proc. Natl. Acad. Sci. USA 110.19(2013):7796-7801.

Alström syndrome

Alström syndrome (ALMS) is an autosomal recessive disease with clinical symptoms that include severe obesity, hyperinsulinemia, and altered glucose metabolism that can lead to the development of type 2 diabetes at a young age in afflicted subjects. ALMS is caused by mutations in *ALMS1*, a gene that has been mapped to chormosome 2p13.

The progression from early onset obesity toward the impaired fasting glucose or impaired glucose tolerance and overt diabetes is believed to occur mostly because of a progressive failure of β-cell insulin secretion without any further worsening of insulin resistance with age, even in the presence of weight reduction (Bettini et al. Pediatr. Diabetes 13:59-67, 2012).

Outcomes

In embodiments, methods described herein result in one or more outcomes, including a reduction of weight (e.g., body weight), a reduction in hunger level, no detectable decrease in energy expenditure (e.g., resting energy expenditure), an increase in energy expenditure (e.g., resting energy expenditure), a reduction in daily/weekly/monthly food intake, a reduction in waist circumference, no detectable increase in blood pressure, or a reduction in blood pressure in a subject, e.g., relative to a control.

In embodiments, the control is the measurement of the parameter in the subject prior to administration of (treatment with) a MC4R agonist. In embodiments, the control is a predetermined value, e.g., the value of the parameter in an average obese human population, e.g., of like age and gender as the subject; or the value of the parameter measured in the subject at a previous time point (e.g., at a previous visit, e.g., to a physician, medical facility or laboratory).

In embodiments, the outcome (e.g., the reduction, increase, no detectable decrease, or no detectable increase in a given parameter) is measured in the subject 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initation of treatment with a MC4R agonist. In other embodiments, the outcome (e.g., the reduction, increase, no detectable decrease, or no detectable increase in a given parameter) is measured in the subject over a period of time (e.g., over a period of 1-2 weeks, 2-4 weeks, 4-6 weeks, 6-8 weeks, 8-12 weeks, or 12-16 weeks) during a course of treatment.

In embodiments, methods described herein result in a reduction of weight (e.g., body weight) in the subject compared to a control (e.g., weight of the subject before treatment or a predetermined value, e.g., average weight of an obese human population of like age and gender as the subject not subjected to therapeutic intervention, or the weight of the subject at a previous measurement, e.g., at a previous visit). In embodiments, the reduction is about 1 kg to 3 kg after 1 week of treatment, about 1 kg to 6 kg after 2 weeks of treatment, about 2 kg to 12 kg after 4 weeks of treatment, about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment. In embodiments, the reduction is at a rate of loss of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment, or 16-32 weeks of treatment, or longer.

Measurement of weight, e.g., body weight, can be performed using standard methods in the art.

In embodiments, methods described herein result in a reduction in hunger level in the subject compared to a control (e.g., hunger level of the subject before treatment or a predetermined hunger level, e.g., average hunger level of an obese human population of like age and gender as the subject or the hunger level of the subject at a previous measurement, e.g., at a previous visit). In embodiments, the methods described herein result in abolishment of hunger in the subject.

In embodiments, hunger is measured by a scale, such as a Likert hunger scale, which ranges from 0 to 10 and is described herein. In embodiments, methods described herein result in a reduction in hunger score in the subject compared to a control (e.g., hunger level of the subject before treatment or a predetermined hunger level, e.g., average hunger level of an obese human population of like age and gender as the subject or the hunger level of the subject at a previous measurement, e.g., at a previous visit). In embodiments, methods described herein result in a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points, compared to the control (e.g., hunger level of the subject before treatment or a predetermined hunger level, e.g., average hunger level of an obese human population of like age and gender as the subject or the hunger level of the subject at a previous measurement, e.g., at a previous visit). In embodiments, methods described herein result in a score of 0 on the Likert hunger scale after treatment.

In embodiments, the reduction in hunger level is measured/observed after 1 to 2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

REE is a measure of the basal metabolic rate of the subject and can be determined using methods such as those described in Chen et al. J. Clin. Endocrinol. Metab. 100.4(2015):1639-45. In embodiments, the REE can be determined by placing the subject in a whole-room indirect calorimeter (also called a metabolic chamber) at a certain time after treatment (e.g., after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks). In embodiments, the REE is measured in 30-minute measurements periods, and in some cases, REE values from several 30-minute periods are averaged to generate an average REE. In embodiments, the REE can be determined after a 10-12 hour fasting period, at thermoneutrality (e.g., around 25 deg C), where the subject is awake without psychological or physical stress. In embodiments, REE is measured in units of energy per unit time (e.g., kcal/h or kcal/day). In embodiments, the REE is measured relative to kg lean body mass in a subject (e.g., REE/kg lean mass), e.g., as described in the Examples.

In embodiments, methods described herein result in no change or no decrease in energy expenditure, e.g., resting energy expenditure (REE), in the subject over an hourly, daily (e.g., in 24 hours), weekly (e.g., in 7 days), or monthly (e.g., in 30 days) period compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., average REE of an obese human population of like age and gender and normalized for weight as the subject or the REE of the subject at a previous measurement, e.g., previous visit), e.g., as measured after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment.

In embodiments, methods described herein result in no detectable change or no detectable decrease in energy expenditure, e.g., resting energy expenditure (REE) per kg lean body mass, in the subject over an hourly, daily (e.g., in 24 hours), weekly (e.g., in 7 days), or monthly (e.g., in 30 days) period compared to the control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., average REE of an obese human population of like age and gender as the subject or the REE of the subject at a previous measurement, e.g., previous visit), e.g., as measured after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment.

In embodiments, methods described herein result in an increase in energy expenditure, e.g., resting energy expenditure (REE), in the subject over a hourly, daily (e.g., in 24 hours), weekly (e.g., in 7 days), or monthly (e.g., in 30 days) period compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., average REE of an obese human population of like age and gender and normalized for weight as the subject or the REE of the subject at a previous measurement, e.g., previous visit), e.g., as measured after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment.

In embodiments, the increase in REE in the subject is at least 20 kcal/day (e.g., at least 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150 kcal/day or more), e.g., as measured after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment.

In embodiments, the increase in REE in the subject is at least 2% (e.g., at least 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15% or more), e.g., as measured after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment, compared to the REE in the subject prior to treatment.

In embodiments, the REE in the subject (e.g., adult subject) after treatment with a MC4R agonist (e.g., after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment) is at least 1800 kcal/day (e.g., at least 1800, 1825, 1850, 1875, 1900, 1925, 1950, 1975, 2000, 2025, 2050, 2100, 2150, 2200, 2250, 2300, 2400 kcal/day, or more), e.g., for an adult subject. In embodiments, the REE in the subject (e.g., pediatric subject) after treatment with a MC4R agonist (e.g., after 3, 4, 5, 6, 7 days, or 1, 2, 3, 4, or more weeks of treatment) is at least 200 kcal/day (e.g., at least 200, 225, 250, 275, 300, 325, 350, 375, 400, 450, 500 kcal/day or more), e.g., for pediatric patients.

In embodiments, methods described herein result in a reduction in food intake by the subject compared to a control (e.g., the food intake of the subject prior to treatment or a predetermined food intake level, e.g., the food intake of an average human obese population or the food intake of the subject at a previous measurement, e.g., at a previous visit), e.g., where the food intake is measured as daily food intake or food intake over a period of 24 hours, or one week,. In embodiments, the reduction is at least 100 kilocalories, e.g., at least

100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, e.g., for daily food intake or food intake over a period of 24 hours, or one week, or 30 days or for longer time periods, e.g., for an adult subject. In embodiments, mean food intake can decrease from a baseline at or above about 100 kcal/kg/day to about 90, 80, 70, 60, 50, 40, 30, 20 or 10 kcal/kg/day or lower after treatment with a MC4R agonist, e.g., setmelanotide, e.g., in a pediatric subject at about 1 year of age. In embodiments, mean food intake can decrease from a baseline at or above about 40 kcal/kg/day to about 35, 30, 20 or 10 kcal/kg/day or lower after treatment with a MC4R agonist, e.g., setmelanotide, e.g., in a pediatric subject in late adolescence.

Food intake can be determined by standard methods, e.g., as described in Rutishauser. Pub. Health Nutr. 8.7A(2005):1100-07.

In embodiments, methods described herein result in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the subject prior to treatment or the waist circumference of the subject at a previous measurement, e.g., previous visit), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the reduction in waist circumference is at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject (e.g., adult subject) compared to a control (e.g., the waist circumference of the subject prior to treatment or a predetermined waist circumference, e.g., the waist circumference of an average obese human population of like age and gender or the waist circumference of the subject at a previous measurement, e.g., previous visit), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the waist circumference is measured using standard methods. In embodiments, the waist circumference is the largest circumference around a subject's mid-section, e.g., around a subject's abdomen. In other embodiments, the waist circumference is measured around the natural waist (e.g., in between the lowest rib and the top of the hip bone), the umbilicus, or at the narrowest point of the midsection.

In embodiments, methods described herein result in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to a control blood pressure (e.g., the blood pressure of the subject prior to treatment or a predetermined blood pressure, e.g., the blood pressure of an average obese human population of like age and gender or the blood pressure of the subject at a previous measurement, e.g., previous visit), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, methods described herein result in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject a control blood pressure (e.g., the blood pressure of the subject prior to treatment or a predetermined blood pressure, e.g., the blood pressure of an average obese human population of like age and gender or the blood pressure of the subject at a previous measurement, e.g., previous visit), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the reduction in blood pressure, e.g., systolic blood pressure, is at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the reduction in blood pressure, e.g., diastolic blood pressure, is at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

In embodiments, the methods described herein do not result in an adverse effect on heart rate or blood pressure.

Subject

In accordance with any method described herein, in certain embodiments, the subject is obese, e.g., prior to administration of an agonist described herein, e.g., at the time the agonist is prescribed, or at the time of the first administration of the agonist. In embodiments, the subject is a severely obese, pediatric or adult patient e.g., prior to administration of an agonist described herein, e.g., at the time the agonist is prescribed or at the time of the first administration of the agonist. In embodiments, the subject is hyperphagic, e.g., prior to administration of an agonist described herein, e.g., at the time the agonist is prescribed, or at the time of the first administration of the agonist.

In embodiments, the subject (e.g., adult subject) has a body mass index (BMI) greater than 25 kg/m^2 or 30 kg/m^2 (e.g., ≥ 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject (e.g., pediatric subject) has a body mass index (BMI) higher than 85-95 percentile prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject has a body weight of at least about 5 kg, e.g., at least about 5 kg, 10 kg, 20kg, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140,145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 200, 205, 210, 215, 220 kg or greater, e.g., prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration. In embodiments, the subject has a body weight of a least 20 kg, at least 60 kg, or at least 100 kg, e.g., prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

In embodiments, the subject is an adult, e.g., 18 years of age or older, e.g., 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, or older.

In embodiments, the subject is a pediatric subject, e.g., less 18 years of age or younger (e.g., 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 year of age or younger.

In embodiments, the subject has or is identified as having a defect, e.g., genetic defect, or a mutation, in one or more genes of the POMC-MC4R pathway. In embodiments, the subject has or is identified as having one or more mutations in the POMC, PCSK1, MAGEL2, leptin receptor, leptin, 5-HT2c receptor, NhHL2, pro-hormone convertase, CPE, MC4R, or Sim1 genes or other genes that impair functioning of the POMC-MC4R pathway. In embodiments, the subject has or is identified as having a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

In embodiments, the subject has Prader Willi Syndrome.

In embodiments, the subject has or is identified as having a loss of function mutation in the 15q11-q13 region of chromosome 15, e.g., in the paternal allele.

In embodiments, the subject has or is identified as having a mutation (e.g., loss of function mutation) in the MAGEL2 gene.

In embodiments, the subject has or is identified as having a POMC-null, PCSK1-null genotype, MAGEL2-null genotype, leptin receptor-null genotype, leptin-null genotype, 5-HT2c receptor-null genotype, NhHL2-null genotype, pro-hormone convertase-null genotype, CPE-null genotype, MC4R-null genotype, and/or SIM1-null genotype. For example, the subject has or is identified as having a POMC-null, PCSK1-null obesity, MAGEL2-null obesity, leptin receptor-null obesity, leptin-null obesity, 5-HT2c receptor-null obesity, NhHL2-null obesity, pro-hormone convertase-null genotype, CPE-null obesity, MC4R-null obesity, and/or SIM1-null obesity.

In embodiments, the subject has or is identified as having a POMC mutation described herein, e.g., a POMC mutation described in Table 1. In embodiments, the subject has or is identified as having a mutation in the POMC amino acid sequence chosen from one or more of: Cys28Phe, Leu37Phe, His143Glu, Phe144Leu, Tyr221Cys, Pro231Leu, Arg236Gly, or Glu244X, where the amino acid sequence numbering is described in Takahashi, et al. 1981 Febs Letters 135(1)97 (and shown as SEQ ID NO: 563) and corresponds to that of the protein containing the signal peptide, and where X corresponds to early termination.

In embodiments, the subject has or is identified as having a POMC mutation (e.g., homozygous POMC mutation) described in a reference in Table 2. In embodiments, the subject has or is identified as having a POMC mutation (e.g., heterozygous POMC mutation) described in a reference in Table 1.

In embodiments, the POMC mutation is a homozygous mutation. In embodiments, the POMC mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the POMC mutation is a loss of function mutation. In embodiments, the POMC mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a hypermethylation in the POMC gene, e.g., a hypermethylation in exon3 of the POMC gene, or a hypermethylation at the intron2-exon3 boundary of the POMC gene, e.g., a hypermethylation at a CpG island at the intron2-exon3 boundary of the POMC gene.

In embodiments, the subject has or is identified as having a PCSK1 mutation described herein, e.g., a heterozygous nonsense variant (p.Arg80*), a PCSK1 mutation (e.g., homozygous mutation) described in a reference of Table 3, or a PCSK1 mutation (e.g., heterozygous mutation) described in a reference of Table 4. In embodiments, the subject has or is identified as having a mutation in the PCSK1 amino acid sequence chosen from: Met125Ile, Thr175Met, Asn180Ser, Tyr181His, Gly262Arg, Ser325Asn, Thr558Ala, Asn221Asp, Gln665E, or S690Thr.

In embodiments, the PCSK1 mutation is a homozygous mutation. In embodiments, the PCSK1 mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the PCSK1 mutation is a loss of function mutation. In embodiments, the PCSK1 mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a MAGEL2 mutation described herein, e.g., c.1652delT (p.Val551fs), c.1802delC (p.Pro601fs), c.3181_3182delAT (p.Ile1061fs), c.3124C>T (p.Gln1024*), or a mutation described in Schaaf et al. Nat. Genet. 45.11(2013):1405-09 or Soden et al. Sci Transl Med. 2014 Dec 3;6(265):265ra168. In embodiments, the MAGEL2 mutation is a homozygous mutation. In embodiments, the MAGEL2 mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the MAGEL2 mutation is a loss of function mutation. In embodiments, the MAGEL2 mutation causes a decrease in function/activity.

In embodiments, the subject has or is identified as having a leptin or leptin-R mutation described herein. In embodiments, the subject has or is identified as having a leptin mutation described herein, e.g., homozygous frame-shift mutation that deletes a guanine nucleotide in codon 133 of the leptin gene, or a homozygous transversion (c.298G→T) that leads to an aspartate to tyrosine change at amino acid position 100 (p.D100Y). In embodiments, the subject has or is identified as having a leptin-R mutation described herein, e.g., a Gln223Arg or a Lys656Asn mutation, or a mutation (e.g., homozygous mutation) described in a reference of Table 5. In embodiments, the subject has or is identified as having a leptin-R mutation (e.g., homozygous leptin-R mutation) described in Table 6. In some embodiments, the subject has or is identified as having a leptin-R mutation chosen from: c.2396-1 G>T, c.1675 G>A, p.Cys604Gly, p.Leu786Pro, p.His800_Asn831del, p.Tyr422His, p.Thr711NfsX18, P.535-1G>A, p.166CfsX7, 4-bp del codon 22, 11-bp del codon 70, 66-bp del codon 514, Trp31X, Ala409Glu, Trp664Arg, His684Pro, 1-bp del codon 15, or Arg612His.

In embodiments, the leptin or leptin-R mutation is a homozygous mutation. In embodiments, the leptin or leptin-R mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the leptin or leptin-R mutation is a loss of function mutation. In embodiments, the leptin or leptin-R mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a 5-HT2c receptor mutation described herein. In embodiments, the 5-HT2c receptor mutation is a homozygous mutation. In embodiments, the 5-HT2c receptor mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the 5-HT2c receptor mutation is a loss of function mutation. In embodiments, the 5-HT2c receptor mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a NhLH2 mutation described herein, e.g., described in Good et al. Nat. Genet. 15(1997):397-401. In embodiments, the NhLH2 mutation is a homozygous mutation. In embodiments, the NhLH2 mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the NhLH2 mutation is a loss of function mutation. In embodiments, the NhLH2 mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a pro-hormone convertase mutation described herein, e.g., as described in Pritchard et al. J. Endocrinol. 172(2002):411-21, or as described in a reference of Table 3 or Table 4. In embodiments, the pro-hormone convertase mutation is a homozygous mutation. In embodiments, the pro-hormone convertase mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the pro-hormone convertase mutation is a loss of function mutation. In embodiments, the pro-hormone convertase mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a CPE mutation described herein, e.g., (c.76_98del; p.E26RfsX68), or as described in Alsters et al. PloS ONE. 10.6(2015):e0131417. In embodiments, the CPE mutation is a homozygous mutation. In embodiments, the CPE mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the CPE mutation is a loss of function mutation. In embodiments, the CPE mutation is a partial loss of function mutation.

In embodiments, the subject has or is identified as having a SIM1 mutation described herein, e.g., as described in Bonnefond et al. J. Clin. Invest. 123.7(2013):3037-41. In embodiments, the SIM1mutation is a homozygous mutation. In embodiments, the SIM1mutation is a heterozygous mutation (e.g., compound heterozygous mutation). In embodiments, the SIM1mutation is a loss of function mutation. In embodiments, the SIM1 mutation is a partial loss of function mutation.

In embodiments, methods herein can comprise identifying or selecting a subject having a defect e.g., genetic defect, or a mutation, in one or more genes of the POMC-MC4R pathway. In embodiments, methods herein can comprise acquiring knowledge of the genotype, predetermined sequence, or mutation. In embodiments, the methods herein can comprise acquiring knowledge of the genotype of, e.g., of a mutation in one or more of POMC, PCSK1, MAGEL2, leptin receptor, leptin, 5-HT2c receptor, NhHL2, pro-hormone convertase, CPE, MC4R, Sim1, and/or other POMC-MC4R pathway genes. In embodiments, the agonist is administered in response to acquiring knowledge, e.g., detection or identification, of a predetermined sequence, e.g., a mutation, in a gene described herein, one or more of POMC, PCSK1, MAGEL2, leptin receptor, leptin, 5-HT2c receptor, NhHL2, pro-hormone convertase, CPE, MC4R, Sim1, or other POMC-MC4R pathway genes.

In embodiments, methods herein can comprise acquiring knowledge of the state of methylation of the POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine). In embodiments, the agonist is administered in response to the detection of hypermethylation.

In embodiments, methods herein can comprise acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype the 15q11-q13 region of chromosome 15 (e.g., in the paternal allele) or of the MAGEL2 gene. In embodiments, the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in 15q11-q13 region of chromosome 15 (e.g., in the paternal allele) or in the MAGEL2 gene.

In embodiments, identification or selection of a subject as having a certain genotype or predetermined sequence, e.g., mutation, in a gene, can comprise acquiring knowledge of the certain genotype or predetermined sequence, e.g., mutation. Knowledge of the sort can be acquired in a number of ways, as described in detail in the Definitions section.

In some embodiments, a sequence is acquired, e.g., by obtaining possession of a nucleotide sequence, by "directly acquiring" or "indirectly acquiring" the sequence. "Directly acquiring a sequence" means performing a process (*e.g.*, performing a synthetic or analytical method) to obtain the sequence, such as performing a sequencing method (*e.g.*, a Next Generation Sequencing (NGS) method). "Indirectly acquiring a sequence" refers to receiving information or knowledge of, or receiving, the sequence from another party or source (*e.g.*, a third party laboratory that directly acquired the sequence). The sequence acquired need not be a full sequence, *e.g.*, sequencing of at least one nucleotide, or obtaining information or knowledge, that identifies a genotype or predetermined sequence, e.g., mutation, disclosed herein as being present in a subject constitutes acquiring a sequence.

In embodiments, the sequence can be directly acquired. Directly acquiring a sequence includes performing a process that includes a physical change in a physical substance, *e.g.*, a starting material, such as a tissue sample, *e.g.*, a blood sample or tissue biopsy, or analysis of an isolated nucleic acid (*e.g.*, DNA or RNA) sample. Exemplary changes include making a physical entity from two or more starting materials, shearing or fragmenting a substance, such as a genomic DNA fragment; separating or purifying a substance (*e.g.*, isolating a nucleic acid sample from a tissue); combining two or more separate entities into a mixture, performing a chemical reaction that includes breaking or forming a covalent or non-covalent bond. Directly acquiring a value includes performing a process that includes a physical change in a sample or another substance as described above.

In some embodiments, acquiring knowledge of the certain genotype or predetermined sequence, e.g., mutation, can comprise acquiring a sample, e.g., from which the genotype or predetermined sequence, e.g., mutation, is determined. "Acquiring a sample" as the term is used herein, refers to obtaining possession of a sample, *e.g.*, a tissue sample or nucleic acid sample, by “directly acquiring” or “indirectly acquiring” the sample. “Directly acquiring a sample” means performing a process (*e.g.*, performing a physical method such as a surgery or extraction) to obtain the sample. “Indirectly acquiring a sample” refers to receiving the sample from another party or source (*e.g.*, a third party laboratory that directly acquired the sample). Directly acquiring a sample includes performing a process that includes a physical change in a physical substance, *e.g.*, a starting material, such as a tissue, *e.g.*, a tissue in a human patient or a tissue that has was previously isolated from a patient. Exemplary changes include making a physical entity from a starting material, dissecting or scraping a tissue; separating or purifying a substance (*e.g.*, a sample tissue or a nucleic acid sample); combining two or more separate entities into a mixture; performing a chemical reaction that includes breaking or forming a covalent or non-covalent bond. Directly acquiring a sample includes performing a process that includes a physical change in a sample or another substance, *e.g.*, as described above.

In some aspects, provided herein is also a method of evaluating a subject, e.g., for likely responsiveness to a MC4R agonist, e.g., a MC4R agonist described herein, e.g., setmelanotide. In some embodiments, the method comprises acquiring information about the genotype of the subject. In embodiments, the method comprises acquiring information about the presence or absence of a defect, e.g., genetic defect, in one or more genes of the POMC-MC4R pathway in the subject.

In embodiments, the subject can be identified as having a defect, e.g., genetic defect, e.g., mutation, in one or more genes of the POMC-MC4R pathway, using methods described herein.

In embodiments, the identification of the subject having a defect, e.g., genetic defect, e.g., mutation, indicates that the subject is likely to respond (e.g., with an improvement in one or more symptoms) to a MC4R agonist, e.g., a MC4R agonist described herein, e.g., setmelanotide. In embodiments, an improvement in a symptom can include an outcome described herein. For example, an improvement in a symptom can include a reduction of weight (e.g., body weight), a reduction in hunger level, no detectable decrease in energy expenditure (e.g., resting energy expenditure), an increase in energy expenditure (e.g., resting energy expenditure), a reduction in daily/weekly/monthly food intake, or a reduction in waist circumference, e.g., relative to a control.

In embodiments, the identification of the subject having the defect, e.g., genetic defect, e.g., mutation, indicates that the subject is more likely to respond to (or is likely to have a greater response to) a MC4R agonist, e.g., a MC4R agonist described herein, e.g., setmelanotide, than a subject (e.g., obese subject, e.g., of like age and/or pre-treatment weight) lacking a genetic defect in the POMC-MC4R pathway, e.g., a wild-type obese subject. In embodiments, a subject that is more likely to respond is more likely to have one or more improved symptoms, such as symptoms described herein, e.g., compared to a control, e.g., a subject (e.g., obese subject, e.g., of like age and/or pre-treatment weight) lacking a genetic defect in the POMC-MC4R pathway, e.g., a wild-type obese subject. In embodiments, a subject that is likely to have a greater response is likely to have a greater improvement in symptoms, e.g., symptoms described herein, e.g., greater weight loss, greater decrease in waist circumference, greater increase in resting energy expenditure, greater decrease in food intake, greater decrease in hunger level, e.g., compared to a control, e.g., a subject (e.g., obese subject, e.g., of like age and/or pre-treatment weight) lacking a genetic defect in the POMC-MC4R pathway, e.g., a wild-type obese subject.

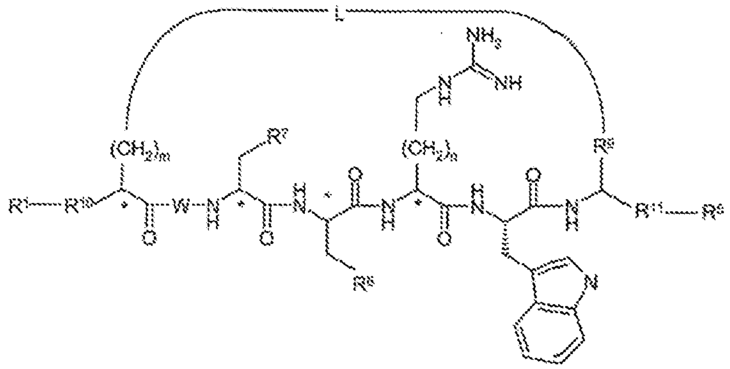
In embodiments, methods described herein further comprise providing a report that identifies the presence or absence of the genetic defect and in some cases an identifier for the subject. In embodiments, the report provides a recommendation on potential therapeutic options, likely effectiveness of a therapeutic option, and/or recommendations/instructions for administration of the therapeutic option (e.g., MC4R agonist, e.g., MC4R agonist described herein, e.g., setmelanotide).

MC4R agonists

Examples of naturally occurring MC4R agonists include α-MSH, β-MSH, γ-MSH and adenocorticitropic hormone (ACTH) or a functional fragment thereof. Examples of synthetic MC4R agonists are described in detail below.

In an example embodiment, an agonist employed by the methods of the present invention can be any known agonist of MC4R. In some example embodiment, the MC4R agonist is not an adrenocorticotropic hormone (ACTH) or a fragment thereof.

In an example embodiment, an MC4R agonist is any of the peptides disclosed in International Application published as WO2005/000339, incorporated herein by reference. Specifically, examples include peptides of the following structural formula:



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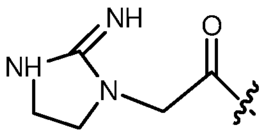
wherein

W is Glu, Gln, Asp, Asn, Ala, Gly, Thr, Ser, Pro, Met, Ile, Val, Arg, His, Tyr, Trp, Phe, Lys, Leu, Cya, or is absent;

R^1 is –H, -C(O)CH_3, -C(O)$(CH_2)_{1-4}CH_3$, -C(O)$(CH_2)_{1-4}$NHC(NH)NH_2, Tyr-ßArg-, Ac-Tyr-ß-hArg-, gluconoyl-Tyr-Arg-, Ac-diaminobutyryl-, Ac-diaminopropionyl-, N-propionyl-, N-butyryl-, N-valeryl-, N-methyl-Tyr-Arg-, N-glutaryl-Tyr-Arg-, N-succinyl-Tyr-Arg-, R^6-SO_2NHC(O)CH_2CH_2C(O)-, R^6-SO_2NHC(O)CH_2CH_2C(O)Arg-, R^6-SO_2NH$CH_2CH_2CH_2$C(O)-, C_3-C_7 cycloalkylcarbonyl, pheylsulfonyl, C_8-C_{14} bicyclic arylsulfonyl, phenyl-$(CH_2)_q$C(O)-, C_8-C_{14} bicyclic aryl-$(CH_2)_q$C(O)-,



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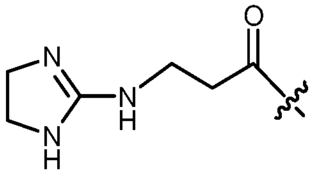

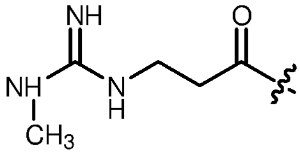

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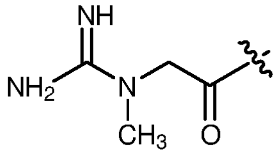
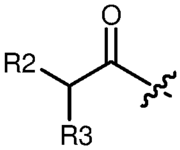


, or

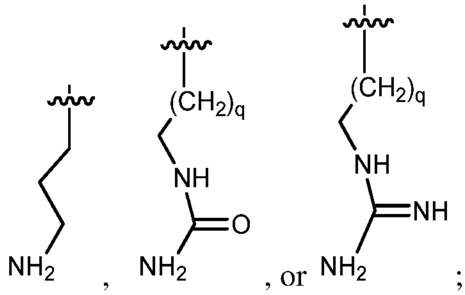


, wherein

R^2 is -H, -NH_2, -NHC(O)CH_3, -NHC(O)$(CH_2)_{1-4}CH_3$, -NH-TyrC(O)CH_3, R^6SO_2NH-, Ac-Cya-NH-, Tyr-NH-, HO-(C_6H_5)-CH_2CH_2C(O)NH-, or CH_3-(C_6H_5)-C(O)CH_2CH_2C(O)NH-;

R^3 is C_1-C_4 straight or branched alkyl, NH_2-CH_2-$(CH_2)_q$-, HO-CH_2-,

$(CH_3)_2CHNH(CH_2)_4$-, $R^6(CH_2)_q$-, R^6SO_2NH-, Ser, Ile,



;

q is 0, 1, 2, or 3;

R^6 is a phenyl or C_8-C_{14} bicyclic aryl;

m is 1 or 2;

n is 1, 2, 3, or 4;

R^9 is $(CH_2)_p$ or $(CH_3)_2C$-;

p is 1 or 2;

R_{10} is NH- or is absent;

R^7 is a 5- or 6-membered heteroaryl or a 5- or 6-membered heteroaryl ring optionally substituted with R^4;

R^4 is H, C_1-C_4 straight or branched alkyl, phenyl, benzyl, or (C_6H_5)-CH_2-O-CH_2-;

R^8 is phenyl, a phenyl ring optionally substituted with X, or cyclohexyl;

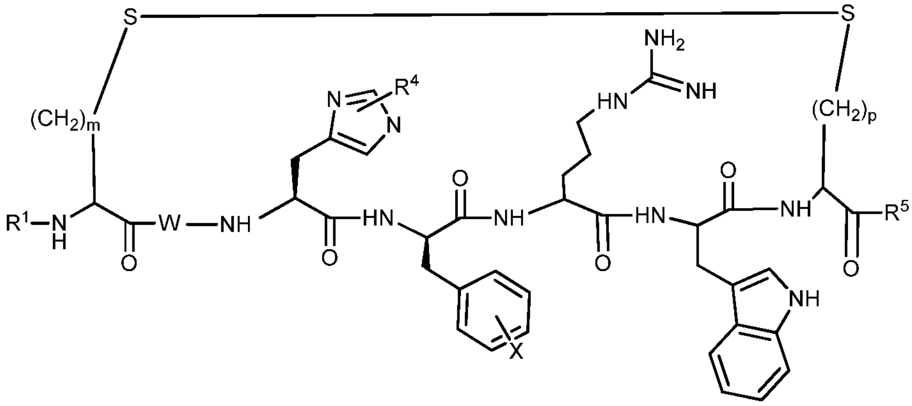
X is H, Cl, F, Br, methyl, or methoxy;

R^{11} is –C(O) or –CH_2;

R^5 is –NH_2, -OH, glycinol, NH_2-Pro-Ser-, NH_2-Pro-Lys-, HO-Ser-, HO-Pro-Ser-, HO-Lys-, Ser alcohol, -Ser-Pro alcohol, -Lys-Pro alcohol, $HOCH_2CH_2$-O-CH_2CH_2NH-, NH_2-Phe-Arg-, NH_2-Glu-, $NH_2CH_2RCH_2NH$-, RHN-, RO- where R is a C_1-C_4 straight or branched alkyl; and

L is –S-S- or –S-CH_2-S-.

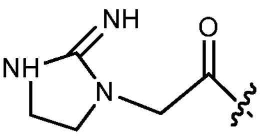
Other examples of MC4R agonists include peptides of the following structural formula:



wherein:

W is a single bond, Glu, Gln, Asp, Asn, Ala, Gly, Thr, Ser, Pro, Met, Ile, Val, Arg, His, Tyr, Trp, or Phe;

R^1 is –H, -C(O)CH_3, -C(O)$(CH_2)_{1\text{-}4}CH_3$, -C(O)$(CH_2)_{1\text{-}4}$-NHC(NH)NH_2, Tyr-ßArg, gluconoyl-Tyr-Arg, Ac-Dab, Ac-Dap, N-succinyl-Tyr-Arg, N-propionyl, N-valeryl, N-glutaryl-Tyr-Arg, N-butyryl,



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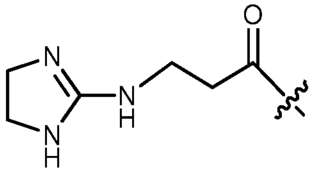

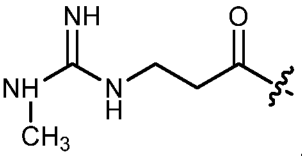

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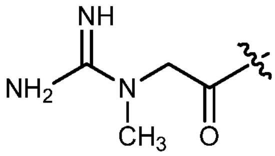

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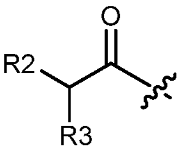
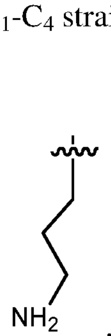


, wherein

R^2 is –H, -NH_2, -NHC(O)CH_3, -NHC(O)$(CH_2)_{1\text{-}4}CH_3$, or –NH-TyrC(O)CH_3;

R^3 is C_1-C_4 straight or branched alkyl, Ser, Ile,



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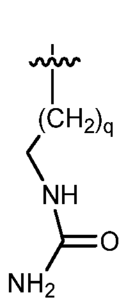

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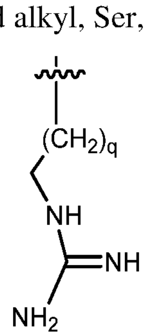


;

q is 0, 1, 2, or 3;

m is 1 or 2;

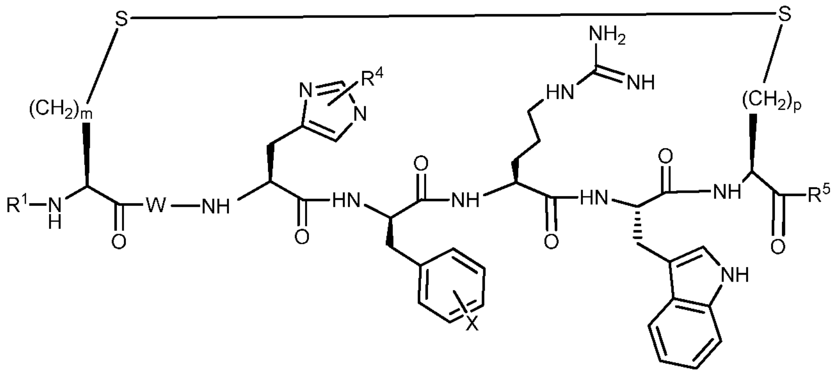
p is 1 or 2;

R^4 is H or C_1-C_4 straight or branched alkyl;

X is H, Cl, F, Br, methyl, or methoxy; and

R^5 is –NH_2, -OH, glycinol, -Ser-Pro-NH2, -Lys-Pro-NH_2, -Ser-OH, -Ser-Pro-OH, -Lys-Pro-OH –Arg-Phe-NH_2, -Glu-NH_2, -NHR, or –OR, where R is a C_1-C_4 straight or branched alkyl.

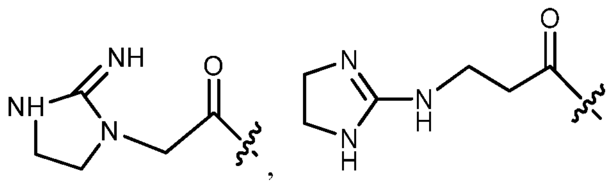
In yet another example embodiment, the MC4R agonist can be represented by the following structural formula:

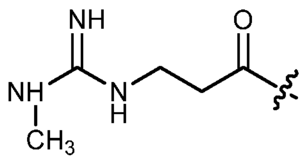
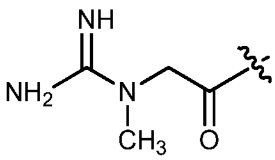


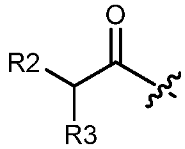
wherein

W is Glu, Gln, Asp, Ala, Gly, Thr, Ser, Pro, Met, Ile, Val, Arg, His, Tyr, Trp, Phe, Lys, Leu, Cya, or is absent;

R^1 is –H, -C(O)CH_3, -C(O)$(CH_2)_{1\text{-}4}CH_3$, -C(O)$(CH_2)_{1\text{-}4}$NHC(NH)NH_2, Tyr-ßArg-, Ac-Tyr-ß-hArg-, gluconoyl-Tyr-Arg-, Ac-diaminobutyryl-, Ac-diaminopropionyl-, N-propionyl-, N-butyryl-, N-valeryl-, N-methyl-Tyr-Arg-, N-glutaryl-Tyr-Arg-, N-succinyl-Tyr-Arg-, R^6-SO_2NHC(O)CH_2CH_2C(O)-, R^6-SO_2NHC(O)CH_2CH_2C(O)Arg-, R^6-SO_2NH$CH_2CH_2CH_2$C(O)-, C_3-C_7 cycloalkylcarbonyl, phenylsulfonyl, C_8-C_{14} bicyclic arylsulfonyl, phenyl-$(CH_2)_q$C(O)-, C_8-C_{14} bicyclic aryl-$(CH_2)_q$C(O)-,

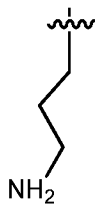
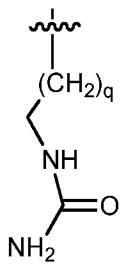
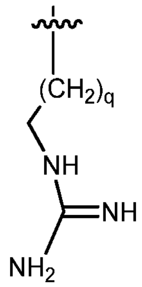


, , or

, wherein

R^2 is –H, $-NH_2$, $-NHC(O)CH_3$, $-NHC(O)(CH_2)_{1\text{-}4}CH_3$, $-NH\text{-}TyrC(O)CH_3$, R^6SO_2NH-, Ac-Cya-NH-, Tyr-NH-, $HO\text{-}(C_6H_5)\text{-}CH_2CH_2C(O)NH$-, or $CH_3\text{-}(C_6H_5)\text{-}C(O)CH_2CH_2C(O)NH$-;

R^3 is C_1-C_4 straight or branched alkyl, $NH_2\text{-}CH_2\text{-}(CH_2)_q$-, $HO\text{-}CH_2$-, $(CH_3)_2CHNH(CH_2)_4$-, $R^6(CH_2)_q$-, R^6SO_2NH-, Ser, Ile,

, , or ;

q is 0, 1, 2, or 3;

R^6 is a phenyl or C_8-C_{14} bicyclic aryl;

m is 1 or 2;

p is 1 or 2;

R^4 is H, C_1-C_4 straight or branched alkyl, phenyl, benzyl, or $(C_6H_5)\text{-}CH_2\text{-}O\text{-}CH_2$-;

X is H, Cl, F, Br, methyl, or methoxy; and

R^5 is $-NH_2$, -OH, glycinol, NH_2-Pro-Ser-, NH_2-Pro-Lys-, HO-Ser-, HO-Pro-Ser-, HO-Lys-, -Ser alcohol, -Ser-Pro alcohol, -Lys-Pro alcohol, $HOCH_2CH_2\text{-}O\text{-}CH_2CH_2NH$-, NH_2-Phe-Arg-, NH_2-Glu-, $NH_2CH_2RCH_2NH$-, or RO- where R is a C_1-C_4 straight or branched alkyl.

Additional examples of MC4R agonists useful to practice the present invention are found in WO2011104378; WO2011104379; WO201060901; WO200887189, WO200887188, WO200887187, WO200887186; US20110065652; WO2010144341;

WO2010144344; WO201065799; WO201065800; WO201065801; WO201065802; WO201037081; WO2009152079; WO2009151383; US20100311648; US20100280079; WO201081666; WO201034500; WO200910299; WO2008116665; WO201052256; WO201052255; WO201126015; US20100120783; WO201096854; US20100190793; WO201025142; and WO201015972. Further examples of MC4R agonists useful to practice the present invention are found in U.S. Pat. No. 8,263,608; U.S. Pat. No. 8,247,530; U.S. Pat. No. 8,114,844; and U.S. Pat. No. 7,968,548. The entire teachings of these publications are incorporated herein by reference.

In one example embodiment, the agonist of MC4R is a tripeptide D-Phe-Arg-Trp (SEQ ID NO: 560) or a pharmaceutical salt thereof. In another example, the agonist is any peptide that includes SEQ ID NO: 560 or a pharmaceutical salt thereof. In yet another example, the MC4R agonist is an acetylated tripeptide Ac-D-Phe-Arg-Trp-NH_2 (SEQ ID NO: 561) or a pharmaceutical salt thereof.

In an example embodiment, the agonists of MC4R are those of Formula (I) or a pharmaceutically acceptable salt, hydrate, solvate or a prodrug thereof (see International Patent Application Publication Number WO 2007/008704, incorporated herein by reference in its entirety):

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \quad \text{(I).}$$

In Formula (I):

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is His, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, $(C_1\text{-}C_{30})$alkyl, $(C_1\text{-}C_{30})$heteroalkyl, $(C_1\text{-}C_{30})$acyl, $(C_2\text{-}C_{30})$alkenyl, $(C_2\text{-}C_{30})$alkynyl, aryl$(C_1\text{-}C_{30})$alkyl, aryl$(C_1\text{-}C_{30})$acyl, substituted $(C_1\text{-}C_{30})$alkyl, substituted $(C_1\text{-}C_{30})$heteroalkyl, substituted $(C_1\text{-}C_{30})$acyl, substituted $(C_2\text{-}C_{30})$alkenyl, substituted $(C_2\text{-}C_{30})$alkynyl, substituted aryl$(C_1\text{-}C_{30})$alkyl, and substituted aryl$(C_1\text{-}C_{30})$acyl;

each of R^4 and R^5 is, independently for each occurrence, H, $(C_1\text{-}C_{40})$alkyl, $(C_1\text{-}C_{40})$heteroalkyl, $(C_1\text{-}C_{40})$acyl, $(C_2\text{-}C_{40})$alkenyl, $(C_2\text{-}C_{40})$alkynyl, aryl$(C_1\text{-}C_{40})$alkyl, aryl$(C_1\text{-}C_{40})$acyl, substituted $(C_1\text{-}C_{40})$alkyl, substituted $(C_1\text{-}C_{40})$heteroalkyl, substituted $(C_1\text{-}C_{40})$acyl, substituted $(C_2\text{-}C_{40})$alkenyl, substituted $(C_2\text{-}C_{40})$alkynyl, substituted aryl$(C_1\text{-}C_{40})$alkyl, substituted aryl$(C_1\text{-}C_{40})$acyl, $(C_1\text{-}C_{40})$alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, $(C_{1\text{-}10})$alkyl, substituted $(C_{1\text{-}10})$alkyl, $(C_{2\text{-}10})$alkenyl, substituted $(C_{2\text{-}10})$alkenyl, $(C_{2\text{-}10})$alkynyl, substituted $(C_{2\text{-}10})$alkynyl, aryl, substituted aryl, OH, NH_2 , NO_2 , or CN.

In exemplary embodiments of the agonists of Formula (I):

(I) when R^4 is $(C_1\text{-}C_{40})$acyl, aryl$(C_1\text{-}C_{40})$acyl, substituted $(C_1\text{-}C_{40})$acyl, substituted aryl$(C_1\text{-}C_{40})$acyl, $(C_1\text{-}C_{40})$alkylsulfonyl, or -C(NH)-NH_2 , then R^5 is H or $(C_1\text{-}C_{40})$alkyl, $(C_1\text{-}C_{40})$heteroalkyl, $(C_2\text{-}C_{40})$alkenyl, $(C_2\text{-}C_{40})$alkynyl, aryl$(C_1\text{-}C_{40})$alkyl, substituted $(C_1\text{-}C_{40})$alkyl, substituted $(C_1\text{-}C_{40})$heteroalkyl, substituted $(C_2\text{-}C_{40})$alkenyl, substituted $(C_2\text{-}C_{40})$alkynyl, or substituted aryl$(C_1\text{-}C_{40})$alkyl;

(II) when R^2 is $(C_1\text{-}C_{30})$acyl, aryl$(C_1\text{-}C_{30})$acyl, substituted $(C_1\text{-}C_{30})$acyl, or substituted aryl$(C_1\text{-}C_{30})$acyl, then R^3 is H, $(C_1\text{-}C_{30})$alkyl, $(C_1\text{-}C_{30})$heteroalkyl, $(C_2\text{-}C_{30})$alkenyl, $(C_2\text{-}C_{30})$alkynyl, aryl$(C_1\text{-}C_{30})$alkyl, substituted $(C_1\text{-}C_{30})$alkyl, substituted $(C_1\text{-}C_{30})$heteroalkyl, substituted $(C_2\text{-}C_{30})$alkenyl, substituted $(C_2\text{-}C_{30})$alkynyl, or substituted aryl$(C_1\text{-}C_{30})$alkyl;

(III) either A^3 or A^8 or both must be present in said compound;

(IV) when A^2 is Cys, D-Cys, hCys, D-hCys, Pen, or D-Pen, then A^9 is Cys, D-Cys, hCys, D-hCys, Pen, or D-Pen;

(V) when A^2 is Asp or Glu, then A^9 is Dab, Dap, Orn, or Lys;

(VI) when A^8 is Ala or Gly, then A^1 is not NIe; and

(VII) when A^1 is deleted, then R^2 and R^3 cannot both be H.

In an example embodiment, the agonists employed by the methods described herein are the compounds of Formula I, wherein:

A^1 is A6c, Arg, D-Arg, Cha, D-Cha, hCha, Chg, D-Chg, Gaba, Ile, Leu, hLeu, Met, β-hMet, 2-Nal, D-2-Nal, Nip, Nle, Oic, Phe, D-Phe, hPhe, hPro, Val, or deleted;

A^2 is Asp, Cys, D-Cys, hCys, D-hCys, Glu, Pen, or D-Pen;

A^3 is D-Abu, Aib, Ala, β-Ala, D-Ala, D-Cha, Gaba, D-Glu, Gly, D-Ile, D-Leu, D-Tle, D-Val, or deleted;

A^4 is His or 3-Pal;

A^5 is D-Bal, D-1-Nal, D-2-Nal, D-Phe, D-Trp, or D-(Et)Tyr;

A^6 is Arg, or hArg;

A^7 is Bal, Bip, 1-Nal, 2-Nal, Trp, D-Trp;

A^8 is A6c, D-Ala, Aha, Ahx, Ala, β-Ala, Apn, Gaba, Gly or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Lys, Pen, or D-Pen;

A^{10} is Thr, or deleted,

wherein at least one of A^3 or A^8 is deleted, but not both, or pharmaceutically acceptable salts thereof.

In an example embodiments, agonists of Formula (I) useful in practicing the invention described herein are compounds of the following formula or a pharmaceutically acceptable salt thereof:

SEQ ID NO: 1

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-β-Ala-Lys)-NH_2;

SEQ ID NO: 2

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-A6c-Lys)- NH_2;

SEQ ID NO: 3

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Ahx-Cys)- NH_2;

SEQ ID NO: 4

D-Phe-c(Cys-His-D-Phe-Arg-Trp-Ala-D-Cys)-Thr- NH_2;

SEQ ID NO: 5

D-Phe-c(Cys-His-D-Phe-Arg-Trp-β-Ala-D-Cys)-Thr-NH_2;

SEQ ID NO: 6

D-Phe-c(Cys-His-D-Phe-Arg-Trp-Gaba-D-Cys)-Thr-NH_2;

SEQ ID NO: 7

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-NH_2;

SEQ ID NO: 8

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Apn-Lys)-NH_2;

SEQ ID NO: 9

Ac-A6c-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-NH_2;

SEQ ID NO: 10

Ac-D-2-Nal-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-NH_2;

SEQ ID NO: 11

Ac-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-NH_2;

SEQ ID NO: 12

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-NH_2;

SEQ ID NO: 13

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 14

Ac-Nle-c(Cys-β-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 15

Ac-Nle-c(Cys-Gaba-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 16

Ac-Nle-c(Cys-Aib-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 17

Ac-Nle-c(Cys-Gly-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 18

Ac-Nle-c(D-Cys-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 19

Ac-Nle-c(D-Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 20

Ac-Nle-c(D-Cys-β-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 21

Ac-Nle-c(D-Cys-Gaba-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 22

Ac-Nle-c(D-Cys-Aib-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 23

Ac-Nle-c(D-Cys-Gly-His-D-Phe-Arg-Trp-Cys)-NH_2;

SEQ ID NO: 24

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-D-Cys)-NH_2;

SEQ ID NO: 25

Ac-Nle-c(Cys-β-Ala-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 26

Ac-Nle-c(Cys-Gaba-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 27

Ac-Nle-c(Cys-Aib-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 28

Ac-Nle-c(Cys-Gly-His-D-Phe-Arg-Trp-D-Cys)-NH_2;

SEQ ID NO: 29

Ac-Nle-c(D-Cys-Ala-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 30

Ac-Nle-c(D-Cys-D-Ala-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 31

Ac-Nle-c(D-Cys-β-Ala-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 32

Ac-Nle-c(D-Cys-Gaba-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 33

Ac-Nle-c(D-Cys-Aib-His-D-Phe-Arg-Trp-D-Cys)- NH_2;

SEQ ID NO: 34

Ac-Oic-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 35

Ac-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 36

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 37

Ac-D-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 38

Ac-D-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 39

Ac-Nip-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 40

Ac-hPro-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 41

Ac-hLeu-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 42

Ac-Phe-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 43

Ac-D-Phe-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-NH_2;

SEQ ID NO: 44

Ac-D-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 45

n-butanoyl-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 46

n-butyryl-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 47

Ac-hPhe-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 48

Ac-β-hMet-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 49

Ac-Gaba-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 50

Ac-Cha-c(Asp-His-D-Phe-Arg-D-Trp-Ala-Lys)- NH_2;

flSEQ ID NO: 51

Ac-hCha-c(Asp-His-D-Phe-Arg-D-Trp-Ala-Lys)- NH_2;

SEQ ID NO: 52

Ac-Leu-c(Asp-His-D-Phe-Arg-D-Trp-Ala-Lys)- NH_2;

SEQ ID NO: 53

Ac-hLeu-c(Asp-His-D-Phe-Arg-D-Trp-Ala-Lys)- NH_2;

SEQ ID NO: 54

Ac-Phe-c(Asp-His-D-Phe-Arg-D-Trp-Ala-Lys)- NH_2;

SEQ ID NO: 55

Ac-Nle-c(Asp-His-D-Phe-Arg-D-Trp-D-Ala-Lys)- NH_2;

SEQ ID NO: 56

Ac-Nle-c(Asp-His-D-Phe-Arg-D-Trp-β-Ala-Lys)- NH_2;

SEQ ID NO: 57

Ac-Nle-c(Asp-His-D-Phe-Arg-D-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 58

Ac-Nle-c(Asp-His-D-Phe-Arg-D-Trp-Aha-Lys)- NH_2;

SEQ ID NO: 59

Ac-Nle-c(Asp-His-D-Phe-Arg-D-Trp-Apn-Lys)- NH_2;

SEQ ID NO: 60

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Apn-Cys)- NH_2;

SEQ ID NO: 61

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 62

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Ahx-Cys)- NH_2;

SEQ ID NO: 63

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-β-Ala-Cys)- NH_2;

SEQ ID NO: 64

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-D-Ala-Cys)- NH_2;

SEQ ID NO: 65

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 66

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-2-Nal-Cys)- NH_2;

SEQ ID NO: 67

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-1-Nal-Cys)- NH_2;

SEQ ID NO: 68

n-butanoyl-Nle-c(Cys-D-Ala-His-D-Phe-Arg-2-Nal-Cys)- NH_2;

SEQ ID NO: 69

n-butanoyl-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 70

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-2-Nal-Cys)- NH_2;

SEQ ID NO: 71

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-1-Nal-Cys)- NH_2;

SEQ ID NO: 72

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Bal-Cys)- NH_2;

SEQ ID NO: 73

Ac-Nle-c(Cys-D-Glu-His-D-Phe-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 74

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-D-Ala-Lys)- NH_2;

SEQ ID NO: 75

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-Bal-Cys)- NH_2;

SEQ ID NO: 76

Ac-Nle-c(Pen-D-Ala-His-D-Phe-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 77

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)- NH_2;

SEQ ID NO: 78

Ac-Nle-c(Pen-D-Ala-His-D-Phe-Arg-Trp-Pen)- NH_2;

SEQ ID NO: 79

D-Phe-c(Cys-His-D-Phe-hArg-Trp-β-Ala-D-Cys)-Thr- NH_2;

SEQ ID NO: 80

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-Thr- NH_2;

SEQ ID NO: 81

D-Phe-c(Cys-His-D-Phe-Arg-Bip-β-Ala-D-Cys)-Thr- NH_2;

SEQ ID NO: 82

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr- NH_2;

SEQ ID NO: 83
D-Phe-c(Cys-His-D-Phe-hArg-Bip-β-Ala-D-Cys)-Thr- NH_2;
SEQ ID NO: 84
D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr- NH_2;
SEQ ID NO: 85
Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)- NH_2;
SEQ ID NO: 86
Ac-Nle-c(Asp-D-Ala-His-D-Phe-Arg-Trp-Lys)- NH_2;
SEQ ID NO: 87
Ac-Nle-c(Asp-D-Ala-His-D-Phe-Arg-Bal-Lys)- NH_2;
SEQ ID NO: 88
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-OH;
SEQ ID NO: 89
Ac-Nle-c(Cys-D-Abu-His-D-Phe-Arg-Trp-Cys)- NH_2;
SEQ ID NO: 90
Ac-Nle-c(Cys-D-Val-His-D-Phe-Arg-Trp-Cys)- NH_2;
SEQ ID NO: 91
Ac-Nle-c(Cys-D-Ile-His-D-Phe-Arg-Trp-Cys)- NH_2;
SEQ ID NO: 92
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)- NH_2;
SEQ ID NO: 93
Ac-Nle-c(Cys-D-Tle-His-D-Phe-Arg-Trp-Cys)- NH_2;
SEQ ID NO: 94
Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)- NH_2;
SEQ ID NO: 95
Ac-Nle-c(Pen-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;
SEQ ID NO: 96
Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Pen)- NH_2;
SEQ ID NO: 97
Ac-Nle-c(Pen-His-D-Phe-Arg-Trp-Gaba-Pen)- NH_2;
SEQ ID NO: 98

Ac-Leu-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 99

Ac-Cha-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 100

Ac-Ile-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 101

Ac-Phe-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 102

Ac-Val-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 103

Ac-2-Nal-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 104

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 105

Phe-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 106

Ac-Nle-c(Cys-3-Pal-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 107

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-OH;

SEQ ID NO: 108

Ac-Nle-c(Cys-His-Phe-Arg-D-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 109

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Ala-Lys)- NH_2;

SEQ ID NO: 110

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-β-Ala-Lys)- NH_2;

SEQ ID NO: 111

Ac-Nle-c(Cys-His-D-2-Nal-Arg-Trp-Gaba-Cys)- NH_2;

SEQ ID NO: 112

Ac-Nle-c(Cys-His-D-2-Nal-Arg-Trp-Ahx-Cys)- NH_2;

SEQ ID NO: 113

Ac-hPhe-c(Asp-His-D-2-Nal-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 114

Ac-Cha-c(Asp-His-D-2-Nal-Arg-Trp-Gaba-Lys)- NH_2;

SEQ ID NO: 115

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-β-Ala-Lys)-OH;

SEQ ID NO: 116

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Ahx-Cys)-OH;

SEQ ID NO: 117

D-Phe-c(Cys-His-D-Phe-Arg-Trp-Ala-D-Cys)-Thr-OH;

SEQ ID NO: 118

D-Phe-c(Cys-His-D-Phe-Arg-Trp-β-Ala-D-Cys)-Thr-OH;

SEQ ID NO: 119

D-Phe-c(Cys-His-D-Phe-Arg-Trp-Gaba-D-Cys)-Thr-OH;

SEQ ID NO: 120

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-OH;

SEQ ID NO: 121

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Apn-Lys)-OH;

SEQ ID NO: 122

Ac-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 123

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 124

Ac-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 125

Ac-D-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 126

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 127

Ac-D-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 128

Ac-hPhe-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-OH;

SEQ ID NO: 129

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Gaba-Cys)-OH;

SEQ ID NO: 130

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Ahx-Cys)-OH;

SEQ ID NO: 131

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-β-Ala-Cys)-OH;

SEQ ID NO: 132

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-D-Ala-Cys)-OH;

SEQ ID NO: 133

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)-OH;

SEQ ID NO: 134

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-2-Nal-Cys)-OH;

SEQ ID NO: 135

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-1-Nal-Cys)-OH;

SEQ ID NO: 136

Ac-Nle-c(Cys-D-Ala-His-D-2-Nal-Arg-Bal-Cys)-OH;

SEQ ID NO: 137

Ac-Nle-c(Pen-D-Ala-His-D-Phe-Arg-Trp-Cys)-OH;

SEQ ID NO: 138

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Pen)-OH;

SEQ ID NO: 139

Ac-Arg-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 140

Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 141

Ac-D-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)- NH_2;

SEQ ID NO: 142

Ac-D-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)- NH_2;

SEQ ID NO: 143

Ac-D-Arg-c(Cys-His-D-Phe-Arg-Trp-Gaba-Pen)- NH_2;

SEQ ID NO: 144

Ac-Arg-c(Cys-His-D-Phe-Arg-Trp-Gaba-Pen)- NH_2;

SEQ ID NO: 145

Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)- NH_2;

SEQ ID NO: 146

Ac-D-Arg-c(Asp-His-D-Phe-Arg-Trp-Ala-Lys)- NH_2;

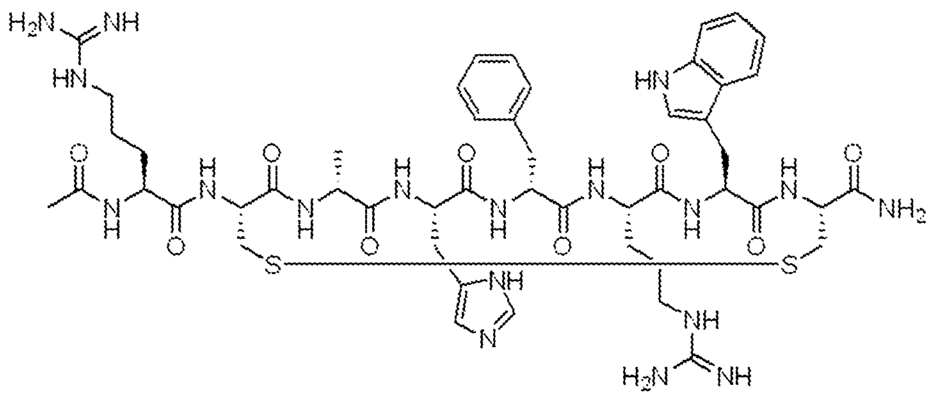
or

SEQ ID NO: 147

Ac-Arg-c(Asp-His-D-Phe-Arg-Trp-Ala-Lys)- NH_2;

or pharmaceutically acceptable salts thereof.

In embodiments, the MC4R agonist is setmelanotide (also called RM-493), having the sequence of Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140). Setmelanotide is a peptide that retains the specificity and functionality of the naturally occurring hormone that activates MC4R and has not been shown to adversely affect blood pressure in clinical trials. See, e.g., Chen et al. J. Clin. Endocrinol. Metab. 2015;100(4):1639-45. The structure of setmelanotide is shown below.



Setmelanotide is an 8 amino acid cyclic peptide that is efficient in activating MC4R. See, e.g., US 8,039,435B2, incorporated herein by reference. Setmelanotide has been generally well-tolerated with little, if any, signs of increased blood pressure and only infrequent effects on sexual activity.

In an example embodiment, an agonist of MC4R receptor useful for practicing methods described herein is any of the compounds described by Formula (II) or a pharmaceutically acceptable salt, hydrate, solvate or a prodrug thereof (see International Patent Application Publication Number WO 2007/008704 incorporated herein by reference in its entirety):

(R^2R^3)-A^1-c(A^2-A^3-A^4-A^5-A^6-A^7-A^8-A^9)-NH_2 (II)

In formula (II):

A^1 is Nle or deleted;

A^2 is Cys or Asp;

A^3 is Glu or D-Ala;

A^4 is H is;

A^5 is D-Phe;

A^6 is Arg;

A^7 is Trp, 2-Nal or Bal;

A^8 is Gly, Ala, D-Ala, (3-Ala, Gaba or Apn;

A^9 is Cys or Lys;

each of R^2 and R^3 is independently selected from the group consisting of H or (C_1-C_6)acyl.

In exemplary embodiments of Formula (II):

(I) when R^2 is (C_1-C_6)acyl, then R^3 is H; and

(II) when A^2 is Cys, then A^9 is Cys.

In alternative example embodiments of the present invention, the compounds useful for practicing the methods disclosed herein are:

SEQ ID NO: 148

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Gly-Cys)- NH_2;

SEQ ID NO: 149

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-D-Ala-Cys)- NH_2;

SEQ ID NO: 150

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-β-Ala-Cys)- NH_2;

SEQ ID NO: 151

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Gaba-Cys)- NH_2;
SEQ ID NO: 152
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Apn-Cys)- NH_2;
SEQ ID NO: 153
Ac-c(Cys-Glu-His-D-Phe-Arg-Trp-Ala-Cys)- NH_2;
SEQ ID NO: 154
Ac-c(Cys-Glu-His-D-Phe-Arg-2-Nal-Ala-Cys)-NH_2;
SEQ ID NO: 155
Ac-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Ala-Cys)- NH_2;
SEQ ID NO: 156
Ac-c(Cys-D-Ala-His-D-Phe-Arg-2-Nal-Ala-Cys)- NH_2;
SEQ ID NO: 157
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Ala-Cys)- NH_2;
or
SEQ ID NO: 158
Ac-Nle-c(Asp-D-Ala-His-D-Phe-Arg-Bal-Ala-Lys)- NH_2;
or a pharmaceutically acceptable salt thereof.

In an exemplary embodiment, the agonists of MC4R useful for practicing the methods described herein is any of the compounds of Formula (III), or a pharmaceutically acceptable salt, hydrate, solvate or a prodrug thereof (see International Application Publication Number WO 2007/008684, incorporated herein by reference in its entirety):

$$(R^2R^3)\text{-}B^1\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}A^{11}\text{-}A^{12}\text{-}A^{13}\text{-}B^2\text{-}B^3\text{-}R^1 \quad \text{(III)}.$$

In Formula (III):

B^1 is a peptide moiety which contains 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 amino acids, wherein at least 5 amino acids are independently selected from the group consisting of L-Arg, D-Arg, L-hArg and D-hArg, or B^1 is optionally deleted;

A^1 is Acc, HN-$(CH_2)_m$-C(O), L- or D-amino acid or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp or Glu;

A^3 is Gly, Glu, Ala, β-Ala, Gaba, Aib, D-amino acid or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi or (X', X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, D-(Et)Tyr, D-Dip, D-Bip or D-Bpa;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, Dip, Bpa, D-Trp, D-1-Nal, D-2-Nal, D-Bal, D-Bip, D-Dip or D-Bpa;

A^8 is Gly, D-Ala, Acc, Ala, β-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O) or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn or Lys;

A^{10} is Acc, HN-$(CH_2)_r$-C(O), Pro, hPro, 3-Hyp, 4-Hyp, Thr, an L- or D-amino acid or deleted;

A^{11} is Pro, hPro, 3-Hyp, 4-Hyp or deleted;

A^{12} is Lys, Dab, Dap, Arg, hArg or deleted;

A^{13} is Asp, Glu or deleted;

B^2 is a peptide moiety containing 1, 2, 3, 4, or 5 amino acids or deleted,

B^3 is a peptide moiety which contains 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or 15 amino acids wherein at least 5 amino acids are independently selected from the group consisting of L-Arg, D-Arg, L-hArg and D-hArg, or is deleted;

R^1 is OH or NH_2;

R^2 and R^3 each is, independently for each occurrence, selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl and substituted aryl(C_1-C_{30})acyl;

R^4 and R^5 each is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted (C_2-C_{40})alkenyl, substituted (C_2-C_{40})alkynyl, substituted aryl(C_1-C_{40})alkyl, substituted aryl(C_1-C_{40})acyl, (C_1-C_{40})alkylsulfonyl or C(NH)-NH_2;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

X^1, X^2, X^3, X^4 and X^5 each is, independently for each occurrence, H, F, Cl, Br, I, (C_{1-10})alkyl, substituted (C_{1-10})alkyl, (C_{2-10})alkenyl, substituted (C_{2-10})alkenyl, (C_{2-10})alkynyl, substituted (C_{2-10})alkynyl, aryl, substituted aryl, OH, NH_2 , NO_2 or CN.

In an example embodiments of Formula (III):

(I) when R^4 is (C_1-C_{40})acyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})acyl, substituted aryl(C_1-C_{40})acyl, (C_1-C_{40})alkylsulfonyl or C(NH)—NH_2 , then R^5 is H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_2-C_{40})alkenyl, substituted (C_2-C_{40})alkynyl or substituted aryl(C_1-C_{40})alkyl;

(II) when R^2 is (C_1-C_{30})acyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})acyl or substituted aryl(C_1-C_{30})acyl, then R^3 is H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl or substituted aryl(C_1-C_{30})alkyl;

(III) neither B^1 nor B^2 contains one or more of the following amino acid sequences: Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$, Tyr-Ala-Arg-Lys-Ala-$(Arg)_2$-Gln-Ala-$(Arg)_2$, Tyr-Ala-Arg-$(Ala)_2$-$(Arg)_2$-$(Ala)_2$-$(Arg)_2$, Tyr-Ala-$(Arg)_9$, Tyr-$(Ala)_3$-$(Arg)_7$, Tyr-Ala-Arg-Ala-Pro-$(Arg)_2$-Ala-$(Arg)_3$ or Tyr-Ala-Arg-Ala-Pro-$(Arg)_2$-Pro-$(Arg)_2$;

(IV) either B^1 or B^2 or both must be present in said compound;

(V) when A^2 is Cys, D-Cys, hCys, D-hCys, Pen or D-Pen, then A^9 is Cys, D-Cys, hCys, D-hCys, Pen or D-Pen; and

(VI) when A^2 is Asp or Glu, then A^9 is Dab, Dap, Orn or Lys.

In exemplary embodiments, in Formula (III);

B^1 is Arg-Lys-Gln-Lys-$(Arg)_5$, Arg-$(Lys)_2$-Arg-Gln-$(Arg)_4$, Arg-$(Lys)_2$-$(Arg)_3$-Gln-$(Arg)_2$, Arg-$(Lys)_2$-$(Arg)_4$-Gln-Arg, Arg-$(Lys)_2$-$(Arg)_5$-Gln, Arg-$(Lys)_2$-Gln-$(Arg)_5$, Arg-Gln-$(Lys)_2$-$(Arg)_5$, Arg-Gln-$(Arg)_7$, Arg-Gln-$(Arg)_8$, $(Arg)_2$-Gln-$(Arg)_6$, $(Arg)_2$-Gln-$(Arg)_7$, $(Arg)_3$-Gln-$(Arg)_5$, $(Arg)_3$-Gln-$(Arg)_6$, $(Arg)_4$-Gln-$(Arg)_4$, $(Arg)_4$-Gln-$(Arg)_5$, $(Arg)_5$, $(Arg)_5$-Gln-$(Arg)_3$, $(Arg)_5$-Gln-$(Arg)_4$, $(Arg)_6$, $(Arg)_6$-Gln-$(Arg)_3$, $(Arg)_7$, $(Arg)_7$-Gln-$(Arg)_2$, $(Arg)_8$, $(Arg)_s$-Gln-Arg, $(Arg)_9$, $(Arg)_9$-Gln, $(D\text{-}Arg)_5$, $(D\text{-}Arg)_6$, $(D\text{-}Arg)_7$, $(D\text{-}Arg)_8$, $(D\text{-}Arg)_9$, Gln-Arg-$(Lys)_2$-$(Arg)_5$, Gln-$(Arg)_8$, Gln-$(Arg)_9$, Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$, Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-Doc; or deleted;

B^2 is β-Ala, β-Ala-Gly, β-Ala-Tyr, β-Ala-Tyr-Gly, (β-Ala)$_2$, (β-Ala)$_2$-Gly, (β-Ala)$_2$-Tyr, (β-Ala)$_2$-Tyr-Gly, Doc, Doc-Gly, Doc-Tyr, Doc-Tyr-Gly, (Doc)$_2$, (Doc)$_2$-Gly, (Doc)$_2$-Tyr, Doc)$_2$-Tyr-Gly, or deleted;

B^3 is Arg-Lys-Gln-Lys-(Arg)$_5$, Arg-Lys-(Arg)$_3$-Gln-(Arg)$_3$, Arg-(Lys)$_2$-Arg-Gln-(Arg)$_4$, Arg-(Lys)$_2$-Gln-(Arg)$_5$, Arg-(Lys)$_2$-(Arg)$_2$-Gln-(Arg)$_3$, Arg-(Lys)$_2$-(Arg)$_3$-Gln-(Arg)$_2$, Arg-(Lys)$_2$-(Arg)$_4$-Gln-Arg, Arg-(Lys)$_2$-(Arg)$_5$-Gln, Arg-Gln-(Lys)$_2$-(Arg)$_5$, Arg-Gln-(Arg)$_7$, Arg-Gln-(Arg)$_s$, (Arg)$_2$-Lys-(Arg)$_2$-Gln-(Arg)$_3$, (Arg)$_2$-Gln-(Arg)$_6$, (Arg)$_2$-Gln-(Arg)$_7$, (Arg)$_3$-Gln-(Arg)$_5$, (Arg)$_3$-Gln-(Arg)$_6$, (Arg)$_4$-Gln-(Arg)$_4$, (Arg)$_4$-Gln-(Arg)$_5$, (Arg)$_5$, (Arg)$_s$-Gln-(Arg)$_3$, (Arg)$_5$-Gln-(Arg)$_4$, (Arg)$_6$, (Arg)$_6$-Gln-(Arg)$_3$, (Arg)$_7$, (Arg)$_7$-Gln-(Arg)$_2$, (Arg)$_8$, (Arg)$_s$-Gln-Arg, (Arg)$_9$, (Arg)$_9$-Gln, (D-Arg)$_5$, (D-Arg)$_6$, (D-Arg)$_7$, (D-Arg)$_8$, (D-Arg)$_9$, Gln-Arg-(Lys)$_2$-(Arg)$_5$, Gln-(Arg)$_8$, Gln-(Arg)$_9$, or deleted;

A^1 is A6c, Cha, hCha, Chg, D-Chg, hChg, Gaba, hLeu, Met, β-hMet, D-2-Nal, Nip, Nle, Oic, Phe, D-Phe, hPhe, hPro, or deleted;

A^2 is Cys;

A^3 is D-Abu, Aib, Ala, β-Ala, D-Ala, D-Cha, Gaba, Glu, Gly, D-Ile, D-Leu, D-Met, D-Nle, D-Phe, D-Tle, D-Trp, D-Tyr, D-Val, or deleted;

A^4 is H;

A^5 is D-Bal, D-1-Nal, D-2-Nal, D-Phe, D-(X^1, X^2, X^3, X^4, X^5)Phe, D-Trp, or D-(Et)Tyr;

A^6 is Arg or hArg;

A^7 is Bal, Bip, 1-Nal, 2-Nal, Trp, or D-Trp;

A^8 is A5c, A6c, Aha, Ahx, Ala, β-Ala, Apn, Gaba, Gly, or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Lys, Pen, or D-Pen;

A^{10} is Pro, Thr or deleted;

A^{11} is Pro or deleted;

A^{12} is arg, Lys, or deleted;

A^{13} is Asp or deleted;

each of R^2 and R^3 is, independently, H or acyl;

or pharmaceutically acceptable salts thereof.

In exemplary embodiments, the MC4R agonists useful for practicing the methods of the present invention are at least one of the following compounds:

(SEQ ID NO: 159)

Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)- NH_2;

(SEQ ID NO: 160)

Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-Doc-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-NH_2;

(SEQ ID NO: 161)

Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 162)

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 163)

Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-$(Doc)_2$ -Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 164)

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-$(Pro)_2$-Lys-Asp-Tyr-Gly-Arg-$(Lys)_2$ -$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 165)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Gly-Cys)-$(Pro)_2$-Lys-Asp-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 166)

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-$(β\text{-}Ala)_2$-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 167)

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-$(Pro)_2$-Lys-Asp-Doc-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 168)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Gly-Cys)-$(Pro)_2$-Lys-Asp-Doc-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 169)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 170)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-Doc-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 171)

Ac-Nle-c(Asp-His-D-2-Nal-Arg-Trp-Lys)-$(Doc)_2$-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 172)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 173)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 174)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 175)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 176)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-Arg-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 177)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-Gln-$(Arg)_5$-NH_2;

(SEQ ID NO: 178)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-Lys-Gln-Lys-$(Arg)_5$-NH_2;

(SEQ ID NO: 179)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_4$-Gln-Arg-NH_2;

(SEQ ID NO: 180)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Aib-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 181)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 182)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$ -Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 183)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 184)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 185)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 186)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_6$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 187)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 188)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 189)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 190)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_3$-Gln-$(Arg)_2$-NH_2;

(SEQ ID NO: 191)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-Gln-$(Lys)_2$-$(Arg)_5$-NH_2;

(SEQ ID NO: 192)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_5$-Gln-NH_2;

(SEQ ID NO: 193)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 194)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 195)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_2$ -Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 196)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 197)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_2$ -Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 198)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 199)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 200)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 201)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 202)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 203)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 204)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 205)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 206)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 207)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 208)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 209)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 210)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 211)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 212)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 213)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 214)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 215)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 216)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 217)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 218)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 219)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 220)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 221)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 222)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 223)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 224)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 225)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 226)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 227)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 228)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 229)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 230)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 231)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 232)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 233)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 234)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 235)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 236)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 237)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 238)
Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 239)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 240)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 241)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 242)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 243)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 244)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 245)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Lys-Asp-β-Ala-Tyr-Gly-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 246)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$-Arg-Asp-β-Ala-Tyr-Gly-$(Arg)_6$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 247)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$-Tyr-Gly-Arg-$(Lys)_2$-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 248)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-Arg-$(Lys)_2$-Arg-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 249)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-Arg-$(Lys)_2$ -$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 250)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 251)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 252)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 253)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 254)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 255)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 256)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Gly-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 257)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Gly-Arg-Lys-$(Arg)_3$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 258)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-$(Arg)_2$-Lys-$(Arg)_2$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 259)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Arg-Lys-$(Arg)_3$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 260)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-$(β\text{-}Ala)_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 261)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 262)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 263)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-(Arg)$_5$-Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 264)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 265)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 266)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(Doc)$_2$ -(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 267)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(Doc)$_2$ -Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 268)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(Doc)$_2$ -Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 269)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;
(SEQ ID NO: 270)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_4$ -NH$_2$;
(SEQ ID NO: 271)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;
(SEQ ID NO: 272)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;
(SEQ ID NO: 273)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 274)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-(Arg)$_5$ -Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 275)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 276)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 277)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(Doc)$_2$ -(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 278)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(Doc)$_2$ -Gly-(Arg)$_5$-Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 279)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-(Doc)$_2$ -Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 280)

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-β-Ala-Tyr-Gly- (Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 281)

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-β-Ala-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 282)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Ala-Lys)-β-Ala-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 283)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Ala-Lys)-β-Ala-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 284)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-β-Ala-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 285)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-β-Ala-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 286)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 287)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(β\text{-}Ala)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 288)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(β\text{-}Ala)_2$ -Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 289)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(β\text{-}Ala)_2$-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 290)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-Doc-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 291)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-Doc-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 292)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-Doc-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 293)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(Doc)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 294)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(Doc)_2$ -Gly-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 295)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(Doc)_2$ -$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 296)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;
(SEQ ID NO: 297)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-β-Ala-Gly-$(Arg)_5$-Gln-$(Arg)_4$ -NH_2;
(SEQ ID NO: 298)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 299)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(β\text{-}Ala)_2$ -Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 300)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(β\text{-}Ala)_2$ -Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 301)
Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(β\text{-}Ala)_2$ -$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 302)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 303)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-Doc-Gly-$(Arg)_5$-Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 304)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-Doc-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 305)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(Doc)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 306)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(Doc)_2$ -Gly-$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 307)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Lys)-$(Doc)_2$ -$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 308)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-β-Ala-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 309)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-β-Ala-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 310)

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Ahx-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 311)

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Ahx-Cys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 312)

D-Phe-c(Cys-His-D-Phe-Arg-Trp-β-Ala-D-Cys)-Thr-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ - NH_2;

(SEQ ID NO: 313)

D-Phe-c(Cys-His-D-Phe-Arg-Trp-β-Ala-D-Cys)-Thr-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 314)

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 315)

Ac-Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 316)

Ac-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly- $(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 317)

Ac-Cha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 318)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 319)

Ac-Nle-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 320)

Ac-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 321)

Ac-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 322)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 323)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 324)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(\beta\text{-Ala})_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ - NH_2;

(SEQ ID NO: 325)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(\beta\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 326)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 327)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-Doc-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 328)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(Doc)_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 329)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(Doc)_2$ -$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 330)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 331)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 332)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(\beta\text{-Ala})_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$ - NH_2;

(SEQ ID NO: 333)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(\beta\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 334)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 335)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-Doc-$(Arg)_5$ -Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 336)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(Doc)_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 337)

Ac-hCha-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 338)

Ac-D-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 339)

Ac-D-Chg-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 340)

Ac-hPhe-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 341)

Ac-hPhe-c(Asp-His-D-Phe-Arg-Trp-Gaba-Lys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 342)

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Apn-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 343)

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Apn-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 344)

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Ahx-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 345)

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-Ahx-Cys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 346)

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-β-Ala-Cys)-β-Ala-Tyr- Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 347)

Ac-Nle-c(Cys-His-D-Phe-Arg-D-Trp-β-Ala-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 348)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-β-Ala-Tyr-Gly -$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 349)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-β-Ala-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 350)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 351)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-$(β\text{-}Ala)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 352)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-(β-Ala)$_2$ -Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 353)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-(β-Ala)$_2$-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 354)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-Doc-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 355)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-Doc-Gly-(Arg)$_5$-Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 356)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-Doc-(Arg)$_5$-Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 357)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-(Doc)$_2$-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 358)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-(Doc)$_2$-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 359)
Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-(Doc)$_2$-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;
(SEQ ID NO: 360)
D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-β-Ala-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ - NH$_2$;
(SEQ ID NO: 361)
D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-β-Ala-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 362)
D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-β-Ala-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;
(SEQ ID NO: 363)
D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-β-Ala-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;
(SEQ ID NO: 364)
D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(β-Ala)$_2$ -Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 365)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(β-Ala)$_2$-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 366)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(β-Ala)$_2$ -Gly-(Arg)$_5$ -Gln-(Arg)$_3$ - NH$_2$;

(SEQ ID NO: 367)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(β-Ala)$_2$ -(Arg)$_5$ -Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 368)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-Doc-Tyr- Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 369)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-Doc-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 370)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-Doc-Gly-(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 371)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-Doc-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 372)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(Doc)$_2$-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 373)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(Doc)$_2$ -(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 374)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(Doc)$_2$-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 375)

D-Phe-c(Cys-His-D-(Et)Tyr-Arg-Trp-β-Ala-D-Cys)-(Doc)$_2$-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 376)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-β- Ala-Tyr-Gly-$(Arg)_5$ -Gln- $(Arg)_3$ -NH_2;

(SEQ ID NO: 377)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-β- Ala-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 378)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-$(β\text{-}Ala)_2$ -Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 379)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-$(β\text{-}Ala)_2$ -$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 380)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-Doc-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 381)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-Doc-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 382)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-$(Doc)_2$-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 383)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-β- Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 384)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-β-Ala-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 385)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-$(β\text{-}Ala)_2$ -Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 386)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-(β-Ala)$_2$ -(Arg)$_5$-Gln-(Arg)$_4$-NH_2;

(SEQ ID NO: 387)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-Doc-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_4$-NH_2;

(SEQ ID NO: 388)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-Doc-(Arg)$_5$ -Gln-(Arg)$_4$-NH_2;

(SEQ ID NO: 389)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-(Doc)$_2$-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH_2;

(SEQ ID NO: 390)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Trp-β-Ala-D-Cys)-Thr-(Doc)$_2$ -(Arg)$_5$-Gln-(Arg)$_4$ - NH_2;

(SEQ ID NO: 391)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-β- Ala-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH_2;

(SEQ ID NO: 392)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-β-Ala-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH_2;

(SEQ ID NO: 393)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-β-Ala-(Arg)$_5$ -Gln-(Arg)$_3$-NH_2;

(SEQ ID NO: 394)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-(β-Ala)$_2$ -Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH_2;

(SEQ ID NO: 395)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-(β-Ala)$_2$ -(Arg)$_5$-Gln-(Arg)$_3$-NH_2;

(SEQ ID NO: 396)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-Doc-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 397)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-Doc-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 398)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-Doc-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 399)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-$(Doc)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 400)

D-Phe-c(Cys-His-D-(Et)Tyr-hArg-Bip-β-Ala-D-Cys)-Thr-$(Doc)_2$ -$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 401)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Gly-Cys)-β-Ala-Tyr -Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 402)

Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Gly-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 403)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 404)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 405)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-$(\beta\text{-Ala})_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 406)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-$(\beta\text{-Ala})_2$ -$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 407)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 408)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$ -NH_2;

(SEQ ID NO: 409)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-(β-Ala)$_2$-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 410)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-(β-Ala)$_2$-(Arg)$_5$-Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 411)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-Doc-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 412)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-Doc-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 413)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-(Doc)$_2$ -Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 414)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-(Doc)$_2$ -(Arg)$_5$ -Gln-(Arg)$_3$ -NH$_2$;

(SEQ ID NO: 415)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-Doc-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 416)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-Doc-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 417)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-(Doc)$_2$-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_4$-NH$_2$;

(SEQ ID NO: 418)

Nle-c(Cys-His-D-Phe-Arg-Trp-Apn-Cys)-(Doc)$_2$-(Arg)$_5$-Gln-(Arg)$_4$ -NH$_2$;

(SEQ ID NO: 419)

Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 420)

Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-β-Ala-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 421)

Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-Tyr-Gly-(Arg)$_5$ -Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 422)

Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-(β-Ala)$_2$-(Arg)$_5$-Gln-(Arg)$_3$-NH$_2$;

(SEQ ID NO: 423)

Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 424)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-Doc-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;
(SEQ ID NO: 425)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 426)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;
(SEQ ID NO: 427)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 428)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 429)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-$(\beta\text{-Ala})_2$ -Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 430)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-$(\beta\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 431)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 432)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-Doc-$(Arg)_5$-Gln-$(Arg)_4$ -NH_2;
(SEQ ID NO: 433)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 434)
Ac-Nle-c(Cys-D-Leu-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;
(SEQ ID NO: 435)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 436)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$ -NH_2;

(SEQ ID NO: 437)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(β\text{-Ala})_2$ -Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 438)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(β\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 439)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 440)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-Doc-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 441)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$ -Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 442)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 443)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 444)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-β-Ala-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 445)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(β\text{-Ala})_2$-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 446)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(β\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 447)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-Doc-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 448)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-Doc-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 449)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$-Tyr-Gly-$(Arg)_5$ -Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 450)

Ac-Nle-c(Cys-D-Cha-His-D-Phe-Arg-Trp-Cys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 451)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 452)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 453)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(\beta\text{-Ala})_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 454)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(\beta\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 455)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-β-Ala-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 456)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-β-Ala-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 457)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(\beta\text{-Ala})_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 458)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(\beta\text{-Ala})_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 459)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-Doc-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 460)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-Doc-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 461)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(Doc)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 462)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_3$-NH_2;

(SEQ ID NO: 463)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-Doc-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 464)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-Doc-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

(SEQ ID NO: 465)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(Doc)_2$-Tyr-Gly-$(Arg)_5$-Gln-$(Arg)_4$-NH_2;

or

(SEQ ID NO: 466)

Nle-c(Cys-His-D-Phe-Arg-Trp-Gaba-Cys)-$(Doc)_2$-$(Arg)_5$-Gln-$(Arg)_4$-NH_2,

or pharmaceutically acceptable salts thereof.

In an example embodiment, the compounds useful for practicing the methods described herein are the compounds of Formula (IV):

Ac-*c*(Cys-Glu-His-A^1-Arg-A^2-A^3-Cys)-$(Pro)_2$-Lys-Asp-NH_2 (IV)

or pharmaceutically acceptable salts thereof. In Formula (IV):

A^1 is the D-isomer of X-Phe or 2-Nal where X is halogen;

A^2 is Bal, 1-Nal, 2-Nal, or Trp; and

A^3 is Aib, Ala, β-Ala or Gly,

In an example embodiments, the at least one of the following compounds is used:

(SEQ ID NO: 467)

Ac-c(Cys-Glu-His-D-4-Br-Phe-Arg-Trp-Gly-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

(SEQ ID NO: 468)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Ala-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

(SEQ ID NO: 469)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Ala-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

(SEQ ID NO: 470)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-1-Nal-Ala-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

(SEQ ID NO: 471)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-Bal-Ala-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

(SEQ ID NO: 472)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-β-Ala-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

or

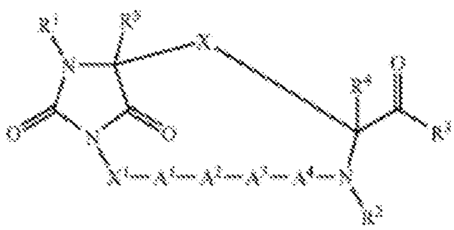
(SEQ ID NO: 473)

Ac-c(Cys-Glu-His-D-2-Nal-Arg-2-Nal-Aib-Cys)-$(Pro)_2$ -Lys-Asp-NH_2;

or pharmaceutically acceptable salts thereof.

In example embodiments, an MC4R agonist useful for practicing the methods described herein is at least one compound modified with a hydantoin moiety according to Formula (V), (VI) or (VII), or a pharmaceutically acceptable salt, hydrate, solvate or a prodrug thereof.

Formula (V) is described below: (see WO2008/147556 or International Patent Application Number PCT/US08/06675 incorporated herein by reference in its entirety).



(V).

In Formula (V):

X is selected from the group consisting of —CH_2—S—S—CH_2—, -$C(CH_3)_2$—S—S—CH_2—, —CH_2—S—S—$C(CH_3)_2$—, —$C(CH_3)_2$—S—S—$C(CH_3)_2$—, —$(CH_2)_2$—S—S—CH_2—, —CH_2—S—S—$(CH_2)_2$-, —$(CH_2)_2$—S—S—$(CH_2)_2$—, —$C(CH_3)_2$—S—S—$(CH_2)_2$—, —$(CH_2)_2$—S—S—$C(CH_3)_2$—, —$(CH_2)_t$—C(O)—NR^8—$(CH_2)_r$—and —$(CH_2)_r$—NR^8—C(O)—$(CH_2)_t$ —;

R^2 each is, independently, H, $(C_1\text{-}C_{10})$alkyl or substituted $(C_1\text{-}C_{10})$alkyl;

R^3 is —OH or —NH_2;

R^4 and R^5 each is, independently, H, $(C_1\text{-}C_{10})$alkyl or substituted $(C_1\text{-}C_{10})$alkyl;

X^1 is


,

A^1 is H is, 2-Pal, 3-Pal, 4-Pal, (X^1, X^2, X^3, X^4, X^5)Phe, Taz, 2-Thi, 3-Thi or is deleted;

A^2 is D-Bal, D-1-Nal, D-2-Nal, D-Phe or D-(X^1, X^2, X^3, X^4, X^5)Phe;

A^3 is Arg, hArg, Dab, Dap, Lys or Orn;

A^4 is Bal, 1-Nal, 2-Nal, (X^1, X^2, X^3, X^4, X^5)Phe or Trp;

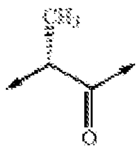
R^6 and R^7 each is, independently for each occurrence thereof, H, (C_1-C_{10})heteroalkyl, aryl(C_1-C_5)alkyl, substituted (C_1-C_{10})alkyl, substituted (C_1-C_{10})heteroalkyl or substituted aryl(C_1-C_5)alkyl provided that R^6 and R^7 may be joined together to form a ring;

R^8 is H, (C_1-C_{10})alkyl or substituted (C_1-C_{10})alkyl;

r is, independently for each occurrence thereof, 1, 2, 3, 4 or 5; and

t is, independently for each occurrence thereof, 1 or 2.

Compounds according the foregoing formula can include compounds wherein X^1 is selected from the group consisting of: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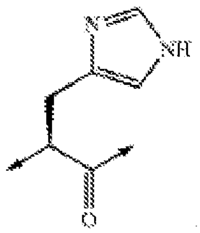
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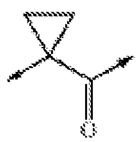
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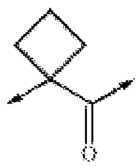
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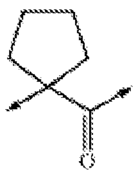
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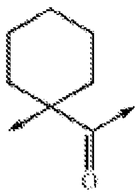
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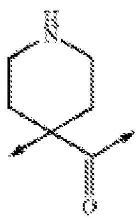
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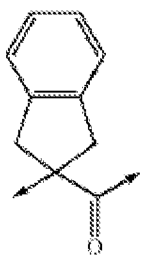
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Representative embodiments of the foregoing class of compounds are as follows:

(SEQ ID NO: 474

c[Hydantoin(C(O)-(Cys-D-Ala))-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 475)

c[Hydantoin(C(O)-(hCys-D-Ala))-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 476)

c[Hydantoin(C(O)-(Cys-D-Ala))-His-D-2-Nal-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 477)

c[Hydantoin(C(O)-(hCys-D-Ala))-His-D-2-Nal-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 478)

c[Hydantoin(C(O)-(Asp-D-Ala))-His-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 479)

c[Hydantoin(C(O)-(Asp-D-Ala))-His-D-Phe-Arg-Trp-Orn]-NH_2;

(SEQ ID NO: 480)

c[Hydantoin(C(O)-(Asp-D-Ala))-His-D-Phe-Arg-Trp-Dab]-NH_2;

(SEQ ID NO: 481)

c[Hydantoin(C(O)-(Asp-D-Ala))-His-D-Phe-Arg-Trp-Dap]-NH_2;

(SEQ ID NO: 482)

c[Hydantoin(C(O)-(Asp-His))-D-2-Nal-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 483)

c[Hydantoin(C(O)-(Asp-His))-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 484)

c[Hydantoin(C(O)-(Asp-A3c))-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 485)

c[Hydantoin(C(O)-(Asp-A5c))-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 486)

c[Hydantoin(C(O)-(Asp-A6c))-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 487)

c[Hydantoin(C(O)-(Asp-A3c))-D-2-Nal-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 488)

c[Hydantoin(C(O)-(Asp-A5c))-D-2-Nal-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 489)

c[Hydantoin(C(O)-(Asp-A6c))-D-2-Nal-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 490)

c[Hydantoin(C(O)-(Asp-Aic))-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 491)

c[Hydantoin(C(O)-(Asp-Apc))-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 492)

c[Hydantoin(C(O)-(Asp-Aic))-D-2-Nal-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 493)

c[Hydantoin(C(O)-(Asp-Apc))-D-2-Nal-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 494)

c[Hydantoin(C(O)-(Glu-D-Ala))-His-D-Phe-Arg-Trp-Orn]-NH_2;

(SEQ ID NO: 495)

c[Hydantoin(C(O)-(Glu-D-Ala))-His-D-Phe-Arg-Trp-Dab]-NH_2;

(SEQ ID NO: 496)

c[Hydantoin(C(O)-(Glu-D-Ala))-His-D-Phe-Arg-Trp-Dap]-NH_2;

(SEQ ID NO: 497)

c[Hydantoin(C(O)-(Glu-D-Ala))-His-D-Phe-Arg-Trp-Lys]-NH_2;

(SEQ ID NO: 498)

c[Hydantoin(C(O)-(Glu-His))-D-Phe-Arg-Trp-Dap]-NH_2;

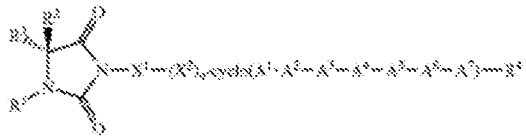
or

(SEQ ID NO: 499)

c[Hydantoin(C(O)-(Glu-His))-D-Phe-Arg-Trp-Lys]-NH_2.

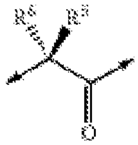
In an example embodiment, an MC4R agonist useful for practicing the methods described herein is at least one compound of Formula (VI), a pharmaceutically-acceptable salt, hydrate, solvate and/or prodrugs thereof (see WO2008/147556 or International Patent

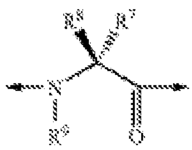
Application Number PCT/US08/06675 which is incorporated herein by reference in its entirety):



(VI).

In Formula (VI):

X^1 is  ;

X^2 is  ;

A^1 is Asp, Cys, D-Cys, Dab, Dap, Glu, Lys, Orn, Pen or D-Pen;

A^2 is an L- or D-amino acid;

A^3 is H is, 2-Pal, 3-Pal, 4-Pal, (X^1, X^2, X^3, X^4, X^5)Phe, Taz, 2-Thi or 3-Thi;

A^4 is D-Bal, D-1-Nal, D-2-Nal, D-Phe or D-(X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is Arg, hArg, Dab, Dap, Lys or Orn;

A^6 is Bal, 1-Nal, 2-Nal, (X^1, X^2, X^3, X^4, X^5)Phe or Trp;

A^7 is Asp, Cys, D-Cys, Dab, Dap, Glu, Lys, Orn, Pen or D-Pen;

R^1 is H, (C_1-C_{10})alkyl or substituted (C_1-C_{10})alkyl;

R^2 and R^3 each is, independently, H, (C_1-C_{10})alkyl, (C_1-C_{10})heteroalkyl, aryl(C_1-C_5)alkyl, substituted (C_1-C_{10})alkyl, substituted (C_1-C_{10})heteroalkyl or substituted aryl(C_1-C_5)alkyl or R^2 and R^3 may be fused together form a cyclic moiety;

R^4 is OH, NH_2, CO_2 H or C(O)NH_2;

R^5 and R^6 each is, independently, H, (C_1-00)alkyl, (C_1-C_{10})heteroalkyl, aryl(C_1-C_5)alkyl, substituted (C_1-C_{10})alkyl, substituted (C_1-C_{10})heteroalkyl or substituted aryl(C_1-C_5)alkyl or R^5 and R^6 may be fused together form a cyclic moiety;

R^7 and R^8 each is, independently, H, $(C_1\text{-}C_{10})$alkyl, $(C_1\text{-}C_{10})$heteroalkyl, aryl$(C_1\text{-}C_5)$alkyl, substituted $(C_1\text{-}C_{10})$alkyl, substituted $(C_1\text{-}C_{10})$heteroalkyl or substituted aryl$(C_1\text{-}C_5)$alkyl; or R^7 and R^8 may be fused together form a cyclic moiety;

R^9 is H, $(C_1\text{-}C_{10})$alkyl or substituted $(C_1\text{-}C_{10})$alkyl; and

n is, independently for each occurrence thereof, 0, 1, 2, 3, 4, 5, 6 or 7;

or a pharmaceutically acceptable salt thereof.

Exemplary embodiments of the compounds of Formula (VI) are those compounds wherein:

A^1 is Cys;

A^2 is D-Ala, Asn, Asp, Gln, Glu or D-Phe;

A^3 is H is;

A^4 is D-2-Nal or D-Phe;

A^5 is Arg;

A^6 is Trp; and

A^7 is Cys or Pen;

each of R', R^2, R^3, and R^9 is, independently, H;

R^4 is $C(O)NH_2$;

each of R^5 and R^6 is, independently, H, $(C_1\text{-}C_{10})$heteroalkyl, substituted $(C_1\text{-}C_{10})$alkyl or substituted $(C_1\text{-}C_{10})$heteroalkyl or R^5 and R^6 may be fused together form a cyclic moiety; and each of R^7 and R^8 is, independently, H, $(C_1\text{-}C_{10})$alkyl, $(C_1\text{-}C_{10})$heteroalkyl, substituted $(C_1\text{-}C_{10})$alkyl or substituted $(C_1\text{-}C_{10})$heteroalkyl;

or pharmaceutically acceptable salts thereof.

Example compounds of the immediately foregoing Formula (VI) include:

(SEQ ID NO: 500)

Hydantoin(C(O)-(Arg-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 501)

Hydantoin(C(O)-(Nle-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 502)

Hydantoin(C(O)-(Gly-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 503)

Hydantoin(C(O)-(Nle-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 504)

Hydantoin(C(O)-(Gly-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 505)

Hydantoin(C(O)-(Nle-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-NH_2;

(SEQ ID NO: 506)

Hydantoin(C(O)-(Gly-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Pen)-NH_2;

(SEQ ID NO: 507)

Hydantoin(C(O)-(Ala-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 508)

Hydantoin(C(O)-(D-Ala-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 509)

Hydantoin(C(O)-(Aib-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 510)

Hydantoin(C(O)-(Val-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 511)

Hydantoin(C(O)-(Ile-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 512)

Hydantoin(C(O)-(Leu-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 513)

Hydantoin(C(O)-(Gly-Gly))-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 514)

Hydantoin(C(O)-(Nle-Gly))-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 515)

Hydantoin(C(O)-(D-Arg-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 516)

Hydantoin(C(O)-(D-Arg-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 517)

Hydantoin(C(O)-(Arg-Gly))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 518)

Hydantoin(C(O)-(D-Arg-Gly))-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 519)

Hydantoin(C(O)-(Arg-Gly))-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 520)

Hydantoin(C(O)-(Ala-Nle))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 521)

Hydantoin(C(O)-(Val-Nle))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 522)

Hydantoin(C(O)-(Gly-Nle))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 523)

Hydantoin(C(O)-(A6c-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 524)

Hydantoin(C(O)-(Gly-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 525)

Hydantoin(C(O)-(Ala-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 526)

Hydantoin(C(O)-(D-Ala-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 527)

Hydantoin(C(O)-(Val-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 528)

Hydantoin(C(O)-(Leu-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 529)

Hydantoin(C(O)-(Cha-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 530)

Hydantoin(C(O)-(Aib-Nle))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 531)

Hydantoin(C(O)-(Gly-Arg))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 532)

Hydantoin(C(O)-(Gly-Arg))-c(Cys-Glu-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 533)

Hydantoin(C(O)-(Gly-Arg))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 534)

Hydantoin(C(O)-(Gly-Arg))-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 535)

Hydantoin(C(O)-(Gly-D-Arg))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 536)

Hydantoin(C(O)-(Gly-D-Arg))-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 537)

Hydantoin(C(O)-(Gly-D-Arg))-c(Cys-D-Ala-His-D-2-Nal-Arg-Trp-Cys)-NH_2;

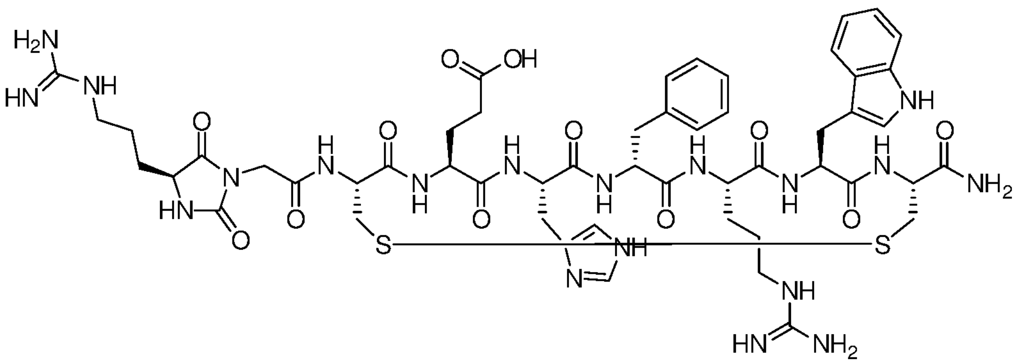
Or

(SEQ ID NO: 538)

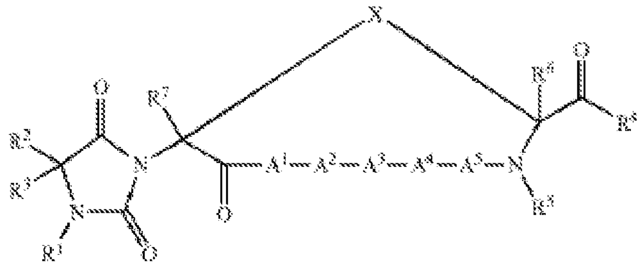
Hydantoin(C(O)-(Nle-Ala))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2;

or a pharmaceutically acceptable salt thereof.

In some embodiments, the MC4R agonist comprises/is:



In an example embodiment, the MC4R agonists useful for practicing the methods described herein are compounds having a structure according to Formula (VII) as depicted below (see WO2008/147556 or International Patent Application Number PCT/US08/06675 which is incorporated herein by reference in its entirety):



(VII).

wherein:

X is selected from the group consisting of —CH_2—S—S—CH_2—, -$C(CH_3)_2SSCH_2$-,—CH_2—S—S—$C(CH_3)_2$—, —$C(CH_3)_2$—S—S—$C(CH_3)_z$-, —$(CH_2)_2$—S—S—CH_2—, —CH_2—S—S—$(CH_2)_2$, $(CH_2)_2$—S—S—$(CH_2)_2$-, —$C(CH_3)_2$—S—S—$(CH_2)_2$—, —$(CH_2)_2$—S—S—$C(CH_3)_2$—, —$(CH_2)_t$—C(O)—NR^8—$(CH_2)_r$— and —$(CH_2)_r$—NR^8—C(O)—$(CH_2)_t$—;

each of R^1 and R^5 is, independently, H, $(C_1$-$C_{10})$alkyl or substituted $(C_1$-$C_{10})$alkyl;

each of R^2 and R^3 is, independently, H, $(C_1$-$C_{10})$alkyl, $(C_1$-00)heteroalkyl, aryl$(C_1$-$C_5)$alkyl, substituted $(C_1$-$C_{10})$alkyl, substituted $(C_1$-$C_{10})$heteroalkyl or substituted aryl$(C_1$-$C_5)$alkyl or R^2 and R^3 may be fused together to form a ring;

R^4 is OH or NH_2;

each of R^6 and R^7 is, independently, H, $(C_1$-$C_{10})$alkyl or substituted $(C_1$-$C_{10})$alkyl;

A^1 is an L- or D-amino acid or deleted;

A^2 is H is, 2-Pal, 3-Pal, 4-Pal, $(X^1, X^2, X^3, X^4, X^5)$Phe, Taz, 2-Thi or 3-Thi;

A^3 is D-Bal, D-1-Nal, D-2-Nal, D-Phe or D-$(X^1, X^2, X^3, X^4, X^5)$Phe;

A^4 is Arg, hArg, Dab, Dap, Lys or Orn;

A^5 is Bal, 1-Nal, 2-Nal, $(X^1, X^2, X^3, X^4, X^5)$Phe or Trp;

r is, independently for each occurrence thereof, 1, 2, 3, 4 or 5; and

t is, independently for each occurrence thereof, 1 or 2;

or pharmaceutically acceptable salts thereof.

In an example embodiment of the compounds of Formula (VII), A[1] is Ala, D-Ala, Asn, Asp, Gln, Glu or Gly.

Example compounds according to Formula (VII) include the following compounds:

(SEQ ID NO: 539)

c[Hydantoin(C(O)-(Nle-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 540)

c[Hydantoin(C(O)-(Ala-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 541)

c[Hydantoin(C(O)-(D-Ala-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 542)

c[Hydantoin(C(O)-(Aib-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 543)

c[Hydantoin(C(O)-(Val-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 544)

c[Hydantoin(C(O)-(Abu-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 545)

c[Hydantoin(C(O)-(Leu-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 546)

c[Hydantoin(C(O)-(Ile-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 547)

c[Hydantoin(C(O)-(Cha-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 548)

c[Hydantoin(C(O)-(A6c-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 549)

c[Hydantoin(C(O)-(Phe-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

(SEQ ID NO: 550)

c[Hydantoin(C(O)-(Gly-Cys))-D-Ala-His-D-Phe-Arg-Trp-Cys]-NH_2;

Or

(SEQ ID NO: 551)

c[Hydantoin(C(O)-(Gly-Cys))-Glu-His-D-Phe-Arg-Trp-Cys]-NH_2;

or pharmaceutically acceptable salts thereof.

In an example embodiment, the MC4R agonist useful for practicing the methods described herein is at least one compound according to Formula (VIII) (see International Patent Application Number PCT/US08/07411, incorporated herein by reference in its entirety):

$$(R^2R^3)\text{-}A^0\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \quad \text{(VIII)}$$

In Formual (VIII):

A^0 is an aromatic amino acid

A^1 is Acc, HN—$(CH_2)_m$—C(O), an L- or D-amino acid;

A^2 is Asp, Cys, D-Cys, hCys, D-hCys, Glu, Pen, or D-Pen;

A^3 is Aib, Ala, β-Ala, Gaba, Gly or a D-amino acid;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, (X^1, X^2, X^3, X^4, X^5)Phe, Taz, 2-Thi, or 3-Thi;

A^5 is D-Bal, D-1-Nal, D-2-Nal, D-Phe, L-Phe, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe, D-Trp or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN—CH($(CH_2)_n$—N(R^4R^5))—C(O);

A^7 is Bal, D-Bal, Bip, D-Bip, 1-Nal, D-1-Nal, 2-Nal, D-2-Nal, or D-Trp;

A^8 is Acc, Aha, Ahx, Ala, D-Ala, β-Ala, Apn, Gaba, Gly, HN—$(CH_2)_s$—C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Dab, Dap, Lys, Orn, Pen, or D-Pen;

A^{10} is Acc, HN—$(CH_2)_t$—C(O), L- or D-amino acid, or deleted;

R^1 is OH, or NH_2;

each of R^2 and R^3 is, independently for each occurrence selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl, and substituted aryl(C_1-C_{30})acyl;

each of R^4 and R^5 is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted $(C_2\text{-}C_{40})$alkenyl, substituted $(C_2\text{-}C_{40})$alkynyl, substituted aryl$(C_1\text{-}C_{40})$allyl, substituted aryl$(C_1\text{-}C_{40})$acyl, $(C_1\text{-}C_{40})$alkylsulfonyl, or —C(NH)—NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X^1, X^2, X^3, X^4, and X^5 each is, independently for each occurrence, H, F, Cl, Br, I, $(C_{1\text{-}10})$alkyl, substituted $(C_{1\text{-}10})$alkyl, $(C_{2\text{-}10})$alkenyl, substituted $(C_{2\text{-}10})$alkenyl, $(C_{2\text{-}10})$alkynyl, substituted $(C_{2\text{-}10})$alkynyl, aryl, substituted aryl, OH, NH_2, NO_2, or CN.

In example embodiments of Formual (VIII),

(I) when R^4 is $(C_1\text{-}C_{40})$acyl, aryl$(C_1\text{-}C_{40})$acyl, substituted $(C_1\text{-}C_{40})$acyl, substituted aryl$(C_1\text{-}C_{40})$acyl, $(C_1\text{-}C_{40})$alkylsulfonyl, or —C(NH)—NH_2, then R^5 is H or $(C_1\text{-}C_{40})$alkyl, $(C_1\text{-}C_{40})$heteroalkyl, $(C_2\text{-}C_{40})$alkenyl, $(C_2\text{-}C_{40})$alkynyl, aryl$(C_1\text{-}C_{40})$alkyl, substituted $(C_1\text{-}C_{40})$alkyl, substituted $(C_1\text{-}C_{40})$heteroalkyl, substituted $(C_2\text{-}C_{40})$alkenyl, substituted $(C_2\text{-}C_{40})$alkynyl, or substituted aryl$(C_1\text{-}C_{40})$alkyl;

(II) when R^2 is $(C_1\text{-}C_{30})$acyl, aryl$(C_1\text{-}C_{30})$acyl, substituted $(C_1\text{-}C_{30})$acyl, or substituted aryl$(C_1\text{-}C_{30})$acyl, then R^3 is H, $(C_1\text{-}C_{30})$alkyl, $(C_1\text{-}C_{30})$heteroalkyl, $(C_2\text{-}C_{30})$alkenyl, $(C_2\text{-}C_{30})$alkynyl, aryl$(C_1\text{-}C_{30})$alkyl, substituted $(C_1\text{-}C_{30})$alkyl, substituted $(C_1\text{-}C_{30})$heteroalkyl, substituted $(C_2\text{-}C_{30})$alkenyl, substituted $(C_2\text{-}C_{30})$alkynyl, or substituted aryl$(C_1\text{-}C_{30})$alkyl;

(III) when A^2 is Cys, D-Cys, hCys, D-hCys, Pen, or D-Pen, then A^9 is Cys, D-Cys, hCys, D-hCys, Pen, or D-Pen;

(IV) when A^2 is Asp or Glu, then A^9 is Dab, Dap, Orn, or Lys;

(V) when A^8 is Ala or Gly, then A^1 is not Nle; or pharmaceutically acceptable salts thereof.

In example embodiments of compoudns of Formula (VIII):

A^0 is 1-Nal, 2-Nal, H is, Pff, Phe, Trp, or Tyr;

A^1 is Arg;

A^2 is Cys;

A^3 is D-Ala;

A^4 is H is;

A^5 is D-Phe

A^6 is Arg;

A^7 is Trp

A^8 is deleted;

A^9 is Cys; and

A^{10} is deleted;

or pharmaceutically acceptable salts thereof.

Particular compounds of the immediately foregoing group of compounds are of the formula:

(SEQ ID NO: 552)

Ac-Tyr-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 553)

Ac-2-Nal-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 554)

Ac-1-Nal-Arg-c(Cys-D-Ala-His-DPhe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 555)

Ac-Phe-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 556)

Ac-Trp-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 557)

Ac-Pff-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

(SEQ ID NO: 558)

H-His-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

or

(SEQ ID NO: 559)

Ac-His-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2;

or a pharmaceutically acceptable salt thereof.

In one example embodiment, the MC4R agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140) or a pharmaceutically acceptable salt thereof. In another example embodiment, the MC4R agonist is Hydantoin(C(O)-(Arg-Gly))-c(Cys-Glu-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 500) or a pharmaceutically acceptable salt thereof.

In some embodiments, the MC4R agonist is an agonist described in WO2014/144260 A1, incorporated herein by reference. Administration of a compound or pharmaceutically acceptable salt thereof or a composition comprising a compound or pharmaceutical salt of a compound of the invention useful to practice the methods described herein, can be continuous, hourly, four times daily, three time daily, twice daily, once daily, once every other day, twice weekly, once weekly, once every two weeks, once a month, or once every two months, or longer or some other intermittent dosing regimen.

Examples of administration of a compound or composition comprising a compound or pharmaceutical salt of a compound of the invention include peripheral administration. Examples of peripheral administration include oral, subcutaneous, intraperitoneal, intramuscular, intravenous, rectal, transdermal or intranasal forms of administration.

As used herein, peripheral administration can include all forms of administration of a compound or a composition comprising a compound of the instant invention which excludes intracranial administration. Examples of peripheral administration include, but are not limited to, oral, parenteral (e.g., intramuscular, intraperitoneal, intravenous or subcutaneous injection, extended release, slow release implant, depot and the like), nasal, vaginal, rectal, sublingual or topical routes of administration, including transdermal patch applications and the like.

The nomenclature used to define the peptides is that typically used in the art wherein the amino group at the N-terminus appears to the left and the carboxyl group at the C-terminus appears to the right. Where the amino acid has D and L isomeric forms, it is the L form of the amino acid that is represented unless otherwise explicitly indicated.

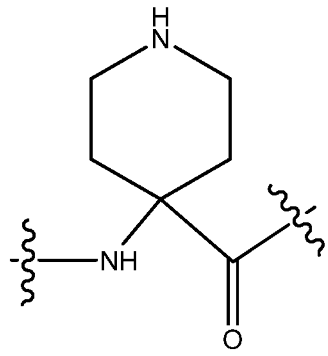
The compounds of the invention useful for practicing the methods described herein may possess one or more chiral centers and so exist in a number of stereoisomeric forms. All stereoisomers and mixtures thereof are included in the scope of the present invention. Racemic compounds may either be separated using preparative HPLC and a column with a chiral stationary phase or resolved to yield individual enantiomers utilizing methods known to those skilled in the art. In addition, chiral intermediate compounds may be resolved and used to prepare chiral compounds of the invention.

The compounds described herein may exist in one or more tautomeric forms. All tautomers and mixtures thereof are included in the scope of the present invention. For example, a claim to 2-hydroxypyridinyl would also cover its tautomeric form, α-pyridonyl.

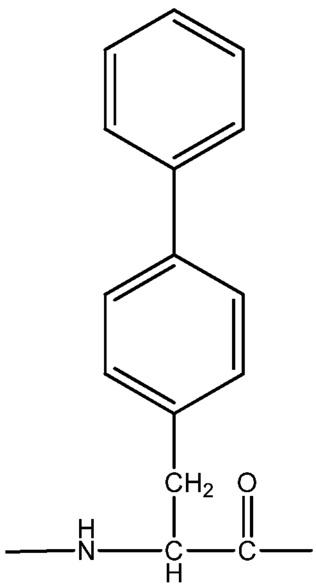
Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Also, all publications, patent applications, patents and other references mentioned herein are incorporated by reference in their entirety.

Symbol	Meaning
Abu	α-aminobutyric acid
Ac	acyl group
Acc	1-amino-1-cyclo(C_3-C_9)alkyl carboxylic acid
A3c	1-amino-1cyclopropanecarboxylic acid
A4c	1-amino-1-cyclobutanecarboxylic acid
A5c	1-amino-1-cyclopentanecarboxylic acid
A6c	1-amino-1-cyclohexanecarboxylic acid
Aha	7-aminoheptanoic acid
Ahx	6-aminohexanoic acid
Aib	α-aminoisobutyric acid
Aic	2-aminoindan-2-carboxylic acid
Ala or A	Alanine
β-Ala	β-alanine

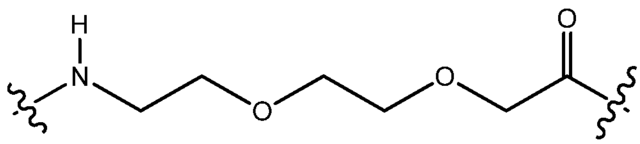
Apc	denotes the structure:



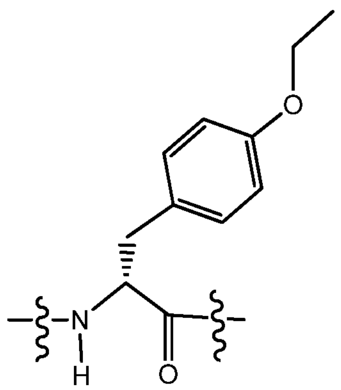
Apn	5-aminopentanoic acid (HN—(CH2)$_4$—C(O)
Arg or R	Arginine
hArg	Homoarginine
Asn or N	Asparagine
Asp or D	aspartic acid
Bal	3-benzothienylalanine
Bip	4,4'-biphenylalanine, represented by the structure



Bpa	4-benzoylphenylalanine
4-Br-Phe	4-bromo-phenylalanine
Cha	β –cyclohexylalanine
hCha	homo-cyclohexylalanine
Chg	Cyclohexylglycine

Cys or C	Cysteine
hCys	Homocysteine
Dab	2,4-diaminobutyric acid
Dap	2,3-diaminopropionic acid
Dip	β,β-diphenylalanine
Doc	8-amino-3,6-dioxaoctanoic acid with the structure of: 
2-Fua	β-(2-furyl)-alanine
Gaba	4-aminobutyric acid
Gln or Q	Glutamine
Glu or E	glutamic acid
Gly or G	Glycine
His or H	Histidine
3-Hyp	trans-3-hydroxy-L-proline, i.e., (2S,3S)-3-hydroxy-pyrrolidine-2-carboxylic acid
4-Hyp	4-hydroxyproline, i.e., (2S,4R)-4-hydorxypyrrolidine-2-carboxylic acid
Ile or 1	Isoleucine
Leu or L	Leucine
hLeu	Homoleucine
Lys or K	Lysine
Met or M	Methionine
β-hMet	β-homomethionine
1-Nal	β-(1-naphthyl)alanine
2-Nal	β-(2-naphthyl)alanine
Nip	nipecotic acid
Nle	Norleucine
Ole	octahydroindole-2-carboxylic acid
Orn	Ornithine

2-Pal	β-(2-pyridiyl)alanine
3-Pal	β-(3-pyridiyl)alanine
4-Pal	β-(4-pyridiyl)alanine
Pen	Penicillamine
Pff	(S)-pentafluorophenylalanine
Phe or F	Phenylalanine
hPhe	homophenylalanine
Pro or P	Proline
hProP	Homoproline
Ser or S	Serine
Tle	tert-Leucine
Taz	β-(4-thiazolyl)alanine
2-Thi	β-(2-thienyl)alanine
3-Thi	β-(3-thienyl)alanine
Thr or T	Threonine
Trp or W	Tryptopham
Tyr or Y	Tyrosine
D-(Et) Tyr	has a structure of



Val or V	Valine

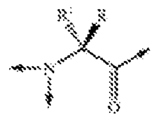
Certain other abbreviations used herein are defined as follows:

Boc:	tert-butyloxycarbonyl
Bzl:	Benzyl

DCM:	Dichloromethane
DIC:	N,N-diisopropylcarbodiimide
DIEA:	diisopropylethyl amine
Dmab:	4-{N-(1-(4,4-dimethyl-2,6-dioxocyclohexylidene)-3-methylbutyl)-amino}benzyl
DMAP:	4-(dimethylamino)pyridine
DMF:	Dimethylformamide
DNP:	2,4-dinitrophenyl
Fm:	Fluorenylmethyl
Fmoc:	fluorenylmethyloxycarbonyl
For:	Formyl
HBTU:	2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate
cHex	Cyclohexyl
HOAT:	O-(7-azabenzotriazol-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate
HOBt:	1-hydroxy-benzotriazole
MBNA	4-methylbenzhydrylamine
Mmt:	4-methoxytrityl
NMP:	N-methylpyrrolidone
O-tBu	oxy-tert-butyl
Pbf:	2,2,4,6,7-pentamethyldihydrobenzofuran-5-sulfonyl
PyBroP	bromo-tris-pyrrolidino-phosphonium hexafluorophosphate
tBu:	tert-butyl
TIS:	triisopropylsilane
TOS:	Tosyl
Trt	Trityl
TFA:	trifluoro acetic acide
TFFH:	tetramethylfluoroforamidiaium hexafluorophosphate
Z:	benzyloxycarbonyl

Unless otherwise indicated, with the exception of the N-terminal amino acid, all abbreviations (e.g. Ala) of amino acids in this disclosure stand for the structure of -NH-C(R)(R′)-CO-, wherein R and R′ each is, independently, hydrogen or the side chain of an amino acid (e.g., R=CH_3 and R′=H for Ala), or R and R′ may be joined to form a ring system.

For the N-terminal amino acid, the abbreviation stands for the structure of:



The designation "NH_2" in e.g., Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO:13), indicates that the C-terminus of the peptide is amidated. Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys) (SEQ ID NO:107), or alternatively Ac-Nle-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-OH (SEQ ID NO:107), indicates that the C-terminus is the free acid.

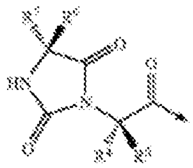
"-c(Cys-Cys)-" or "-cyclo(Cys-Cys)-" denotes the structure:

"-c(Cys-Pen)-" or "-cyclo(Cys-Pen)-" denotes the structure:

"-c(Asp-Lys)-" or "-cyclo(Asp-Lys)-" denotes the structure:

Applicants have devised the following shorthand used in naming the specific embodiments and/or species:

"Hydantoin-(C(O)-(A^a-A^b))" denotes the structure:



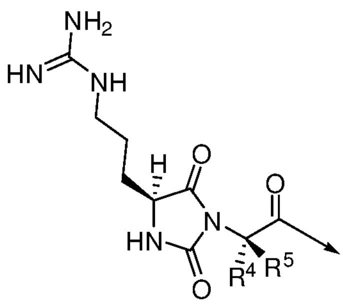
.

wherein amino acid "A^{a}" has the structure:

and amino acid "A^{b}" the structure:

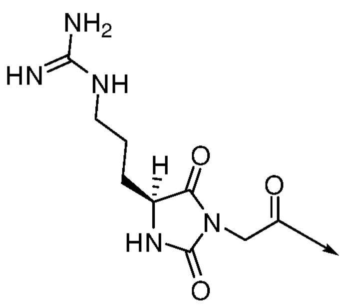
.

For example, "Hydantoin-(C(O)-Arg-A^{b}))" would have the following structure:



.

For example, "Hydantoin-(C(O)-(Arg-Gly))" would have the following structure:



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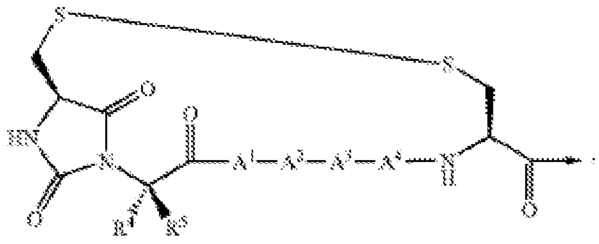
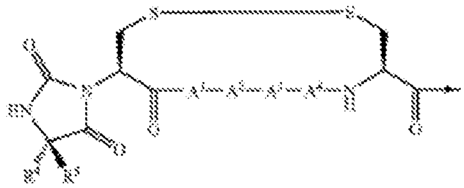
For example, a compound represented as "c[Hydantoin(C(O)-(Cys-A^{b}))-A^{1}-A^{2}-A^{3}-A^{4}-Cys]-" would have the following the structure:



whereas a compound represented as "c[Hydantoin(C(O)-(A^b-Cys))-A^1-A^2-A^3-A^4-Cys]-" would have the structure:



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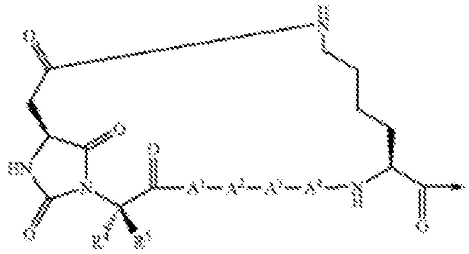
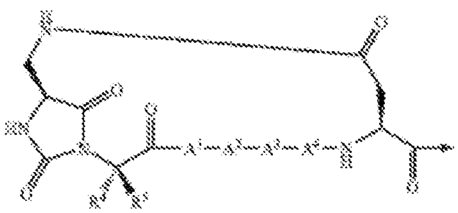
For further guidance, "c[Hydantoin(C(O)-(Asp-A^b))-A^1-A^2-A^3-A^4-Lys]-" represents the following compound:



,

whereas "c[Hydantoin(C(O)-(Dap-A^b))-A^1-A^2-A^3-A^4-Asp]-" has the following formula:



.

"Acyl" refers to R″-C(O)-, where R″ is H, alkyl, substituted alkyl, heteroalkyl, substituted heteroalkyl, alkenyl, substituted alkenyl, aryl, alkylaryl, or substituted alklyaryl, and is indicated in the general formula of a particular embodiment as "Ac".

"Alkyl" refers to a hydrocarbon group containing one or more carbon atoms, where multiple carbon atoms if present are joined by single bonds. The alkyl hydrocarbon group may be straight-chain or contain one or more branches or cyclic groups.

"Hydroxyalkyl" refers to an alkyl group wherein one or more hydrogen atoms of the hydrocarbon group are substituted with one or more hydroxy radicals, such as hydroxymethyl, hydroxyethyl, hydroxypropyl, hydroxybutyl, hydroxypentyl, hydroxyhexyl and the like.

"Substituted alkyl" refers to an alkyl wherein one or more hydrogen atoms of the hydrocarbon group are replaced with one or more substituents selected from the group consisting of halogen, (i.e., fluorine, chlorine, bromine, and iodine), -OH, -CN, -SH, amine (e.g., $-NH_2$, $-NHCH_3$), $-NO_2$, guanidine, urea, amidine, and $-C_{1-20}$ alkyl, wherein said $-C_{1-20}$ alkyl optionally may be substituted with one or more substituents selected, independently for each occurrence, from the group consisting of halogens, $—CF_3$, $—OCH_3$, $—OCF_3$, and $-(CH_2)_{0-20}$-COOH. In different embodiments 1, 2, 3 or 4 substituents are present. The presence of $-(CH_2)_{0-20}$-COOH results in the production of an alkyl acid. Non-limiting examples of alkyl acids containing, or consisting of, $-(CH_2)_{0-20}$-COOH include 2-norbornane acetic acid, tert-butyric acid, 3-cyclopentyl propionic acid, and the like.

The term "halo" encompasses fluoro, chloro, bromo and iodo.

Guanidines are a group of organic compounds that share a common functional group with the general structure $(R^1R^2N)(R^3R^4N)C=N-R^5$. The central bond within this group is an imine, and the group is related structurally to amidines and ureas.

"Heteroalkyl" refers to an alkyl wherein one of more of the carbon atoms in the hydrocarbon group is replaced with one or more of the following groups: amino, amido, —O—, —S— or carbonyl. In different embodiments 1 or 2 heteroatoms are present.

"Substituted heteroalkyl" refers to a heteroalkyl wherein one or more hydrogen atoms of the hydrocarbon group are replaced with one or more substituents selected from the group consisting of halogen, (i.e., fluorine, chlorine, bromine, and iodine), -OH, —CN, —SH, $—NH_2$, $—NHCH_3$, $—NO_2$, and $-C_{1-20}$ alkyl, wherein said $-C_{1-20}$ alkyl optionally may be substituted with one or more substituents selected, independently for each occurrence, from the group consisting of halogens, $—CF_3$, $-OCH_3$, $-OCF_3$, and $-(CH_2)_{0-20}$-COOH. In different embodiments 1, 2, 3 or 4 substituents are present.

"Alkenyl" refers to a hydrocarbon group made up of two or more carbons where one or more carbon-carbon double bonds are present. The alkenyl hydrocarbon group may be straight-chain or contain one or more branches or cyclic groups.

"Substituted alkenyl" refers to an alkenyl wherein one or more hydrogens are replaced with one or more substituents selected from the group consisting of halogen (i.e., fluorine, chlorine, bromine, and iodine), —OH, —CN, —SH, —NH_2, —$NHCH_3$, —NO_2, and —C_{1-20} alkyl, wherein said —C_{1-20} alkyl optionally may be substituted with one or more substituents selected, independently for each occurrence, from the group consisting of halogens, —CF_3, —OCH_3, —OCF_3, and —$(CH_2)_{0-20}$—COOH. In different embodiments 1, 2, 3 or 4 substituents are present.

"Aryl" refers to an optionally substituted aromatic group with at least one ring having a conjugated pi-electron system, containing up to three conjugated or fused ring systems. Aryl includes carbocyclic aryl, heterocyclic aryl and biaryl groups. Preferably, the aryl is a 5- or 6-membered ring. Preferred atoms for a heterocyclic aryl are one or more sulfur, oxygen, and/or nitrogen. Non-limiting examples of aryl include phenyl, 1-naphthyl, 2-naphthyl, indole, quinoline, 2-imidazole, 9-anthracene, and the like. Aryl substituents are selected from the group consisting of —C_{1-20} alkyl, —C_{1-20} alkoxy, halogen (i.e., fluorine, chlorine, bromine, and iodine), —OH, —CN, —SH, —NH_2, -NO_2, —C_{1-20} alkyl substituted with halogens, —CF_3, —OCF_3, and —$(CH_2)_{0-20}$—COOH. In different embodiments the aryl contains 0, 1, 2, 3, or 4 substituents.

"Alkylaryl" refers to an "alkyl" joined to an "aryl".

The term "(C_{1-12})hydrocarbon moiety" encompasses alkyl, alkenyl and alkynyl and in the case of alkenyl and alkynyl there is C_2-C_{12}.

For the avoidance of doubt, unless otherwise indicated, the term substituted means substituted by one or more defined groups. In the case where groups may be selected from a number of alternative groups, the selected groups may be the same or different. For the avoidance of doubt, the term independently means that where more than one substituent is selected from a number of possible substituents, those substituents may be the same or different.

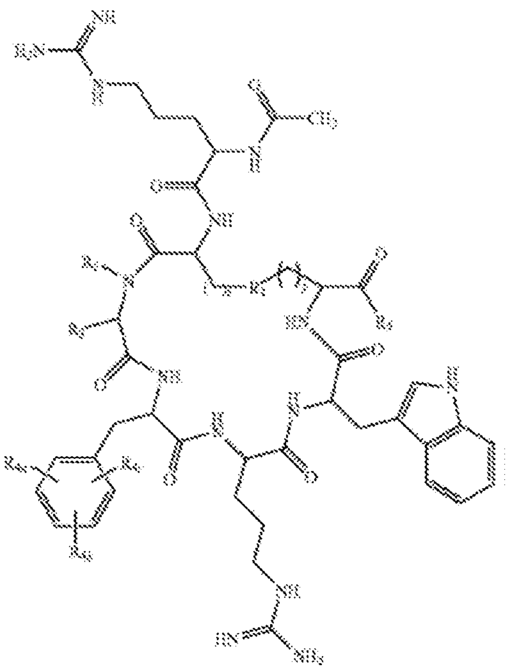
The pharmaceutically acceptable salts of the compounds of the invention which contain a basic center are, for example, non-toxic acid addition salts formed with inorganic acids such as hydrochloric, hydrobromic, hydroiodic, sulfuric and phosphoric acid, with carboxylic acids or with organo-sulfonic acids. Examples include the HCl, HBr, HI, sulfate or bisulfate, nitrate, phosphate or hydrogen phosphate, acetate, benzoate, succinate, saccharate, fumarate, maleate, lactate, citrate, tartrate, gluconate, camsylate, methanesulfonate, ethanesulfonate, benzenesulfonate, p-toluenesulfonate and pamoate salts. Compounds of the invention can also provide pharmaceutically acceptable metal salts, in particular non-toxic alkali and alkaline earth metal salts, with bases. Examples include the sodium, potassium, aluminum, calcium, magnesium, zinc and diethanolamine salts (Berge, S. M. *et al., J. Pharm. Sci.*, 66:1-19 (1977); Gould, P. L., *Int'l J. Pharmaceutics*, 33:201-17 (1986); and Bighley, L. D. *et al.*, *Encyclo. Pharma. Tech* ., Marcel Dekker Inc, New York, 13:453-97 (1996).

The pharmaceutically acceptable solvates of the compounds of the invention include the hydrates thereof. Also included within the scope of the invention and various salts of the invention are polymorphs thereof. Hereinafter, compounds their pharmaceutically acceptable salts, their solvates or polymorphs, defined in any aspect of the invention (except intermediate compounds in chemical processes) are referred to as "compounds of the invention".

Designation "(amino acid)$_n$" means that an amino acid is repeated *n* times. For example, designation "(Pro)$_2$" or "(Arg)$_3$" mean that proline or arginine residues are repeated, respectively, two or three times.

MC4R agonists and pharmaceutically acceptable salts thereof described herein can also be used to treat individuals, including human subjects sdefective melanocortin receptor signaling, due to mutations/defects upstream of the MC4R. MC4R agonists and pharmaceutically acceptable salts thereof described herein can also be used to treat individuals, including human subjects that carry mutations in the genes coding for pro-opiomelanocortin (POMC) and leptin such that these mutations result in POMC haplo-insufficientcy or haplo-deficiency and/or leptin haplo-insufficiency or haplo-deficiency.

In one example embodiment, an MC4R agonist is a compound represented by structural formula (X):



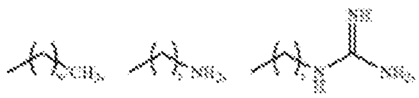
(X)

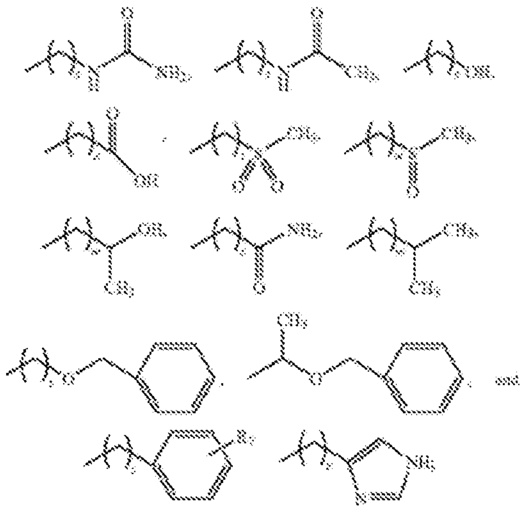
or a pharmaceutically acceptable salt thereof. In structural formula (X), the chemical substituents are defined as follows:

R_1 is –NH-C(O)- or –C(O)-NH-;

R_2 is –H, $–CH_2$-, or, R_2 , together with R_3, forms a pyrrolidine ring optionally substituted with –OH;

R_3 is $–(CH_2)_2$- if R_2 is $–CH_2$-, and otherwise R_3 is selected from





;

R_{4a}, R_{4b}, and R_{4c} are each independently selected from hydrogen, halo, (C_1-C_{10})alkyl-halo, (C_1-C_{10})alkyl-dihalo, (C_1-C_{10})alkyl-trihalo, (C_1-C_{10})alkyl, (C_1-C_{10})alkoxy, (C_1-C_{10})alkylthio, aryl, aryloxy, nitro, nitrile, sulfoniamide, amino, hydroxyl, carboxy, and akoxy-carbonyl. In one example embodiment, R_{4a}, R_{4b}, and R_{4c} is not hydrogen.

R_5 is –OH or –N(R_{6a})(R_{6b});

R_{6a} and R_{6b} are each independently H or C_1 to C_4 linear, branched or cyclic alkyl chain;

R_7 is –H or –C(O)-NH_2;

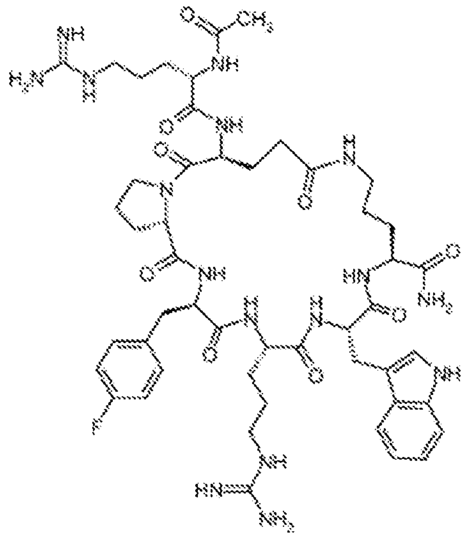
w is in each instance independently 0 to 5;

x is 1 to 5;

y is 1 to 5;

z is in each instance independently 1 to 5.

An example of a compound of structural formula (X) is a cyclic peptide defined by structural formula (XI):



(XI),

or a pharmaceutically acceptable salt thereof.

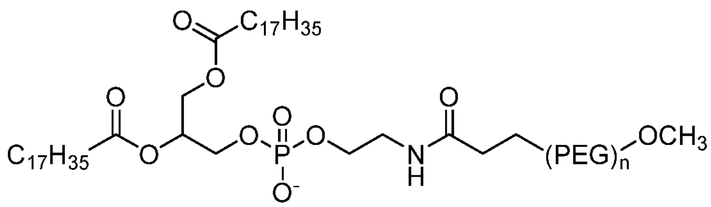
Pharmaceutical compositions/Administration

In accordance with any method or composition described herein, in embodiments, provided herein is a unit dosage of a MC4R agonist described herein, e.g., setmelanotide. In embodiments, the unit dosage contains 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist. In embodiments, the unit dosage is suitable for injection, e.g., subcutaneous injection. In embodiments, the unit dosage is disposed in a delivery device suitable for injection, e.g., subcutaneous injection. In embodiments, the unit dosage is disposed in a syringe suitable for injection, e.g., subcutaneous injection, or a pen-type injector. Exemplary pen-type injectors are described, e.g., in US 8512297B2, US5688251A, US5820602A, US2014/0163526A1, and US5226895A, incorporated herein by reference.

In embodiments, also provided herein is a pharmaceutical composition comprising a MC4R agonist described herein, e.g., setmelanotide. In embodiments, the pharmaceutical composition includes a therapeutically effective amount of a MC4R agonist described herein, e.g., setmelanotide. A therapeutically effective amount of the agonist can vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the agonist to elicit a desired response in the individual, *e.g.,* amelioration of at least one disorder parameter, *e.g.,* a parameter of obesity or hyperphagia, or amelioration of at least one symptom of the disorder, *e.g.,* obesity, hyperphagia, Prader Willi Syndrome (PWS), or other obesity-associated genetic disorder (e.g., POMC-null or PCSK1-null obesity, among others). In embodiments, a therapeutically effective amount is also one in which any toxic or a detrimental effect of the composition is outweighed by the therapeutically beneficial effects.

In certain embodiments, the agonist may be prepared with a carrier that will protect it against rapid release, such as a controlled release formulation, including implants, and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Many methods for the preparation of such formulations are patented or generally known. See, *e.g.,* Sustained and Controlled Release Drug Delivery Systems, J. R. Robinson, ed., Marcel Dekker, Inc., New York, 1978.

In other embodiments, the agonist can be prepared as described in WO2014/144842, incorporated herein by reference. In embodiments, the agonist is prepared in a formulation comprising an anionic excipient, e.g., PEG-carboxylic acid, fatty acid having 10 or more carbon atoms, and/or anionic phospholipid. In embodiments, the anionic phospholipid is described in WO2014/144842 (e.g., at pages 7-9). In some embodiments, the anionic phospholipid is 1,2-distearoyl-sn-Glycero-3-Phosphoethanolamine (DSPE), optionally conjugated to polyethylene glycol (PEG), the structure of which is:



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with the value of "n" varying with molecular weight. In emboidments, the fatty acid is described in WO2014/144842 (e.g., at page 9). In embodiments, the PEG-carboxylic acid is described in WO2014/144842 (e.g., at pages 9-11). In embodiments, the molar ratio of the agonist to the anionic excipient ranges from about 1:1 to about 1:10.

In embodiments, the agonist forms an ionic complex with the other components of the formulation, and e.g., provides a desirable pharmacokinetic profile for the agonist (e.g., extend duration of drug action and/or minimize adverse effects). In embodiments, the formulation is a sustained release formulation. In embodiments, the formulation provides reduced fluctuations in concentration of the agonist after administration.

A MC4R agonist described herein, e.g., setmelanotide, can be administered to a subject, e.g., human subject, by various methods. In embodiments, the route of administration is one of: intravenous injection or infusion, subcutaneous injection, or intramuscular injection. In embodiments, the route of administration is subcutaneous injection.

In embodiments, pharmaceutical compositions, e.g., comprising a MC4R agonist described herein, can be administered with medical devices. For example, compositions comprising the agonist can be administered with a needleless hypodermic injection device, such as the devices disclosed in U.S. Pat. No. 5,399,163, 5,383,851, 5,312,335, 5,064,413, 4,941,880, 4,790,824, or 4,596,556. Examples of implants and modules include: U.S. Pat. No. 4,487,603, which discloses an implantable micro-infusion pump for dispensing medication at a controlled rate; U.S. Pat. No. 4,486,194, which discloses a therapeutic device for administering medicaments through the skin; U.S. Pat. No. 4,447,233, which discloses a medication infusion pump for delivering medication at a precise infusion rate; U.S. Pat. No. 4,447,224, which discloses a variable flow implantable infusion apparatus for continuous drug delivery; U.S. Pat. No. 4,439,196, which discloses an osmotic drug delivery system having multi-chamber compartments; and U.S. Pat. No. 4,475,196, which discloses an osmotic drug delivery system. Other such implants, delivery systems, and modules can also be used.

In embodiments, continuous administration can be indicated, e.g., via subcutaneous pump. In embodiments, the agonist is administered via a syringe (e.g., prefilled syringe), an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

In embodiments, the agonist is administered at a unit dosage, e.g., comprising 0.1-10 mg, e.g., 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10 mg of the agonist, e.g., subcutaneously.

In embodiments, the agonist is adminsiterd in a bolus at a dose of between 0.1-10 mg, e.g., 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10 mg of the agonist, e.g., subcutaneously.

In embodiments, the agonist is administered continuously, e.g., via a pump, e.g., subcutaneous pump.

In embodiments, the agonist, e.g., a unit dosage of the agonist, is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe), an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

In embodiments, a daily dosage of the agonist is administered, e.g., subcutaneously, to a subject. In embodiments, the daily dosage of the agonist is about 0.1 mg to about 10 mg, e.g., 0.1-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1, 1-1.2, 1.2-1.5, 1.5-2, 2-2.5, 2.5-3, 3-3.5, 3.5-4, 4-4.5, 4.5-5, 5-5.5, 5.5-6, 6-6.5, 6.5-7, 7-7.5, 7.5-8, 8-8.5, 8.5-9, 9-9.5, 9.5-10 mg, e.g., administered subcutaneously.

In embodiments, the agonist, e.g., setmelanotide, is administered, e.g., via one or multiple administrations, over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more. In embodiments, where multiple administrations are provided of the agonist, the time interval in between any two of the administrations is at least 6 hours, e.g., 6 h, 12 h, 24 h, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days, 1 week, 2 weeks, 3 weeks, 4 weeks, or more. In embodiments, the interval in between any two of the administrations is 1 day.

Kits

A MC4R agonist described herein, e.g., setmelanotide, can be provided in a kit. The kit includes a MC4R agonist described herein and, optionally, a container, a pharmaceutically acceptable carrier and/or informational material. The informational material can be descriptive, instructional, marketing or other material that relates to the methods described herein and/or the use of the agonist for the methods described herein.

The informational material of the kits is not limited in its form. In one embodiment, the informational material can include information about production of the agonist, physical properties of the agonist, concentration, date of expiration, batch or production site information, and so forth. In one embodiment, the informational material relates to methods for administering the agonist, *e.g.,* by a route of administration described herein and/or at a dose and/or dosing schedule described herein.

In one embodiment, the informational material can include instructions to administer an agonist described herein in a suitable manner to perform the methods described herein, *e.g.,* in a suitable dose, dosage form, or mode of administration (*e.g.,* a dose, dosage form, or mode of administration described herein). In another embodiment, the informational material can include instructions to administer an agonist to a suitable subject, *e.g.,* a human, *e.g.,* an obese human, e.g., severely obese human, e.g., having PWS or a genetic defect in one or more genes of the POMC-MC4R pathway.

The informational material of the kits is not limited in its form. In many cases, the informational material, *e.g.,* instructions, is provided in printed matter, *e.g.,* a printed text, drawing, and/or photograph, *e.g.,* a label or printed sheet. However, the informational material can also be provided in other formats, such as Braille, computer readable material, video recording, or audio recording. In another embodiment, the informational material of the kit is contact information, *e.g.,* a physical address, email address, website, or telephone number, where a user of the kit can obtain substantive information about an agonist described herein and/or its use in the methods described herein. The informational material can also be provided in any combination of formats.

In addition to an agonist, the composition of the kit can include other ingredients, such as a surfactant, a lyoprotectant or stabilizer, an antioxidant, an antibacterial agent, a bulking agent, a chelating agent, an inert gas, a tonicity agent and/or a viscosity agent, a solvent or buffer, a stabilizer, a preservative, a pharmaceutically acceptable carrier and/or a second agent for treating a condition or disorder described herein. Alternatively, the other ingredients can be included in the kit, but in different compositions or containers than an agonist described herein.

In some embodiments, a component of the kit is stored in a sealed vial, *e.g.,* with a rubber or silicone closure (*e.g.,* a polybutadiene or polyisoprene closure). In some embodiments, a component of the kit is stored under inert conditions (*e.g.,* under Nitrogen or another inert gas such as Argon). In some embodiments, a component of the kit is stored under anhydrous conditions (*e.g.,* with a desiccant). In some embodiments, a component of the kit is stored in a light blocking container such as an amber vial.

An agonist described herein can be provided in any form, *e.g.,* liquid, frozen, dried or lyophilized form. It is preferred that a composition including the agonist described herein be substantially pure and/or sterile. When an agonist described herein such as setmelanotide is provided in a liquid solution, the liquid solution preferably is an aqueous solution, with a sterile aqueous solution being preferred. In one embodiment, the agonist is supplied with a diluents or instructions for dilution. The diluent can include for example, a salt or saline solution, *e.g.,* a sodium chloride solution having a pH between 6 and 9, lactated Ringer's injection solution, D5W, or PLASMA-LYTE A Injection pH 7.4® (Baxter, Deerfield, IL).

The kit can include one or more containers for the composition containing an agonist described herein. In some embodiments, the kit contains separate containers, dividers or compartments for the composition and informational material. For example, the composition can be contained in a bottle, vial, IV admixture bag, IV infusion set, piggyback set or syringe (e.g., prefilled syringe), and the informational material can be contained in a plastic sleeve or packet. In other embodiments, the separate elements of the kit are contained within a single, undivided container. For example, the composition is contained in a bottle, vial or syringe that has attached thereto the informational material in the form of a label. In embodiments, the composition is contained in an injector device, e.g., a pen-type injector. The containers of the kits can be air tight, waterproof (*e.g.,* impermeable to changes in moisture or evaporation), and/or light-tight.

EXAMPLES

The invention is further described in detail by reference to the following experimental examples. These examples are provided for purposes of illustration only, and are not intended to be limiting unless otherwise specified. Thus, the invention should in no way be construed as being limited to the following examples, but rather, should be construed to encompass any and all variations which become evident as a result of the teaching provided herein.

Without further description, it is believed that one of ordinary skill in the art can, using the preceding description and the following illustrative examples, make and utilize the compounds of the present invention and practice the claimed methods. The following working examples specifically point out various aspects of the present invention, and are not to be construed as limiting in any way the remainder of the disclosure.

Example 1: Treatment with a melanocortin-4 Receptor (MC4R) agonist in a POMC deficient patient with severe obesity and hyperphagia

Patients with POMC gene defects, such as POMC loss of function mutations, suffer from severe early onset obesity, hyperphagia, red hair, adrenal insufficiency, and ACTH deficiency. It is believed that the early onset obesity and hyperphagia is caused by a deficiency of POMC-derived peptides, such as MSH and ACTH, which are ligands to melanocortin receptors. MSH, a cleavage product of POMC, is the ligand of the hypothalamic MC4R, which is important for regulating feeding behavior and energy homeostasis. There is a need for a targeted replacement therapy for patients with genetic defects of the leptin-melanocortin pathway, such as patients with POMC loss of function mutations.

This example describes a study in which an adult POMC deficient patient was administered the MC4R agonist, setmelanotide (also called RM-493), having the sequence, Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140). See, e.g., Chen et al. J. Clin. Endocrinol. Metab. 2015;100:1639-45. The study was an investigator initiated, open label, phase 2, non-randomized proof of concept study (EudraCT No. 2014-002392-28; Clinical Trials Identifier No. NCT02507492) with three parts: pre-study evaluation, main study (about 13 weeks) and after a short interval off drug, a long-term extension phase.

In the pre-study period, baseline examinations were performed, including analysis of metabolic parameters, including OGTT, GnRH test, fasting blood glucose, Leptin measurements as well as bioelectrical impedance analysis (BIA, according standard protocols; Data-in, Nutriguard-MS), indirect calorimetry (CareFusion, VMAX® Encore system), heart rate and blood pressure monitoring (after the first injection and after each dosage escalation blood pressure was measured regularly over 12 hours; in addition, blood was measured at home 3 times daily) as well as a dermatological and psychological examination. All parameters were in the normal range with the exception of elevated fasting insulin reflecting insulin resistance. These measurements were repeated after 13 and 26 weeks of treatment. Baseline examination also included physical examination, e.g., measurement of height and body-weight. Setmelanotide treatment was started at a dose of 0.25 mg subcutaneously (s.c.) once daily. The dose escalated every 1-2 weeks after careful assessment of safety and weight loss. After the first injection and after each dosage escalation, blood pressure was measured regularly over 12 hours. In addition, blood was measured 3 times daily. Setmelanotide injections were given once a day.

After about 90 days of treatment (main study), assessments were repeated, including assessments of metabolic parameters, e.g., blood tests, skin examination, and psychological evaluation. Setmelanotide treatment was ended, and a rapid and large weight gain off-treatment was observed. Subsequently, setmelanotide treatment was continued for another 3 months (extension phase) along with continued assessments (of metabolic parameters). The hunger score was evaluated using a Likert hunger scale from 0 to 10 points (0=no hunger; 10=severe hunger). See, e.g., Sibilia. Psychologicol Topics 19 (2010), 2, 341-354.

Bioelectric Impedance Analysis (BIA) and indirect calorimetric analysis was performed according standard protocols, e.g., as described in Barak et al. JPEN J. Parenter. Enteral Nutr. 27.1(2003):43-6; and Compher et al. J. Am. Diet Assoc. 106.6(2006):881-903.

Statistical analysis: The values of systolic and diastolic blood pressure and heart rate were analyzed with a non-parametric student t-test.

MAINTAIN control group: The Maintain-Z-Project is a randomized controlled trial (ClinicalTrials.gov: NCT00850629) analyzing the effects of a multimodal lifestyle intervention on weight maintenance after weight loss of children and adolescents. The primary outcome was to describe the dynamic of hormonal and metabolic mechanisms counter-balancing sustained weight loss during puberty and adolescence. 147 participants reached the initial weight reduction of -0.2 BMI-standard deviation score (SDS) (weight reduction phase last in average 15.7 ± 5.2 standard deviation (SD) weeks). Out of this study-cohort, 12 girls with extreme, but not monogenetic obesity (age 16.5 ± 0.6 SD years; BMI 38.8 ± 2.5 SD kg/m²) were selected as control group for weight loss using the same study protocol (except GnRH-testing).

Results

Phenotype of the POMC deficient index patient

The patient was a 21 year old woman, with a compound heterozygous loss of function *POMC* gene mutation (p.Lys51Term g.A6851>T, p.Arg145ProfsX12 g.7134delG). See, e.g., Krude et al. Nat. Genet. 1998;19:155-7. Her older brother, who retrospectively was identified also as a carrier of compound heterozygous mutations, had died at 7 months of age due to liver failure caused by adrenal failure caused by a lack of adrenocorticotropic hormone (ACTH). As the patient was diagnosed with adrenal insufficiency early after birth, she was treated with hydrocortisone since she was three weeks old. After three months of age, development of obesity and severe hyperphagia was observed in the patient. At four years of age, a genetic analysis of the *POMC* gene in the patient identified a POMC gene defect. This was the first description of POMC loss of function mutation in humans.

Despite enormous efforts, where the patient received pharmacotherapy for adrenal insufficiency and received intense counseling for diet, exercise and behavioral appetite control, the patient was not able to stabilize her body-weight, except for brief periods of weight stabilization, during which she was never able to lose a substantial amount of body weight. In all cases of short-term weight loss, an immediate weight regain occurred in the patient. The extreme obesity resulted in moderate metabolic disturbances and a progressive distortion of her lower extremity, which necessitated severeal surgical orthopedic interventions. Similar to leptin deficient patients[1] (see, e.g., Farooqi et al. N. Engl. J. Med. 1999;341:879-84), her pubertal development stopped at tanner stage 2 and menarche was still missing at the age of 21 years. She was treated with L-Thyroxine (175 µg/day) because of elevated TSH serum levels (range: 6-15 mU/l) and with hydrocortisone replacement (at a dose of 12.7 $^{mg}/_{m^2}$ BSA)).

Body weight, Body composition and hunger score

At baseline (prior to treatment with setmelanotide), the body weight of the patient was 155 kg with a height of 176.5 cm (BMI 49.8 $^{kg}/_{m^2}$; BMI standard deviation score (SDS) + 4.52). At baseline, the patient was severely hyperphagic: her Likert hunger scale score was 9 out of 10 points (extreme hunger). Psychological evaluation constantly revealed extreme discomfort with her quality of life due to extreme obesity.

Weight Loss and Change in Hunger Scores

Setmelanotide was given subcutaneously once daily with a dose escalation starting with a low dose of 0.25 mg and weekly increments to 0.5 mg, 1.0 mg and finally 1.5 mg. Initially, with low dosage, the weight loss was moderate with only little changes in hunger. However, with increasing dosage, the patient noticed a clear reduction of hunger with 1 mg setmelanotide (5 out of 10 points), and her appetite was nearly completely abolished at the 1.5 mg dose (0 to 1 out of 10 points; no hunger). With this change in satiety, she reached a constant rate of weight loss of 2-3 kg per week at the 1.5 mg dose, leading to total weight loss of 25.8 kg after the first 13 weeks of treatment (16.7% of her initial body weight; end body weight 129.2 kg; BMI 41.5 kg/m2; BMI SDS + 3.86).

Due to regulatory obligations, the clinical trial with setmelanotide treatment was stopped after 13 weeks. Soon after, the patient recognized markedly increased hunger (Likert hunger score 7 points) and regained weight (4.8 kg). The patient developed an acute situational depression as a result of this reversal in clinical course, and for this reason therapy was restarted (after three weeks off drug). Immediately after restart of setmelanotide (1 mg for 4 weeks and 1.5 mg thereafter) hunger decreased again and weight loss recommenced. During this second treatment phase the patient lost approximately 1-2 kg per week and reached a total loss of 35.9 kg body weight after 26 weeks of treatment (23.2% of her initial body weight). The patient has continued to lose weight since then.and at 86 weeks of treatment has lost 60.5 kg of body weight. The patient remains responsive to the setmelanotide treatment.

Metabolism

Metabolic parameters and blood pressure were monitored. An oral glucose tolerance test was performed before the study start, after 13 weeks, and during the extension phase. During the study, the patient's blood glucose values remained always in the normal range (fasting and after glucose challenge). The pre-study elevated insulin levels demonstrating marked insulin resistance improved significantly under setmelanotide treatment.

Despite severe weight loss, the resting energy expenditure (REE)/kg lean body mass stayed relatively stable. This is in contrast to the significant reduction of REE after weight loss in common obese patients (see, e.g., Leibel et al. N Engl J Med 1995;332:621-8; Johannsen et al. J Clin Endocrinol Metab 2012;97:2489-96; Ebbeling et al. JAMA 2012;307:2627-34; and de Jonge et al. Obesity (Silver Spring) 2012;20:2384-9), which is thought to be one factor in regaining weight in normal obese patients. Also, in the POMC deficient subject, lean body mass was not greatly altered, and the reduction of body weight was mainly due to a loss of body-fat mass, which was accompanied by a significant decrease in serum leptin concentrations. Blood sugar values were relatively stable in all tests; insulin sensitivity improved significantly during the duration of setmelanotide treatment.

Cholesterol, HDL, LDL, and tryglyceride levels were also measured at 13 weeks and compared to baseline. HDL cholesterol and triglycerides did not change, while LDL cholesterol and total cholesterol were reduced, after a 13-week treatment with setmelanotide. Triglycerides, LDL and total cholesterol were further reduced after 26 weeks of treatment.

Blood pressure

Blood pressure (BP) and heart rate (HR) during the study were assessed. In this study, blood pressure (BP) and heart rate (HR) were measured three times per day and over 12 hours after start of the therapy and after each dosage escalation.

There was no increase in blood pressure during all steps of dose escalation (analyzed with non-parametric student t-test). There were significant decreases in systolic and diastolic BP as well as HR.

Safety and Tolerability of setmelanotide treatment

Generally, setmelanotide treatment was well tolerated. The patient reported infrequent dry mouth. In general, there were no changes in safety laboratories of clinical concern.

Conclusions

As demonstrated herein, setmelanotide resulted in substantial reduction of weight and decreased hunger without adverse events. This study represents the first successful treatment of a POMC deficient patient with a targeted replacement therapy (MSH replacement therapy) with setmelanotide. The therapy using setmelanotide completely reversed hyperphagia and normalized insulin resistance caused by the disturbed hypothalamic leptin-melanocortin pathway in the POMC deficient patient. Treatment with setmelanotide resulted in an exceptional and sustained weight loss and termination of the life-long existing hyperphagia. The significant and continuous reduction of body weight while on therapy, which indicates a complete reversibility of the severe obesity, was comparable to if not greater than the changes observed after leptin administration to leptin deficient individuals. Treatment using setmelanotide can permit a normal long-term outcome and improvement of quality of life for the patient, who, prior to treatment, was at risk for severe comorbidities and a reduced life-expectancy.

In this study, the strong treatment effect was strongly supported by the long history of weight gain and severe hyperphagia prior to treatment. In addition, there was a strong dose-response for both hunger and weight loss in the dose escalation phase. The stopping of treatment in between the main study (first 13 weeks) and the extension phase allowed the patient to serve as her own “control”. There was an immediate and rapid increase in hunger and weight after a short term withdrawal and a rapid response to re-treatment, thereby demonstrating the strong effect of setmelanotide. Quality of life improved dramatically after the initiation of setmelanotide treatment. The sustained weight loss under setmelanotide was surprising. Diet induced weight loss in patients with common obesity is generally accompanied by significant counter-regulatory effects, including reduction in resting energy expenditure (REE) and increases in hunger that lead to weight regain in the majority of patients. See, e.g., Johannsen et al. J. Clin. Endocrinol. Metab. 2012;97:2489-96. Weight loss as observed in this patient under treatment with the MC4R agonist setmelanotide did not result in counter-regulatory responses even after more than 26 weeks of therapy and tremendous reduction of body weight. . These data show that setmelanotide (RM-493) treatment also benefits obese individuals in avoiding weight regain after a period of significant weight loss. This is consistent with reports showing that the leptin-melanocortin signaling cascade plays an important role in the regulation of weight regain and energy expenditure after a period of severe weight loss e.g. caused by a dietary intervention (Rosenbaum et al. JCI, 2005; Kissileff et al. Am J Clin Nutr 2012).

Compared to wild-type obese patients administered setmelanotide, the weight loss seen in the POMC deficient patient was much greater. For example, as described in Example

3, wild-type obese patients given setmelanotide exhibited weight loss of about 0.6 to about 0.9 kg per week. In this example, the POMC deficient patient treated with setmelanotide exhibited weight loss of about 2-2.5 kg per week. This data show that POMC deficient (e.g., POMC null genotype) subjects are hyperresponsive to MC4R agonists such as setmelanotide, compared to wild-type obese patients, e.g., who do not have a POMC deficiency (e.g., POMC null genotype). As POMC operates upstream of the MC4R, deficiencies in other genes in the POMC-MC4R pathway upstream of MC4R likely also convey hyperresponsiveness to MC4R agonists such as setmelanotide, when compared to wild-type obese patients.

POMC deficiency is a childhood onset “ultra-rare disease”, which has been reported in only approximately 15-20 children, of whom only three so far have reached adulthood. No adult-diagnosed patients have been reported to date. The efficacy and safety demonstrated in this study on an adult POMC deficient human are likely applicable to pediatric subjects and/or those subjects having other deficiencies of the hypothalamic leptin-melanocortin pathway, e.g., that lead to reduced or impaired POMC function or signaling, altered POMC processing, reduced hypothalamic POMC expression (e.g., which can be caused by genetic and epigenetic variations in the *POMC* gene, such as POMC heterozygous variant carriers); in subjects with mutations in the leptin receptor gene; in subjects with functional hypothalamic syndromes, such as Prader-Willi syndrome or PCSK1 deficiency; or in subject with MC4R mutations or other defects that impact functioning of the POMC-MC4R pathway.

Example 2: A melanocortin 4 receptor (MC4R) agonist is effective in a mouse model (*Magel2-null*) of Prader-Willi syndrome (PWS)

PWS is a contiguous gene disorder resulting from the loss of expression of several paternally inherited genes in a ~2 Mb region on chromosome 15 (15q11.2-13), known as the PWS region. The maternal genes at this locus are normally inactive. See, e.g., Elena et al. J of Obesity (2012). The PWS region includes several protein coding genes, along with DNA regions that generate long noncoding RNAs, numerous small nucleolar RNA (snoRNAs), and antisense transcripts. The inactivation of this 2 Mb region, which normally expresses several gene products, brings about the PWS symptoms. Symptoms associated with PWS are described herein.

Deficiency in the function of the *MAGEL2* gene, located in the 2 Mb PWS locus, is likely causative for a number of the signs and symptoms in PWS patients. *Magel2-null* mice recapitulate many aspects of the PWS phenotype (Bischof et. al., Hum Mol Gen, 2007, Vol 16, no 22, 2713-2719). *Magel2-null* mice start with a failure to thrive phenotype (including growth retardation and reduced food intake) in the neonatal phase, followed by excessive weight gain after weaning associated with only moderately increased food intake. These progressive changes in energy metabolism mimic what is observed in human PWS, leading to significantly increased adiposity through adulthood. *Magel2-null* mice also exhibit delayed gonadal development, altered behavior with increased anxiety, and defects in the hypothalamic-pituitary axis -- all features reminiscent of defects in the PWS. Mechanistically, the failure to thrive phase of *Magel2-null* mice aligns with the period where the POMC neurons still respond normally to the anorectic hormone leptin. However, POMC neurons in *Magel2-null* mice lose the ability to respond to leptin at about 8 weeks of age, leading progressively to significant changes in body composition and a profound increase in fat mass (Pravdivyi et. al., Hum Mol Gen, 2015, May 14, 1-8). Thus, the loss of function noted in the POMC neurons of *Magel2-null* mice may recapitulate important aspects of the PWS phenotype, mimicking progression from an early life failure to thrive phenotype into later metabolic disturbances and obesity. Magel2-null mice are a relevant rodent model of PWS.

Methods

Experiments were performed to determine the effect of a MC4R agonist, setmelanotide, on *Magel2-null* mice. Setmelanotide was evaluated in wild type and *Magel2-null* mice. Adult mice (N=6 per group) were acclimated to metabolic chambers, and food intake and energy expenditure (kcal/h) were measured over time. Mice were 8 weeks old. At this age, *Magel2-null* mice do not yet show the moderate hyperphagia noted later in life in this animal model. Vehicle and drug (setmelanotide) were administered intraperitoneally (i.p.) (n=6 for each treatment). A 0.1 mg/kg dose of setmelanotide was injected i.p. before the start of the dark cycle in the mice.

Food intake (cumulative in grams (g)) through 3 hours post dose and overnight cumulative food intake were assessed. Energy expenditure was also measured after dosing. Post-setmelanotide treatment data were compared to the data from post-vehicle injections in the same groups of mice. Statistical analysis was by two-way ANOVA followed by Bonferroni post-testing.

Results

A 0.1 mg/kg dose of setmelanotide significantly suppressed spontaneous food intake in *Magel2-null* mice (~ 75% decrease over the first 3 hours; $P < 0.05$) (Figure 1A). This food intake suppression persisted throughout the dark cycle (Figure 1B). Setmelanotide also increased energy expenditure by 11% at 3 hours post-dosing in *Magel2-null* mice compared to vehicle-dosed *Magel2-null* mice. Thus, setmelanotide decreased food intake and increased energy expenditure in *Magel2-null* mice.

In addition, *Magel2-null* mice were much more sensitive than wildtype mice to setmelanotide, as wildtype mice dosed with 0.1 mg/kg retained normal levels of food intake and did not respond to this dose of setmelanotide (Figures 1A-B). These data show that *Magel2-null* mice, a model for PWS in humans, were surprisingly sensitive to MSH "replacement therapy" with setmelanotide. This is likely in part due to the lack of expression of the anorectic hormone MSH in PWS patients due to dysfunctional POMC hypothalamic neurons (Pravdivyi et. al., Hum Mol Gen, 2015, May 14, 1-8). The large effects on food intake suppression noted in *Magel2-null* mice compared to wild type mice observed here show that setmelanotide treatment as replacement of missing MSH signaling may impact key efficacy endpoints in PWS patients, e.g., by restoring signaling downstream of the defective POMC neurons.

Conclusions

Magel2-null mice are a robust and relevant model for PWS. Treatment of *Magel2-null* mice with 0.1 mg/kg setmelanotide showed a statistically significant decrease in cumulative food intake ($P < 0.05$). These data demonstrate that the MC4R agonist setmelanotide is effective in a mouse model of PWS, and suggest that setmelanotide may be efficacious in treating PWS, e.g., reducing appetite and hyperphagia behaviors in addition to modulating body weight in PWS patients. Also, Magel2-null mice were much more responsive to setmelanotide (e.g., in decreasing food intake) than wild-type obese mice.

Example 3: MC4R agonist effect on wild-type obese patients

The effect of MC4R agonist setmelanotide on wild-type obese human patients was assessed. The patients were treated with placebo or setmelanotide twice daily (BID) at 0.01 mg/kg or 0.015 mg/kg. There were 9 patients in each treatment group (6 with setmelanotide and 3 with placebo).

The amount of weight loss was determined after 2 weeks or after 4 weeks of treatment. Figure 2 shows the placebo-subtracted differences in weight of the wild-type obese patients after administration with setmelanotide at various doses after 2 or 4 weeks. The weight loss among the wild-type obese patients was about 0.6 to about 0.9 kg per week.

Example 4: Treatment of PWS

PWS is a rare genetic disorder that causes life-threatening obesity. It is believed that defects in the MC4 pathway are a cause of the weight and appetite abnormalities in PWS.

A phase 2 clinical trial is conducted to evaluate the safety and efficacy of setmelanotide on weight and eating behaviors (weight reduction and food-related behaviors) in obese patients with Prader-Willi syndrome (PWS). The trial is a double-blind, placebo-controlled parallel group study with a randomized placebo-controlled withdrawal phase and open label active treatment extension. The trial assesses the effect of setmelanotide as a replacement therapy for the treatment of severe obesity and hyperphagia in PWS, using a personalized medicine approach to restore lost function believed to be caused by a defect in the MC4 signaling pathway.

About 36 obese adolescent and adult patients with PWS are enrolled in the trial. Setmelanotide is administered once daily by subcutaneous injection for up to 10 weeks of treatment. After a two-week placebo-controlled baseline period, patients are randomized into one of three of the following treatment groups: 1) setmelanotide at 0.5 mg daily, 2) setmelanotide at 1.5 mg daily, and 3) placebo daily. After treatment for four weeks, patients are evaluated at the primary efficacy timepoint for weight, hyperphagia, and body composition. After the four weeks, patients are subjected to a 2-week randomized withdrawal period, where 50% of the patients are in a double-blind withdrawal (50% patients given setmelanotide and 50% patients given placebo). Following the 2-week withdrawal period, patients are treated with a 2-week active dose extension period.

PWS obese patients may exhibit a response (e.g., greater response, e.g., greater efficacy) to setmelanotide than obese patients that do not have PWS.

Example 5: Treatment of POMC-null obesity (POMC deficiency)

POMC-null obesity is a very rare, life-threatening genetic disorder for which there have been no reported effective treatments. POMC-null patients lack a functioning POMC gene and have severe, early-onset obesity and extreme hunger. It is believed that these symptoms are due to a genetic defect in the MC4 pathway.

An open-label phase 2 clinical trial is conducted to evaluate the safety and efficacy of setmelanotide on weight and appetite in POMC-null patients.

About six obese adolescent and adult patients with POMC-null genetic defects are expected to be enrolled in the trial. Setmelanotide is administered once daily by subcutaneous injection for up to 13 weeks.

Patients are monitored for body weight, hunger level, waist circumference, daily food intake, blood pressure (systolic and diastolic), and heart rate before, during, and after the course of treatment. Adverse events are also monitored during and after the course of treatment to evaluate safety.

POMC-null obese patients may exhibit a response, e.g., greater response, e.g., efficacy, to setmelanotide than obese patients that are not POMC-null.

Example 6. The effect of varying concentrations of setmelanotide on food intake in wild-type and *db/db* mice (leptin receptor deficient mice)

Mice carrying the *db/db* mutation lack the letptin receptor gene. It was postulated that these mice would be particularly sensitive to the MC4R agonist setmelanotide.

To determine this, wild-type and d*b/db* mice were exposed to vehicle or varying concentrations of setmelanotide (0.0554 mpk; 0.137 mpk, 0.344mpk, or 1.37 mpk), and their food intake was measured over four hours.

The results are shown in FIGS.3A- F. For instance, at the 0.0544 mpk dose, the wildtype and vehicle treated mice showed identical food intake at the 4 hour timepoint, while the food intake in the *db/db* mice was significantly suppressed at the end of the 4 hour time period, by about 80% (Figure 3A). Decreased food intake in wild-type mice was observed with this dose of drug at 1 and 2 hours, although food intake approached wt amounts after three hours and was indistinguishable from vehicle-treated wt and DB/DV mice at 4 hours. vehicle.

Suppression of food intake was even more prosnounced at higher doses of setmelanotide (FIG. 3B-3D). Higher doses of setmelanotide (0.137 mpk, 0/344 mpk, and 1.37 mpk) lead to significantly decreased food intake in wt mice as well as *db/db* mice when compared to vehicle-treated wt and *db/db* mice. Dose responses for wt and *db/db* mice for the setmelanotide concentrations tested are shown in FIGS. 3E and 3F, respectively. For all concentrations *db/db* mice always show a more profound suppression of foodintake than wildtype mice treated with setmelanotide.

These results demonstrate that wildtype mice consumed less food when exposed to increasing concentrations of setmelanotide. In addition, these results show that *db/db* mice are hypersensitive to the effects of this MC4R agonist.

EQUIVALENTS

The disclosures of each and every patent, patent application, and publication cited herein are hereby incorporated herein by reference in their entirety. While this invention has been disclosed with reference to specific aspects, it is apparent that other aspects and variations of this invention may be devised by others skilled in the art without departing from the true spirit and scope of the invention. The appended claims are intended to be construed to include all such aspects and equivalent variations.

CLAIMS

1. A method of treating Prader Willi Syndrome (PWS) in a subject in need thereof, comprising:

administering an agonist of the melanocortin-4 receptor (MC4R) at a daily dosage of about 0.1 mg (e.g., 0.1 mg +/- 5%) to about 10 mg (e.g., 10 mg +/- 5%),

wherein the agonist is a MC4R agonist described herein, e.g., the agonist is

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \quad \text{(I)},$$

wherein:

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, $(C_1\text{-}C_{30})$alkyl, $(C_1\text{-}C_{30})$heteroalkyl, $(C_1\text{-}C_{30})$acyl, $(C_2\text{-}C_{30})$alkenyl, $(C_2\text{-}C_{30})$alkynyl, aryl$(C_1\text{-}C_{30})$alkyl, aryl$(C_1\text{-}C_{30})$acyl, substituted $(C_1\text{-}C_{30})$alkyl, substituted $(C_1\text{-}C_{30})$heteroalkyl, substituted $(C_1\text{-}C_{30})$acyl, substituted $(C_2\text{-}C_{30})$alkenyl, substituted $(C_2\text{-}C_{30})$alkynyl, substituted aryl$(C_1\text{-}C_{30})$alkyl, and substituted aryl$(C_1\text{-}C_{30})$acyl;

each of R^4 and R^5 is, independently for each occurrence, H, $(C_1\text{-}C_{40})$alkyl, $(C_1\text{-}C_{40})$heteroalkyl, $(C_1\text{-}C_{40})$acyl, $(C_2\text{-}C_{40})$alkenyl, $(C_2\text{-}C_{40})$alkynyl, aryl$(C_1\text{-}C_{40})$alkyl, aryl$(C_1\text{-}C_{40})$acyl, substituted $(C_1\text{-}C_{40})$alkyl, substituted $(C_1\text{-}C_{40})$heteroalkyl, substituted $(C_1\text{-}C_{40})$acyl, substituted $(C_2\text{-}C_{40})$alkenyl, substituted $(C_2\text{-}C_{40})$alkynyl, substituted aryl$(C_1\text{-}C_{40})$alkyl, substituted aryl$(C_1\text{-}C_{40})$acyl, $(C_1\text{-}C_{40})$alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, (C_{1-10})alkyl, substituted (C_{1-10})alkyl, (C_{2-10})alkenyl, substituted (C_{2-10})alkenyl, (C_{2-10})alkynyl, substituted (C_{2-10})alkynyl, aryl, substituted aryl, OH, NH_2 , NO_2 , or CN,

thereby treating PWS.

2. The method of any of the preceding claims, wherein the subject has or is identified as having a loss of function mutation in the 15q11-q13 region of chromosome 15.

3. The method of claim 2, wherein the subject has or is identified as having a mutation (e.g., loss of function mutation) in the MAGEL2 gene.

4. The method of any of claims 1-3, wherein the daily dosage is 0.1 mg to 10 mg.

5. The method of claim 4, wherein the daily dosage is about 0.1 mg to about 7.5 mg.

6. The method of claim 4, wherein the daily dosage is about 0.1 mg to about 5 mg.

7. The method of claim 4, wherein the daily dosage is about 0.1 mg to about 2.5 mg.

8. The method of claim 4, wherein the daily dosage is about 0.1 mg to about 2 mg.

9. The method of claim 4, wherein the daily dosage is about 0.1 mg to about 1 mg.

10. The method of any of claims 1-3, wherein the daily dosage is about 0.2 mg to about 10 mg.

11. The method of claim 10, wherein the daily dosage is about 0.2 mg to about 7.5 mg.

12. The method of claim 10, wherein the daily dosage is about 0.2 mg to about 5 mg.

13. The method of claim 10, wherein the daily dosage is about 0.2 mg to about 2.5 mg.

14. The method of claim 10, wherein the daily dosage is about 0.2 mg to about 2 mg.

15. The method of claim 10, wherein the daily dosage is about 0.2 mg to about 1.5 mg.

16. The method of claim 10, wherein the daily dosage is about 0.2 mg to about 1 mg.

17. The method of any of claims 1-3, wherein the daily dosage is about 0.3 mg to about 10 mg.

18. The method of claim 17, wherein the daily dosage is about 0.3 mg to about 7.5 mg.

19. The method of claim 17, wherein the daily dosage is about 0.3 mg to about 5 mg.

20. The method of claim 17, wherein the daily dosage is about 0.3 mg to about 2.5 mg.

21. The method of claim 17, wherein the daily dosage is about 0.3 mg to about 2 mg.

22. The method of claim 17, wherein the daily dosage is about 0.3 mg to about 1.5 mg.

23. The method of claim 17, wherein the daily dosage is about 0.3 mg to about 1 mg.

24. The method of any of claims 1-3, wherein the daily dosage is about 0.25 mg (e.g., 0.25 mg) to about 0.5 mg (e.g., 0.5 mg).

25. The method of any of claims 1-3, wherein the daily dosage is about 0.5 mg (e.g., 0.5 mg) to about 0.75 mg (e.g., 0.75 mg).

26. The method of claim 24, wherein the daily dosage is about 0.25 mg (e.g., 0.25 mg).

27. The method of 24 or 25, wherein the daily dosage is about 0.5 mg (e.g., 0.5 mg).

28. The method of any of claims 1-3, wherein the daily dosage is about 0.75 mg (e.g., 0.75 mg) to about 1.25 mg (1.25 mg).

29. The method of claim 28, wherein the daily dosage is about 1 mg (e.g., 1 mg).

30. The method of any of claims 1-3, wherein the daily dosage is about 1.25 mg (e.g., 1.25 mg) to about 2 mg (e.g., 2 mg).

31. The method of claim 30, wherein the daily dosage is about 1.5 mg (e.g., 1.5 mg).

32. The method of claim 30, wherein the daily dosage is about 2 mg (e.g., 2 mg).

33. The method of any of the preceding claims, comprising administering the agonist in a unit dosage suitable for injection, e.g., subcutaneous injection, to the subject.

34. The method of claim 33, wherein the unit dosage comprises about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

35. The method of claim 33 or 34, wherein the unit dosage is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe),an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

36. The method of any of the preceding claims, wherein the agonist is administered subcutaneously, e.g., by subcutaneous injection.

37. The method of any of the preceding claims, wherein the agonist is administered daily over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more.

38. The method of any of the preceding claims, wherein the subject is obese, e.g., severely obese.

39. The method of any of the preceding claims, wherein the subject has early onset severe obesity.

40. The method of any of the preceding claims, wherein the subject is hyperphagic.

41. The method of any of the preceding claims, wherein the subject has a body mass index (BMI) greater than 25 kg/m^2 (e.g., $\geq$25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

42. The method of any of the preceding claims, wherein the subject has a body mass index (BMI) greater than 35 kg/m^2 (e.g., ≥36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

43. The method of any of the preceding claims, wherein the subject has a body mass index (BMI) greater than 40 kg/m^2 (e.g., ≥41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

44. The method of any of the preceding claims, wherein the subject has a body mass index (BMI) greater than 45 kg/m^2 (e.g., ≥46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

45. The method of any of the preceding claims, wherein the subject has failed one or more previous therapies, e.g., exercise, diet, or behavioral therapies, prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

46. The method of any of the preceding claims, wherein the subject has a lower body weight after administration of the agonist than before administration of the agonist.

47. The method of any of the preceding claims, wherein administration of the agonist results in a reduction of weight in the subject compared to the weight of the subject before treatment of about 1 kg to 3 kg after 1 week of treatment, or about 1 kg to 6 kg after 2 weeks of treatment, or about 2 kg to 12 kg after 4 weeks of treatment, or about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment.

48. The method of any of the preceding claims, wherein administration of the agonist results in weight loss in the subject at a rate of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment or longer, 16-32 weeks or longer, or 32-64 weeks or longer.

49. The method of any of the preceding claims, wherein administration of the agonist results in a reduction in hunger level (e.g., a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points) in the subject compared to the hunger level of the subject before treatment, e.g., results in abolishment of hunger (e.g., a score of 0 on the Likert hunger scale) in the subject, e.g., after 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

50. The method of any of the preceding claims, wherein administration of the agonist results in no detectable/significant decrease in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days or longer, e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass).

51. The method of claim 50, wherein administration of the agonist results in an increase in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days, or longer e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or compared to a predetermined REE, e.g., in subjects of similar pre-treatment BMI, when expressed as REE per kg of lean body mass, e.g., after a similar level of weight loss has been attained by fasting).

52. The method of any of the preceding claims, wherein administration of the agonist results in a reduction in food intake by the subject compared to a control (e.g., the food intake of the

subject prior to treatment), e.g., wherein the food intake is daily food intake or food intake over a period of 24 hours, or one week.

53. The method of claim 52, wherein administration of the agonist results in a reduction in food intake of at least 100 kilocalories, e.g., at least 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, compared to a control (e.g., the food intake of the subject prior to treatment or a predetermined food intake level), e.g., wherein the food intake is daily food intake or food intake over a period of 24, hours, or one week.

54. The method of any of the preceding claims, wherein administration of the agonist results in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

55. The method of claim 54, wherein administration of the agonist results in a reduction in waist circumference of at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

56. The method of any of the preceding claims, wherein administration of the agonist results in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

57. The method of any of the preceding claims, wherein administration of the agonist results in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

58. The method of claim 57, wherein administration of the agonist results in a reduction in systolic blood of the subject of at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

59. The method of claim 57, wherein administration of the agonist results in a reduction in diastolic blood pressure of the subject of at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

60. The method of any of the preceding claims, wherein the subject is a mammal, e.g., a human.

61. The method of any of the preceding claims, wherein the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

62. The method of any of the preceding claims, comprising acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype the 15q11-q13 region of chromosome 15 or of the MAGEL2 gene.

63. The method of claim 62, wherein the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in 15q11-q13 region of chromosome 15 or in the MAGEL2 gene.

64. A method of treating a disorder in a subject in need thereof, comprising:

administering an agonist of the melanocortin-4 receptor (MC4R) at a daily dosage of about 0.1 mg (e.g., 0.1 mg +/- 5%) to about 10 mg (e.g., 10 mg +/- 5%), wherein the disorder is chosen from:

(i) Prader Willi Syndrome (PWS);

(ii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the POMC gene;

(iii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene;

(iv) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the MAGEL2 gene;

(v) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin receptor gene;

(vi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin gene;

(vii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene;

(viii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene;

(ix) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the pro-hormone convertase gene;

(x) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene;

(xi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene;

(xii) a disorder characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising one or more methylated cytosines, e.g., a 5'methyl cytosine); or

(xiii) a disorder characterized by a defect in the POMC-MC4R pathway other than:

(e) a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,

(f) a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,

(g) a melanocortin-4 receptor (MC4R) mutation (e.g., loss of function mutation),

(h) a pro-hormone convertase mutation (e.g., loss of function mutation);

(i) a mutation in a gene associated with Bardet-Biedl syndrome (e.g., a mutation in *BBS1-BBS20*); or

(j) a mutation in a gene associated with Alström syndrome,

wherein the agonist is a MC4R agonist described herein, e.g., the agonist is

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \quad \text{(I)},$$

wherein:

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl, and substituted aryl(C_1-C_{30})acyl;

each of R^4 and R^5 is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted $(C_2\text{-}C_{40})$alkenyl, substituted $(C_2\text{-}C_{40})$alkynyl, substituted aryl$(C_1\text{-}C_{40})$alkyl, substituted aryl$(C_1\text{-}C_{40})$acyl, $(C_1\text{-}C_{40})$alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, $(C_{1\text{-}10})$alkyl, substituted $(C_{1\text{-}10})$alkyl, $(C_{2\text{-}10})$alkenyl, substituted $(C_{2\text{-}10})$alkenyl, $(C_{2\text{-}10})$alkynyl, substituted $(C_{2\text{-}10})$alkynyl, aryl, substituted aryl, OH, NH_2 , NO_2 , or CN.

65. The method of claim 64, wherein the disorder is Prader Willi Syndrome (PWS).

66. The method of 64 or 65, wherein the subject has or is identified as having a loss of function mutation in the paternal allele of the 15q11-q13 region of chromosome 15.

67. The method of claim 65 or 66, wherein the subject has or is identified as having a mutation, e.g., loss of function mutation, in the MAGEL2 gene.

68. The method of claim 64, wherein the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the POMC gene.

69. The method of any of claim 68, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional POMC allele and one non-functional POMC allele.

70. The method of claim 68, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two distinct non-functional POMC alleles, e.g., having a POMC null genotype.

71. The method of claim 68, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a homozygous POMC null genotype.

72. The method of claim 64, wherein the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene.

73. The method of claim 72, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional PCSK1 allele and one non-functional PCSK1 allele.

74. The method of claim 72, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional PCSK1 alleles, e.g., having a PCSK1 null genotype.

75. The method of claim 72, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a homozygous PCSK1 null genotype.

76. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the MAGEL2 gene.

77. The method of claim 76, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional MAGEL2 allele and one non-functional MAGEL2 allele, including the subjects where the remainingfunctional allele is silenced by maternal imprinting, as result of which the subject is a functional MAGEL2 null patient.

78. The method of claim 76, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two mutated non-functional MAGEL2 alleles, e.g., having a MAGEL2 null genotype.

79. The method of claim 76, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a MAGEL2 null genotype.

80. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the leptin receptor gene.

81. The method of any of claim 80, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional leptin receptor allele and one non-functional leptin receptor allele.

82. The method of claim 80, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional leptin receptor alleles, e.g., having a leptin receptor null genotype.

83. The method of claim 80, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a leptin receptor null genotype.

84. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the leptin gene.

85. The method of any of claim 84, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional leptin allele and one non-functional leptin allele.

86. The method of claim 84, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional leptin alleles, e.g., having a leptin null genotype.

87. The method of claim 84, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a leptin null genotype.

88. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene.

89. The method of any of claim 88, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional 5-HT2c receptor allele and one non-functional 5-HT2c receptor allele.

90. The method of claim 88, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional 5-HT2c receptor alleles, e.g., having a 5-HT2c receptor null genotype.

91. The method of claim 88, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a 5-HT2c receptor null genotype.

92. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene.

93. The method of any of claim 92, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional NhHL2 allele and one non-functional NhHL2 receptor allele.

94. The method of claim 92, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional NhHL2 alleles, e.g., having a NhHL2 null genotype.

95. The method of claim 92, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a NhHL2 null genotype.

96. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the pro-hormone convertase gene.

97. The method of claim 96, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional pro-hormone convertase allele and one non-functional pro-hormone convertase allele.

98. The method of claim 96, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional pro-hormone convertase alleles, e.g., having a pro-hormone convertase null genotype.

99. The method of claim 96, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a pro-hormone convertase null genotype.

100. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene.

101. The method of any of claim 100, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional CPE allele and one non-functional CPE allele.

102. The method of claim 100, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional CPE alleles, e.g., having a CPE null genotype.

103. The method of claim 100, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a CPE null genotype.

104. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene.

105. The method of any of claim 104, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional SIM1 allele and one non-functional SIM1 allele.

106. The method of claim 104, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional SIM1 alleles, e.g., having a SIM1 null genotype.

107. The method of claim 104, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a SIM1 null genotype.

108. The method of claim 64, wherein the disorder is characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

109. The method of claim 64, wherein the disorder is characterized by a defect in the POMC-MC4R pathway other than:

(e) a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,

(f) a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,

(g) a heterozygous melanocortin-4 receptor (MC4R) mutation characterized by the presence of one functional MC4R allele and one non-functional MC4R allele, ~~or~~

(h) a pro-hormone convertase mutation (e.g., loss of function mutation);

(i) a mutation in a gene associated with Bardet-Biedl syndrome (e.g., a mutation in *BBS1-BBS20*); or

(j) a mutation in a gene associated with Alström syndrome.

110. The method of any of claims 64-109, wherein the daily dosage is 0.1 mg to 10 mg.

111. The method of claim 110, wherein the daily dosage is about 0.1 mg to about 7.5 mg.

112. The method of claim 110, wherein the daily dosage is about 0.1 mg to about 5 mg.

113. The method of claim 110, wherein the daily dosage is about 0.1 mg to about 2.5 mg.

114. The method of claim 110, wherein the daily dosage is about 0.1 mg to about 2 mg.

115. The method of claim 110, wherein the daily dosage is about 0.1 mg to about 1 mg.

116. The method of any of claims 64-109, wherein the daily dosage is about 0.2 mg to about 10 mg.

117. The method of claim 116, wherein the daily dosage is about 0.2 mg to about 7.5 mg.

118. The method of claim 116, wherein the daily dosage is about 0.2 mg to about 5 mg.

119. The method of claim 116, wherein the daily dosage is about 0.2 mg to about 2.5 mg.

120. The method of claim 116, wherein the daily dosage is about 0.2 mg to about 2 mg.

121. The method of claim 116, wherein the daily dosage is about 0.2 mg to about 1.5 mg.

122. The method of claim 116, wherein the daily dosage is about 0.2 mg to about 1 mg.

123. The method of any of claims 64-109, wherein the daily dosage is about 0.3 mg to about 10 mg.

124. The method of claim 123, wherein the daily dosage is about 0.3 mg to about 7.5 mg.

125. The method of claim 123, wherein the daily dosage is about 0.3 mg to about 5 mg.

126. The method of claim 123, wherein the daily dosage is about 0.3 mg to about 2.5 mg.

127. The method of claim 123, wherein the daily dosage is about 0.3 mg to about 2 mg.

128. The method of claim 123, wherein the daily dosage is about 0.3 mg to about 1.5 mg.

129. The method of claim 123, wherein the daily dosage is about 0.3 mg to about 1 mg.

130. The method of any of claims 64-109, wherein the daily dosage is about 0.25 mg (e.g., 0.25 mg) to about 0.5 mg (e.g., 0.5 mg).

131. The method of any of claims 64-109, wherein the daily dosage is about 0.5 mg (e.g., 0.5 mg) to about 0.75 mg (e.g., 0.75 mg).

132. The method of claim 130, wherein the daily dosage is about 0.25 mg (e.g., 0.25 mg).

133. The method of 130 or 131, wherein the daily dosage is about 0.5 mg (e.g., 0.5 mg).

134. The method of any of claims 64-109, wherein the daily dosage is about 0.75 mg (e.g., 0.75 mg) to about 1.25 mg (1.25 mg).

135. The method of claim 134, wherein the daily dosage is about 1 mg (e.g., 1 mg).

136. The method of any of claims 64-109, wherein the daily dosage is about 1.25 mg (e.g., 1.25 mg) to about 2 mg (e.g., 2 mg).

137. The method of claim 136, wherein the daily dosage is about 1.5 mg (e.g., 1.5 mg).

138. The method of claim 136, wherein the daily dosage is about 2 mg (e.g., 2 mg).

139. The method of any of claims 64-138, comprising administering the agonist in a unit dosage suitable for injection, e.g., subcutaneous injection, to the subject.

140. The method of claim 139, wherein the unit dosage comprises about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

141. The method of claim 139 or 140, wherein the unit dosage is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe),an implantable device, a needleness

hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

142. The method of any of claims 64-141, wherein the agonist is administered subcutaneously, e.g., by subcutaneous injection.

143. The method of any of claims 64-142, wherein the agonist is administered daily over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more.

144. The method of any of claims 64-143, wherein the subject is obese, e.g., severely obese.

145. The method of any of claims 64-144, wherein the subject has early onset severe obesity.

146. The method of any of claims 64-145, wherein the subject is hyperphagic.

147. The method of any of claims 64-146, wherein the subject has a body mass index (BMI) greater than 25 kg/m^2 (e.g., ≥25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

148. The method of any of claims 64-147, wherein the subject has a body mass index (BMI) greater than 35 kg/m^2 (e.g., ≥36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

149. The method of any of claims 64-148, wherein the subject has a body mass index (BMI) greater than 40 kg/m^2 (e.g., ≥41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

150. The method of any of claims 64-149, wherein the subject has a body mass index (BMI) greater than 45 kg/m^2 (e.g., ≥46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

151. The method of any of claims 64-150, wherein the subject has failed one or more previous therapies, e.g., exercise, diet, or behavioral therapies, prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

152. The method of any of claims 64-151, wherein the subject has a lower body weight after administration of the agonist than before administration of the agonist.

153. The method of any of claims 64-152, wherein administration of the agonist results in a reduction of weight in the subject compared to the weight of the subject before treatment of about 1 kg to 3 kg after 1 week of treatment, or about 1 kg to 6 kg after 2 weeks of treatment, or about 2 kg to 12 kg after 4 weeks of treatment, or about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment.

154. The method of any of claims 64-153, wherein administration of the agonist results in weight loss in the subject at a rate of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment or longer, 16-32 weeks or longer, or 32-64 weeks or longer.

155. The method of any of claims 64-154, wherein administration of the agonist results in a reduction in hunger level (e.g., a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points) in the subject compared to the hunger level of the subject before treatment, e.g., results in abolishment of hunger (e.g., a score of 0 on the Likert hunger scale) in the subject, e.g., after 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

156. The method of any of claims 64-155, wherein administration of the agonist results in no detectable/significant decrease in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days or longer, e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass).

157. The method of claim 156, wherein administration of the agonist results in an increase in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days, or longer e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or compared to a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass, e.g., after a similar level of weight loss has been attained by fasting).

158. The method of any of claims 64-157, wherein administration of the agonist results in a reduction in food intake by the subject compared to a control (e.g., the food intake of the subject prior to treatment), e.g., wherein the food intake is daily food intake or food intake over a period of 24 hours, or one week.

159. The method of claim 158, wherein administration of the agonist results in a reduction in food intake of at least 100 kilocalories, e.g., at least 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, compared to a control (e.g., the food intake of the subject prior to treatment or a

predetermined food intake level), e.g., wherein the food intake is daily food intake or food intake over a period of 24, hours, or one week.

160. The method of any of claims 64-159, wherein administration of the agonist results in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

161. The method of claim 160, wherein administration of the agonist results in a reduction in waist circumference of at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

162. The method of any of claims 64-161, wherein administration of the agonist results in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

163. The method of any of claims 64-162, wherein administration of the agonist results in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

164. The method of claim 163, wherein administration of the agonist results in a reduction in systolic blood of the subject of at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

165. The method of claim 163, wherein administration of the agonist results in a reduction in diastolic blood pressure of the subject of at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

166. The method of any of claims 64-165, wherein the subject is a mammal, e.g., a human.

167. The method of any of claims 64-166, wherein the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

168. The method of any of claims 64-167, comprising acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype of, e.g., of a mutation in:

the POMC gene;the prohormone convertase gene, including the PCSK1 gene;
the MAGEL2 gene;
the leptin receptor gene;
the leptin gene;
the 5-HT2c receptor gene;
the nescient helix loop helix 2 (NhHL2) gene;
the carboxypeptidase E (CPE) gene;
the single-minded 1 (SIM1) gene;
a POMC-MC4R pathway gene;
BBS1-BBS20);
ALMS1,
BDNF, MCH1R, MCH, NTRK2,SIM1, ENPP1, COH1, CNR1, NPC1, c-MAF, PTER, FTO, TMEM18 (childhood), SDCCAG8, TNKS/MSRA, GNPDA2 (childhood), NEGr1, INSIG2, KCTD15, NROB2, and 16p11.2 deletions (including the SH2B1 gene).

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169. The method of claim 168, wherein the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in a gene in claim 168.

170. A method of treating a disorder chosen from:

(i) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene;

(ii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the MAGEL2 gene;

(iii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the leptin receptor gene;

(iv) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene;

(v) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene;

(vi) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene;

(vii) a disorder characterized by one or more mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene;

(viii) a disorder characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine);

(ix) a disorder characterized by a defect in the POMC-MC4R pathway other than:

(e) a POMC mutation, e.g., a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,

(f) a leptin mutation, e.g., a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele,

(g) a melanocortin-4 receptor (MC4R) mutation, or

(h) a prohormone convertase mutation;

(x) a disorder characterized by a homozygous POMC mutation (e.g., loss of function mutation), e.g., characterized by a POMC null genotype;

(xi) a disorder characterized by a compound heterozygous POMC mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a POMC null genotype;

(xii) a disorder characterized by a homozygous leptin mutation (e.g., loss of function mutation), e.g., characterized by a leptin null genotype;

(xiii) a disorder characterized by a compound heterozygous leptin mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a leptin null genotype,

(xiv) a disorder characterized by a mutation in a gene associated with Bardet-Biedl syndrome (e.g., a mutation in *BBS1-BBS20*); or

(xv) a disorder characterized by a a mutation in a gene associated with Alström syndrome,

in a subject in need thereof, comprising administering an agonist of the melanocortin-4 receptor (MC4R),

wherein the agonist is a MC4R agonist described herein, e.g., the agonist is

$$(R^2R^3)\text{-}A^1\text{-}c(A^2\text{-}A^3\text{-}A^4\text{-}A^5\text{-}A^6\text{-}A^7\text{-}A^8\text{-}A^9)\text{-}A^{10}\text{-}R^1 \quad \text{(I)},$$

wherein:

A^1 is Acc, HN—$(CH_2)_m$—C(O), L- or D-amino acid, or deleted;

A^2 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Asp, or Glu;

A^3 is Gly, Ala, β-Ala, Gaba, Aib, D-amino acid, or deleted;

A^4 is H is, 2-Pal, 3-Pal, 4-Pal, Taz, 2-Thi, 3-Thi, or (X^1, X^2, X^3, X^4, X^5)Phe;

A^5 is D-Phe, D-1-Nal, D-2-Nal, D-Trp, D-Bal, D-(X^1, X^2, X^3, X^4, X^5)Phe, L-Phe or D-(Et)Tyr;

A^6 is Arg, hArg, Dab, Dap, Lys, Orn, or HN-CH($(CH_2)_n$-N(R^4R^5))-C(O);

A^7 is Trp, 1-Nal, 2-Nal, Bal, Bip, D-Trp, D-2-Nal, D-Bal or D-Bip;

A^8 is Gly, D-Ala, Acc, Ala, 13-Ala, Gaba, Apn, Ahx, Aha, HN-$(CH_2)_s$-C(O), or deleted;

A^9 is Cys, D-Cys, hCys, D-hCys, Pen, D-Pen, Dab, Dap, Orn, or Lys;

A^{10} is Acc, HN-$(CH_2)_t$-C(O), L- or D-amino acid, or deleted;

R^1 is OH or NH_2;

each of R^2 and R^3 is, independently for each occurrence, selected from the group consisting of H, (C_1-C_{30})alkyl, (C_1-C_{30})heteroalkyl, (C_1-C_{30})acyl, (C_2-C_{30})alkenyl, (C_2-C_{30})alkynyl, aryl(C_1-C_{30})alkyl, aryl(C_1-C_{30})acyl, substituted (C_1-C_{30})alkyl, substituted (C_1-C_{30})heteroalkyl, substituted (C_1-C_{30})acyl, substituted (C_2-C_{30})alkenyl, substituted (C_2-C_{30})alkynyl, substituted aryl(C_1-C_{30})alkyl, and substituted aryl(C_1-C_{30})acyl;

each of R^4 and R^5 is, independently for each occurrence, H, (C_1-C_{40})alkyl, (C_1-C_{40})heteroalkyl, (C_1-C_{40})acyl, (C_2-C_{40})alkenyl, (C_2-C_{40})alkynyl, aryl(C_1-C_{40})alkyl, aryl(C_1-C_{40})acyl, substituted (C_1-C_{40})alkyl, substituted (C_1-C_{40})heteroalkyl, substituted (C_1-C_{40})acyl, substituted (C_2-C_{40})alkenyl, substituted (C_2-C_{40})alkynyl, substituted aryl(C_1-C_{40})alkyl, substituted aryl(C_1-C_{40})acyl, (C_1-C_{40})alkylsulfonyl, or -C(NH)-NH_2;

m is, independently for each occurrence, 1, 2, 3, 4, 5, 6 or 7;

n is, independently for each occurrence, 1, 2, 3, 4 or 5;

s is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

t is, independently for each occurrence, 1, 2, 3, 4, 5, 6, or 7;

X', X^2, X^3, X^4, and X^8 each is, independently for each occurrence, H, F, Cl, Br, I, (C_{1-10})alkyl, substituted (C_{1-10})alkyl, (C_{2-10})alkenyl, substituted (C_{2-10})alkenyl, (C_{2-10})alkynyl, substituted (C_{2-10})alkynyl, aryl, substituted aryl, OH, NH_2, NO_2, or CN.

171. The method of claim 170, wherein the disorder is characterized by a homozygous POMC mutation (e.g., loss of mutation), e.g., characterized by a POMC null genotype.

172. The method of claim 170, wherein the disorder is characterized by a compound heterozygous POMC mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a POMC null genotype.

173. The method of claim 172, wherein the mutations are p.Lys51Term g.A6851>T and p.Arg145ProfsX12 g.7134delG.

174. The method of claim 170, wherein the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the PCSK1 gene.

175. The method of claim 174, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional PCSK1 allele and one non-functional PCSK1 allele.

176. The method of claim 174, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional PCSK1 alleles, e.g., having a PCSK1 null genotype.

177. The method of claim 174, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a PCSK1 null genotype.

178. The method of claim 170, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the MAGEL2 gene.

179. The method of claim 178, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional MAGEL2 allele and one non-functional MAGEL2 allele.

180. The method of claim 178, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional MAGEL2 alleles, e.g., having a MAGEL2 null genotype.

181. The method of claim 178, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a MAGEL2 null genotype.

182. The method of claim 170, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the leptin receptor gene.

183. The method of any of claim 182, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional leptin receptor allele and one non-functional leptin receptor allele.

184. The method of claim 182, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional leptin receptor alleles, e.g., having a leptin receptor null genotype.

185. The method of claim 182, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a leptin receptor null genotype.

186. The method of claim 170, wherein the disorder is characterized by a homozygous leptin mutation (e.g., loss of mutation), e.g., characterized by a leptin null genotype.

187. The method of claim 170, wherein the disorder is characterized by a compound heterozygous leptin mutation (e.g., characterized by the presence of two non-functional alleles) e.g., characterized by a leptin null genotype.

188. The method of claim 170, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the 5-HT2c receptor gene.

189. The method of any of claim 188, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional 5-HT2c receptor allele and one non-functional 5-HT2c receptor allele.

190. The method of claim 188, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional 5-HT2c receptor alleles, e.g., having a 5-HT2c receptor null genotype.

191. The method of claim 188, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a 5-HT2c receptor null genotype.

192. The method of claim 170, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the nescient helix loop helix 2 (NhHL2) gene.

193. The method of any of claim 192, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional NhHL2 allele and one non-functional NhHL2 receptor allele.

194. The method of claim 192, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional NhHL2 alleles, e.g., having a NhHL2 null genotype.

195. The method of claim 192, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a NhHL2 null genotype.

196. The method of claim 170, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the carboxypeptidase E (CPE) gene.

197. The method of any of claim 196, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional CPE allele and one non-functional CPE allele.

198. The method of claim 196, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional CPE alleles, e.g., having a CPE null genotype.

199. The method of claim 196, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a CPE null genotype.

200. The method of claim 170, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in the single-minded 1 (SIM1) gene.

201. The method of any of claim 200, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional SIM1 allele and one non-functional SIM1 allele.

202. The method of claim 200, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional SIM1 alleles, e.g., having a SIM1 null genotype.

203. The method of claim 200, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a SIM1 null genotype.

204. The method of claim 170, wherein the disorder is characterized by a hypermethylated POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

205. The method of claim 204, wherein the subject has or is identified as having a hypermethylated CpG island in the POMC gene, e.g., at the intron2-exon3 boundary of the POMC gene.

206 The method of claim 170, wherein the disorder is characterized by a defect in the POMC-MC4R pathway other than a POMC mutation, e.g., a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele.

207. The method of claim 170, wherein the disorder is characterized by a defect in the POMC-MC4R pathway other than a leptin mutation, e.g, a heterozygous leptin mutation characterized by the presence of one functional leptin allele and one non-functional leptin allele.

208. The method of claim 170, wherein the disorder is characterized by a defect in the POMC-MC4R pathway other than a MC4R mutation, e.g., a heterozygous melanocortin-4 receptor (MC4R) mutation characterized by the presence of one functional MC4R allele and one non-functional MC4R allele.

209. The method of claim 170, wherein the disorder is characterized by a defect in the POMC-MC4R pathway other than a pro-hormone convertase mutation.

210. The method of any of claims 170-209, comprising administering the agonist in a unit dosage suitable for injection, e.g., subcutaneous injection, to the subject.

211. The method of claim 210, wherein the unit dosage comprises about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

212. The method of claim 210 or 211, wherein the unit dosage is disposed within a delivery device, e.g., a syringe (e.g., prefilled syringe),an implantable device, a needleness hypodermic injection device, an infusion pump (e.g., implantable infusion pump), or an osmotic delivery system.

213. The method of any of claims 170-211, wherein the agonist is administered subcutaneously, e.g., by subcutaneous injection.

214. The method of any of claims 170-213, wherein the agonist is administered daily over a period of at least 3 weeks, e.g., at least 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, or 40 weeks or more, or at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months or more, or at least 1, 2, 3, 4 years or more.

215. The method of any of claims 170-214, wherein the subject is obese, e.g., severely obese.

216. The method of any of claims 170-215, wherein the subject has early onset severe obesity.

217. The method of any of claims 170-216, wherein the subject is hyperphagic.

218. The method of any of claims 170-217, wherein the subject has a body mass index (BMI) greater than 25 kg/m^2 (e.g., ≥25, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

219. The method of any of claims 170-218, wherein the subject has a body mass index (BMI) greater than 35 kg/m^2 (e.g., ≥36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

220. The method of any of claims 170-219, wherein the subject has a body mass index (BMI) greater than 40 kg/m^2 (e.g., ≥41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

221. The method of any of claims 170-220, wherein the subject has a body mass index (BMI) greater than 45 kg/m^2 (e.g., ≥46, 47, 48, 49, 50, 51, 52, 53, 54, 55 kg/m^2 or greater) prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

222. The method of any of claims 170-221, wherein the subject has failed one or more previous therapies, e.g., exercise, diet, or behavioral therapies, prior to administration of the agonist, e.g., at the time the agonist is prescribed, or at the time of the first administration.

223. The method of any of claims 170-222, wherein the subject has a lower body weight after administration of the agonist than before administration of the agonist.

224. The method of any of claims 170-223, wherein administration of the agonist results in a reduction of weight in the subject compared to the weight of the subject before treatment of about 1 kg to 3 kg after 1 week of treatment, or about 1 kg to 6 kg after 2 weeks of treatment, or about 2 kg to 12 kg after 4 weeks of treatment, or about 4 kg to 24 kg after 8 weeks of treatment, or about 8 kg to 48 kg after 16 weeks of treatment.

225. The method of any of claims 170-224, wherein administration of the agonist results in weight loss in the subject at a rate of about 1-2 kg/week, e.g., about 2 kg/week, e.g., over a period of 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, 8-16 weeks of treatment or longer, 16-32 weeks or longer, or 32-64 weeks or longer.

226. The method of any of claims 170-225, wherein administration of the agonist results in a reduction in hunger level (e.g., a lower score on the Likert hunger scale, e.g., a lower score by at least 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 points) in the subject compared to the hunger level of the subject before treatment, e.g., results in abolishment of hunger (e.g., a score of 0 on the

Likert hunger scale) in the subject, e.g., after 1-2 weeks of treatment or longer, 2-4 weeks of treatment or longer, 4-8 weeks of treatment or longer, or 8-16 weeks of treatment or longer.

227. The method of any of claims 170-226, wherein administration of the agonist results in no detectable/significant decrease in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days or longer, e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass).

228. The method of claim 227, wherein administration of the agonist results in an increase in resting energy expenditure (REE) in the subject, e.g., over a period of 24 hours, one week, or 30 days, or longer e.g., as compared to a control REE (e.g., the REE in the subject prior to treatment or compared to a predetermined REE, e.g., in subjects of similar pre-treatment BMI, e.g., when expressed as REE per kg of lean body mass, e.g., after a similar level of weight loss has been attained by fasting).

229. The method of any of claims 170-228, wherein administration of the agonist results in a reduction in food intake by the subject compared to a control (e.g., the food intake of the subject prior to treatment), e.g., wherein the food intake is daily food intake or food intake over a period of 24 hours, or one week.

230. The method of claim 229, wherein administration of the agonist results in a reduction in food intake of at least 100 kilocalories, e.g., at least 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 1000 kilocalories or more, compared to a control (e.g., the food intake of the subject prior to treatment or a predetermined food intake level), e.g., wherein the food intake is daily food intake or food intake over a period of 24, hours, or one week.

231. The method of any of claims 170-230, wherein administration of the agonist results in a reduction in waist circumference of the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

232. The method of claim 231, wherein administration of the agonist results in a reduction in waist circumference of at least 2 cm (e.g., at least 2, 3, 4, 5, 6, 7, 8, 9, 10 cm or more) in the subject compared to a control (e.g., the waist circumference of the subject prior to treatment), as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

233. The method of any of claims 170-232, wherein administration of the agonist results in no detectable increase in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

234. The method of any of claims 170-233, wherein administration of the agonist results in a reduction in blood pressure (e.g., diastolic and/or systolic blood pressure) of the subject compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

235. The method of claim 234, wherein administration of the agonist results in a reduction in systolic blood of the subject of at least 3 mmHg (e.g., at least 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

236. The method of claim 234, wherein administration of the agonist results in a reduction in diastolic blood pressure of the subject of at least 4 mmHg (e.g., at least 4, 7, 7.5, 8, 8.5, 9, 9.5, 10 mmHg or more) compared to the blood pressure of the subject prior to treatment, as measured 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 weeks or more after initiation of treatment.

237. The method of any of claims 170-236, wherein the subject is a mammal, e.g., a human.

238. The method of any of claims 170-237, wherein the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

239. The method of any of claims 170-238, comprising acquiring knowledge of the genotype of the subject, e.g., acquiring knowledge of the genotype of, e.g., of a mutation in:

the POMC gene;
the PCSK1 gene;
the MAGEL2 gene;
the leptin receptor gene;
the leptin gene;
the 5-HT2c receptor gene;
the nescient helix loop helix 2 (NhHL2) gene;
the carboxypeptidase E (CPE) gene;
the single-minded 1 (SIM1) gene.;
any of the BBS1-BBS20 genes;
the ALMS1 gene,
or the BDNF, MCH1R, MCH, NTRK2,SIM1, ENPP1, COH1, CNR1, NPC1, c-MAF, PTER, FTO, TMEM18 (childhood), SDCCAG8, TNKS/MSRA, GNPDA2 (childhood), NEGr1, INSIG2, KCTD15, or NROB2 gene, or 16p11.2 deletions (including the SH2B1 gene).

240. The method of claim 239, wherein the agonist is administered in response to the detection of a predetermined sequence, e.g., a mutation, in a gene in claim 239.

241. The method of any of claims 170-238, comprising acquiring knowledge of the state of methylation of the POMC gene (e.g., hypermethylated at a POMC intron, e.g., at a CpG island of the POMC gene, e.g., comprising a methylated cytosine, e.g., a 5'methyl cytosine).

242. The method of claim 241, wherein the agonist is administered in response to the detection of hypermethylation.

243. A unit dosage of an agonist described herein, wherein the unit dosage contains 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist.

244. The unit dosage of claim 243, which contains 0.5 mg of agonist.

245. The unit dosage of claim 243, which contains 1.0 mg of agonist.

246. The unit dosage of claim 243, which contains 1.5 mg of agonist.

247. The unit dosage of any of claims 243-246, suitable for injection, e.g., subcutaneous injection.

248. The unit dosage of any of claims 243-247, disposed in a delivery device suitable for injection, e.g., subcutaneous injection.

249. The unit dosage of any of claims 243-248, disposed in a syringe suitable for injection, e.g., subcutaneous injection.

250. The unit dosage of any of claims 243-249, wherein the agonist is Ac-Arg-c(Cys-D-Ala-His-D-Phe-Arg-Trp-Cys)-NH_2 (SEQ ID NO: 140).

251. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in a BBS1-19, or 20 gene.

252. The method of claim 96, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional BBS1-19, or 20 allele and one non-functional BBS1-19, or 20 allele.

253. The method of claim 96, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional BBS1-19, or 20 alleles, e.g., having a BBS1-19, or 20 null genotype.

254. The method of claim 96, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having a BBS1-19, or 20 null genotype.

255. The method of claim 64, wherein the disorder is characterized by one or mutations (e.g., loss of function mutations) in an ALMS1 gene.

256. The method of claim 255, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional ALMS1 allele and one non-functional ALM1 allele.

257. The method of claim 256, wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional ALMS1 alleles, e.g., having an ALMS1 null genotype.

258 The method of claim 256, wherein the subject is or is identified as being a homozygous carrier of the mutation(s), e.g., having an ALMS1 null genotype.

259. The method of claim 64, wherein the disorder is characterized by one or more mutations (e.g., loss of function mutations) in the BDNF, MCH1R, MCH, NTRK2,SIM1, ENPP1, COH1, CNR1, NPC1, c-MAF, PTER, FTO, TMEM18 (childhood), SDCCAG8, TNKS/MSRA, GNPDA2 (childhood), NEGr1, INSIG2, KCTD15, or NROB2 gene, or 16p11.2 deletions (including the SH2B1 gene).

260. The method of claim 250, wherein the subject is or is identified as being a heterozygous carrier of the mutation(s), e.g., having one functional allele and one non-functional allele of the BDNF, MCH1R, MCH, NTRK2,SIM1, ENPP1, COH1, CNR1, NPC1, c-MAF, PTER, FTO, TMEM18 (childhood), SDCCAG8, TNKS/MSRA, GNPDA2 (childhood), NEGr1, INSIG2, KCTD15, or NROB2 gene, or 16p11.2 deletions (including the SH2B1 gene).

261. The method of claim 250, , wherein the subject is or is identified as being a compound heterozygous carrier of the mutation(s), e.g., having two non-functional alleles, e.g., having a null genotype, of of the BDNF, MCH1R, MCH, NTRK2,SIM1, ENPP1, COH1, CNR1, NPC1, c-MAF, PTER, FTO, TMEM18 (childhood), SDCCAG8, TNKS/MSRA, GNPDA2 (childhood), NEGr1, INSIG2, KCTD15, or NROB2 gene, or 16p11.2 deletions (including the SH2B1 gene).

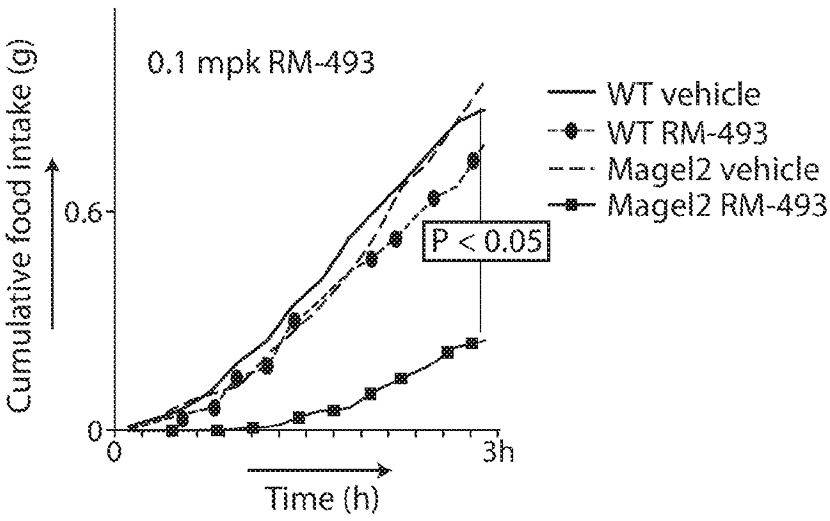
0.1 mpk RM-493
Cumulative food intake (g)
0.6
0
0
3h
Time (h)
P < 0.05
WT vehicle
WT RM-493
Magel2 vehicle
Magel2 RM-493

FIG. 1A

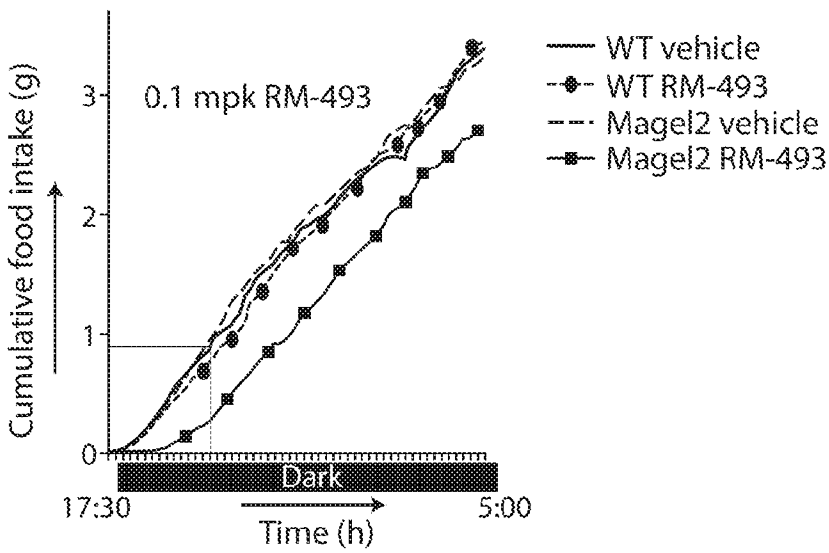
0.1 mpk RM-493
Cumulative food intake (g)
3
2
1
0
Dark
17:30
5:00
Time (h)
WT vehicle
WT RM-493
Magel2 vehicle
Magel2 RM-493

FIG. 1B

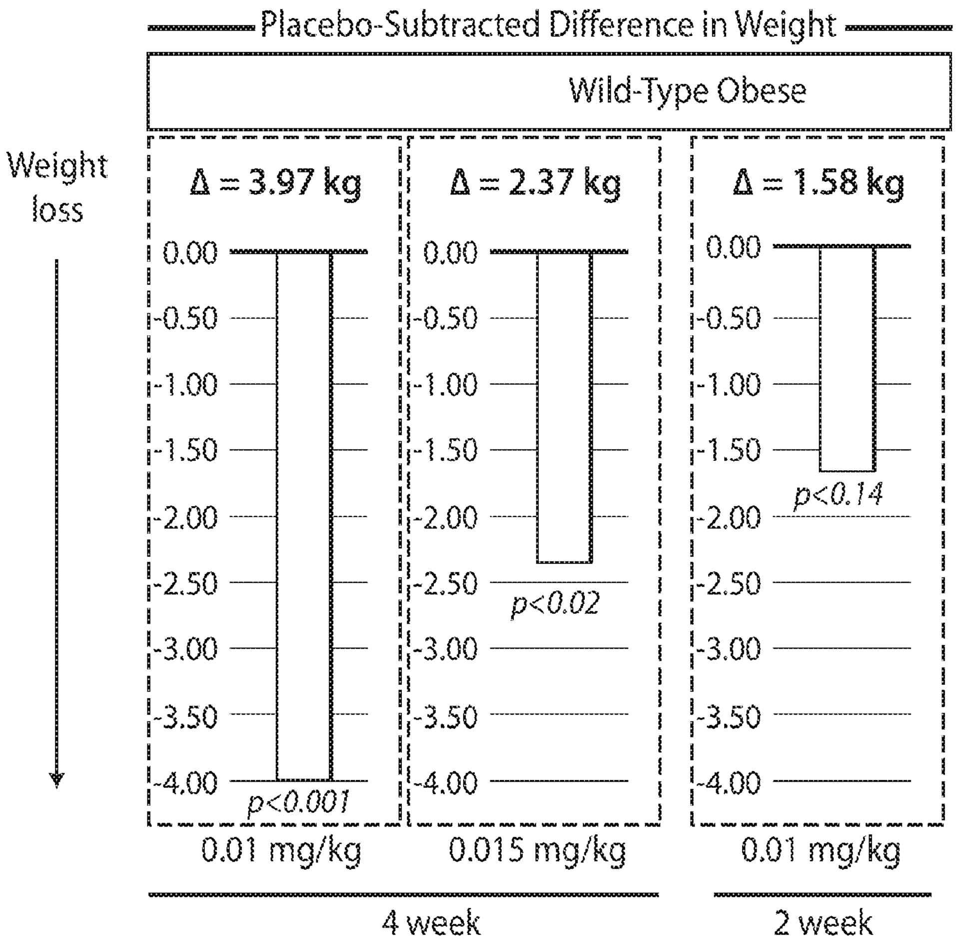
Placebo-Subtracted Difference in Weight
Wild-Type Obese
Weight loss
Δ = 3.97 kg
Δ = 2.37 kg
Δ = 1.58 kg
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
-4.00
p<0.001
p<0.02
p<0.14
0.01 mg/kg
0.015 mg/kg
0.01 mg/kg
4 week
2 week

FIG. 2

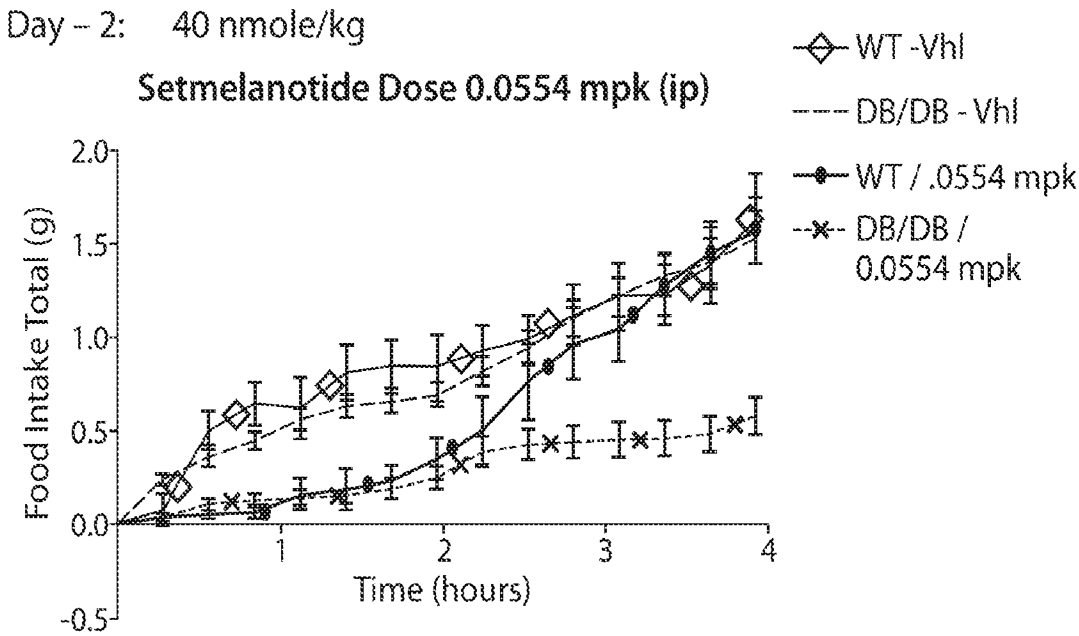
Day – 2: 40 nmole/kg
Setmelanotide Dose 0.0554 mpk (ip)
WT -Vhl
DB/DB - Vhl
WT / .0554 mpk
DB/DB / 0.0554 mpk
Food Intake Total (g)
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
Time (hours)

FIG. 3A

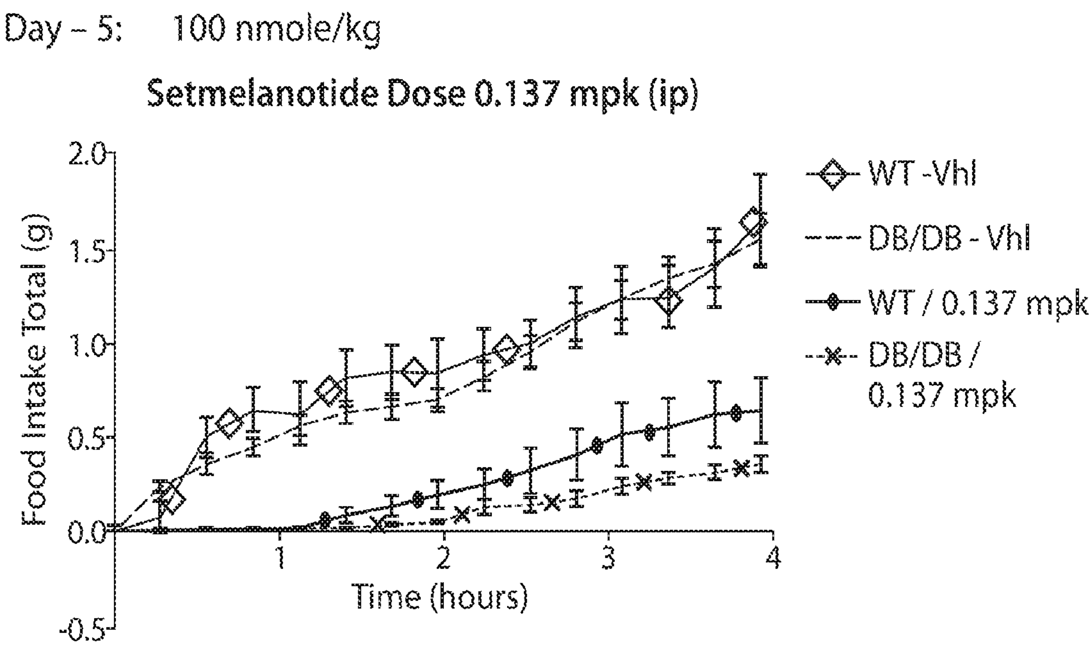
Day – 5: 100 nmole/kg
Setmelanotide Dose 0.137 mpk (ip)
WT -Vhl
DB/DB - Vhl
WT / 0.137 mpk
DB/DB / 0.137 mpk
Food Intake Total (g)
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4
Time (hours)

FIG. 3B

Day – 8: 250 nmole/kg

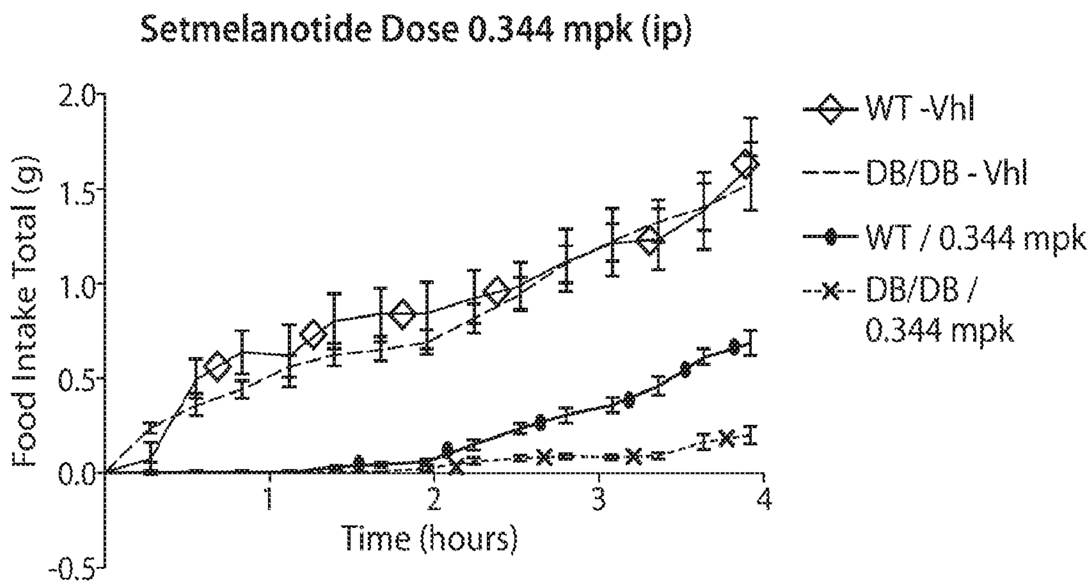

FIG. 3C

Day – 11: 1000 nmole/kg

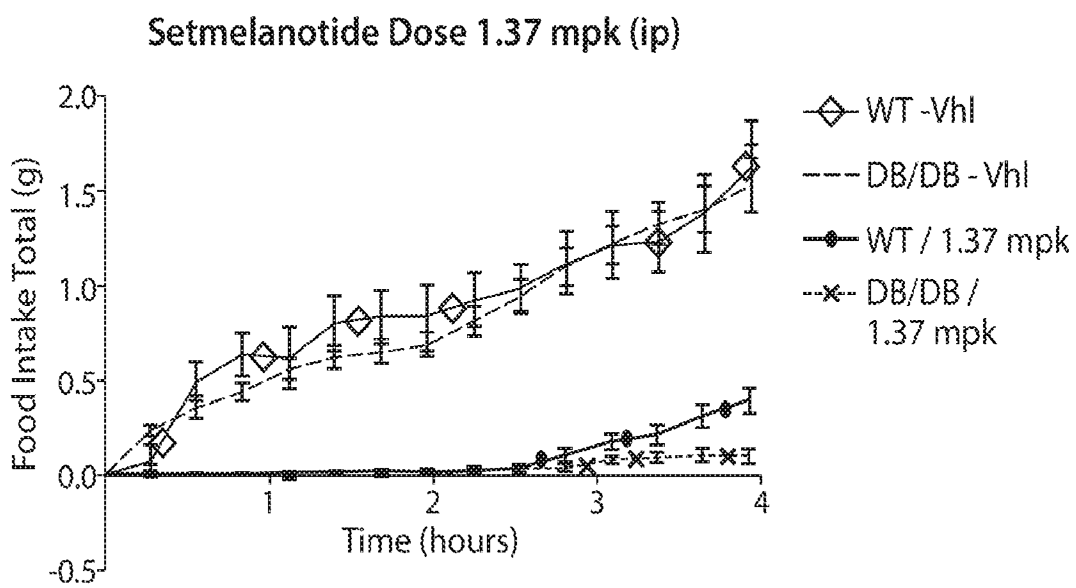

FIG. 3D

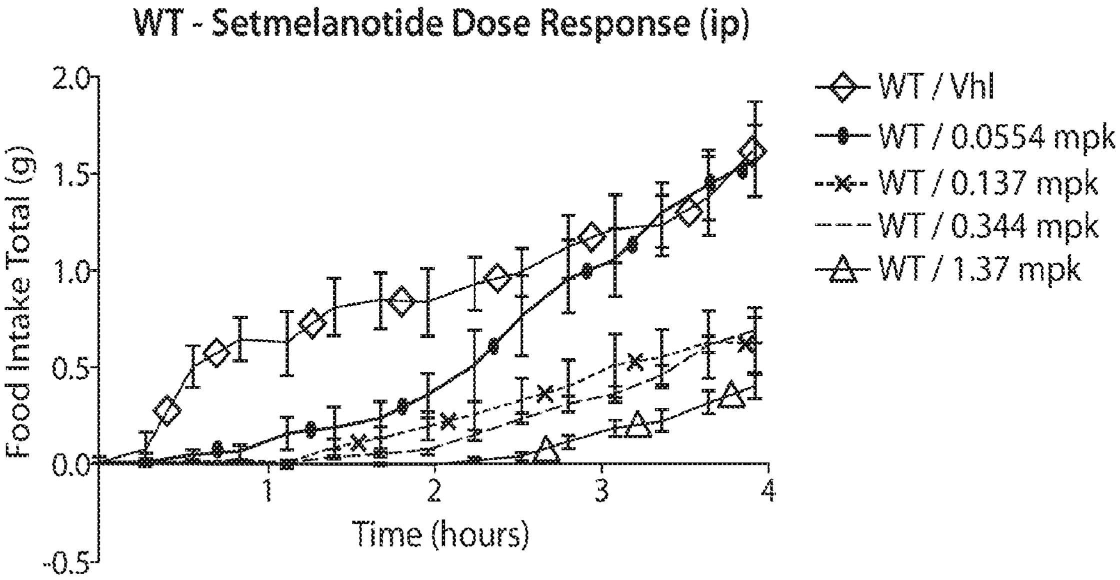
WT - Setmelanotide Dose Response (ip)
Food Intake Total (g)
Time (hours)
WT / Vhl
WT / 0.0554 mpk
WT / 0.137 mpk
WT / 0.344 mpk
WT / 1.37 mpk
2.0
1.5
1.0
0.5
0.0
-0.5
1
2
3
4

FIG. 3E

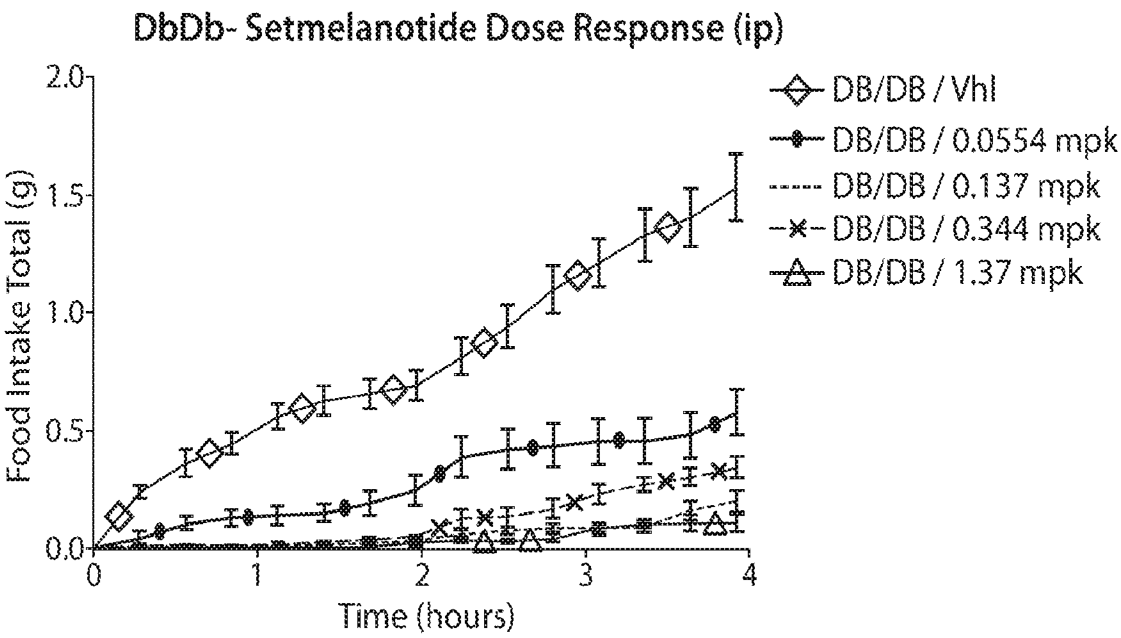
DbDb- Setmelanotide Dose Response (ip)
Food Intake Total (g)
Time (hours)
DB/DB / Vhl
DB/DB / 0.0554 mpk
DB/DB / 0.137 mpk
DB/DB / 0.344 mpk
DB/DB / 1.37 mpk
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4

FIG. 3F

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/054457

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K38/12 A61P3/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, BIOSIS, EMBASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Keith Gottesdiener: "2014 FPWR Research Conference", , 16 November 2014 (2014-11-16), pages 1-15, XP055319604, Retrieved from the Internet: URL:https://www.fpwr.org/wp-content/uploads/2014/11/Rhythm.ppt [retrieved on 2016-11-15] page 2 -----	1-67, 76-79, 110-170, 210-240

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 November 2016	14/02/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hars, Jesko

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Anonymous: "2014 FPWR Research Conference Foundation for Prader-Willi Research", , 1 November 2014 (2014-11-01), pages 1-8, XP055319658, Retrieved from the Internet: URL:https://www.fpwr.org/events/2014-fpwr-research-conference/ [retrieved on 2016-11-15] page 3	1-67, 76-79, 110-170, 178-181, 210-240
A	Anonymous: "Index of /wp-content/uploads/2014/11", , 22 November 2014 (2014-11-22), pages 1-23, XP055319662, Retrieved from the Internet: URL:https://www.fpwr.org/wp-content/uploads/2014/11/ [retrieved on 2016-11-15] page 23	1-67, 76-79, 110-170, 178-181, 210-240
X	Anonymous: "Rhythm Initiates Two Phase 2 Clinical Trials of Setmelanotide (RM-493) in Rare Genetic Disorders of Obesity Caused by MC4 Pathway Deficiencies - Rhythm Pharmaceuticals", , 4 June 2015 (2015-06-04), pages 1-2, XP055319670, Retrieved from the Internet: URL:http://www.rhythmtx.com/news-resources/press-releases/rhythm-initiates-two-phase-2-clinical-trials-of-setmelanotide-rm-493-in-rare-genetic-disorders-of-obesity-caused-by-mc4-pathway-deficiencies/ [retrieved on 2016-11-15] page 1	1-67, 76-79, 110-170, 178-181, 210-240
X,P	PETER KÜHNEN ET AL: "RM-493, a Melanocortin-4 Receptor (MC4R) Agonist, is Being Therapeutically Evaluated in Patients with Deficiencies in the Leptin - Proopiomelanocortin (POMC) - MC4R Hypothalamic Pathway, Including Prader-Willi Syndrome (PWS)", 54TH ANNUAL ESPE, 1 October 2015 (2015-10-01), page 58, XP055319732, page 58	1-67, 76-79, 110-170, 178-181, 210-240

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/102047 A1 (RHYTHM PHARMACEUTICALS INC [US]) 4 July 2013 (2013-07-04) page 2 -----	1-67, 76-79, 110-170, 178-181, 210-240
A	Anonymous: "Setmelanotide - Wikipedia", , 29 September 2015 (2015-09-29), pages 1-3, XP055319744, Retrieved from the Internet: URL:https://en.wikipedia.org/w/index.php?title=Setmelanotide&oldid=683313790 [retrieved on 2016-11-15] page 2 -----	1-67, 76-79, 110-170, 178-181, 210-240
X	WO 2014/144260 A1 (RHYTHM METABOLIC INC [US]) 18 September 2014 (2014-09-18) page 2 -----	1-67, 76-79, 110-170, 178-181, 210-240
X	Anonymous: "Rhythm: MC4/RM-493", , 17 August 2015 (2015-08-17), page 1, XP055319771, Retrieved from the Internet: URL:http://web.archive.org/web/20150817060354/http://www.rhythmtx.com/PROGRAMS/RM493.html [retrieved on 2016-11-15] page 1 -----	1-67, 76-79, 110-170, 178-181, 210-240
X	REBECCA E. MERCER ET AL: "Magel2 Is Required for Leptin-Mediated Depolarization of POMC Neurons in the Hypothalamic Arcuate Nucleus in Mice", PLOS GENETICS, vol. 9, no. 1, 17 January 2013 (2013-01-17), page e1003207, XP055321378, US ISSN: 1553-7390, DOI: 10.1371/journal.pgen.1003207 page e1003207 -----	1-67, 76-79, 110-170, 178-181, 210-240

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Anonymous: "Melanotan II - Wikipedia", , 15 March 2015 (2015-03-15), pages 1-3, XP055321390, Retrieved from the Internet: URL:https://de.wikipedia.org/w/index.php?title=Melanotan_II&oldid=139806007 [retrieved on 2016-11-21] page 1 -----	1-67, 76-79, 110-170, 178-181, 210-240
X	Anonymous: "NCT02311673 on 2015_08_03: ClinicalTrials.gov Archive", , 3 August 2015 (2015-08-03), pages 1-5, XP055321396, Retrieved from the Internet: URL:https://clinicaltrials.gov/archive/NCT02311673/2015_08_03 [retrieved on 2016-11-21] page 1 -----	1-67, 76-79, 110-170, 178-181, 210-240
A	CHRISTIAN P SCHAAF ET AL: "Truncating mutations of MAGEL2 cause Prader-Willi phenotypes and autism", NATURE GENETICS., vol. 45, no. 11, 1 November 2013 (2013-11-01), pages 1405-1408, XP055321420, NEW YORK, US ISSN: 1061-4036, DOI: 10.1038/ng.2776 page 1406 -----	1-67, 76-79, 110-170, 178-181, 210-240
X	Keith Gottesdiener: "Project Information 1R01FD005094-01A1", , 10 July 2015 (2015-07-10), pages 1-2, XP055321431, Retrieved from the Internet: URL:https://projectreporter.nih.gov/project_info_description.cfm?aid=8948091&icde=31996156 [retrieved on 2016-11-21] page 1 -----	1-67, 76-79, 110-170, 178-181, 210-240

International application No.
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INTERNATIONAL SEARCH REPORT

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-63, 65-67, 76-79, 178-181(completely); 64, 110-170, 210-240(partially)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-63, 65-67, 76-79, 178-181(completely); 64, 110-170, 210-240(partially)

   A method of treating Prader Willi Syndrome (PWS) in a subject in need thereof, comprising: administering an agonist of the melanocortin-4 receptor (MC4R), optionally (compare claim 170) at a daily dosage of about 0.1 mg to about 10 mg, wherein the agonist has the formula (I) of claim 1.

2-33. claims: 68-75, 80-109, 171-177, 182-209, 241, 242, 251-261(completely); 64, 110-170, 210-240(partially)

A method of treating a disorder in a subject in need thereof, comprising: administering an agonist of the melanocortin-4 receptor (MC4R), optionally (compare claim 170) at a daily dosage of about 0.1 mg to about 10 mg, wherein the agonist has the formula (I) of claims 64 or 170, wherein the disorder is (invention number in brackets):
(2) a disorder characterized by one or more mutations in the POMC gene or by a hypermethylated POMC gene;
(3) a disorder characterized by one or more mutations in the PCSK1 gene;
(4) a disorder characterized by one or more mutations in the leptin receptor gene;
(5) a disorder characterized by one or more mutations in the leptin gene;
(6) a disorder characterized by one or more mutations in the 5-HT2c receptor gene;
(7) a disorder characterized by one or more mutations in the nescient helix loop helix 2 (NhHL2) gene;
(8) a disorder characterized by one or more mutations in the pro-hormone convertase gene;
(9) a disorder characterized by one or more mutations in the carboxypeptidase E (CPE) gene;
(10) a disorder characterized by one or more mutations in the single-minded 1 (SIM1) gene;
a disorder characterized by one or more mutations in one of the following genes: BDNF (11), MCH1R (12), MCH (13), NTRK2 (14), ENPP1 (15), COH1 (16), CNR1 (17), NPC1 (18), c-MAF (19), PTER (20), FTO (21), TMEM18 (childhood) (22), SDCCAG8 (23), TNKS/MSRA (24), GNPDA2 (childhood) (25), NEGrl (26), INSIG2 (27), KCTD15 (28), NROB2 (29), or 16p11.2 deletions (including the SH2B 1 gene) (30);
(31) a disorder characterized by a defect in the POMC-MC4R pathway other than:
- any of inventions 1-30, 32, 33,
(e) a heterozygous POMC mutation characterized by the presence of one functional POMC allele and one non-functional POMC allele,
(f) a heterozygous leptin mutation characterized by the

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

presence of one functional leptin allele and one non-functional leptin allele,
(g) a melanocortin-4 receptor (MC4R) mutation (e.g., loss of function mutation),
(h) a pro-hormone convertase mutation (e.g., loss of function mutation);
(i) a mutation in a gene associated with Bardet-Biedl syndrome (e.g., a mutation in BBS1-BBS20);
(j) a mutation in a gene associated with Alström syndrome;
(32) a disorder characterized by one or more mutations in a gene associated with Bardet-Biedl syndrome;
(33) a disorder characterized by one or more mutations in a gene associated with Alström syndrome.

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34. claims: 243-250

A unit dosage of an agonist described herein, wherein the unit dosage contains 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 mg of the agonist [supposedly the agonist of formula (I) of claim 1].

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/054457

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013102047 A1	04-07-2013	CA 2862444 A1	04-07-2013
		EP 2797615 A1	05-11-2014
		US 2014329743 A1	06-11-2014
		WO 2013102047 A1	04-07-2013
WO 2014144260 A1	18-09-2014	AU 2014227712 A1	01-10-2015
		CA 2906694 A1	18-09-2014
		CN 105492456 A	13-04-2016
		EP 2970388 A1	20-01-2016
		JP 2016516719 A	09-06-2016
		US 2016017001 A1	21-01-2016
		WO 2014144260 A1	18-09-2014