



- (51) International Patent Classification:
A61P 25/06 (2006.01) A61K 39/395 (2006.01)
- (21) International Application Number:
PCT/US2016/027981
- (22) International Filing Date:
15 April 2016 (15.04.2016)
- (25) Filing Language:
English
- (26) Publication Language:
English
- (30) Priority Data:
62/148,550 16 April 2015 (16.04.2015) US
62/148,557 16 April 2015 (16.04.2015) US
62/148,562 16 April 2015 (16.04.2015) US
62/148,583 16 April 2015 (16.04.2015) US
62/148,596 16 April 2015 (16.04.2015) US
62/148,640 16 April 2015 (16.04.2015) US
62/148,643 16 April 2015 (16.04.2015) US

Washington 98133 (US). **BILLGREN, Jens, J.** [US/US]; 7309 Sand Point Way NE, #B948, Seattle, Washington 98115 (US).

- (72) Inventors: **KUBURAS, Adisa**; 1480 Harvest Street, North Liberty, Iowa 52317 (US). **MASON, Bianca**; 808 Benton Drive #13, Iowa City, Iowa 52246 (US). **SOWERS, Levi, P.**; 2526 Nevada Avenue, Iowa City, Iowa 52240 (US). **RUSSO, Andrew, F.**; 1762 Winston Drive, Iowa City, Iowa 52245 (US). **LOOMIS, Maria-Cristina**; 4807 196th Street, SE, Bothell, Washington 98012 (US). **DUTZAR, Benjamin, H.**; 511 NE 81st Street, Seattle, Washington 98115 (US). **GARCIA-MARTINEZ, Leon**; 4926 214th Street, SE, Woodinville, Washington 98072 (US).

(74) Agents: **TESKIN, Robin L.** et al.; Leclair Ryan, P.C., Intellectual Property Department, 2318 Mill Road, Suite 1100, Alexandria, Virginia 22314 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

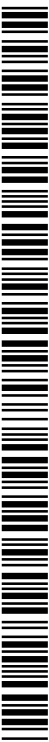
[Continued on next page]

(54) Title: USE OF ANTI-PACAP ANTIBODIES AND ANTIGEN BINDING FRAGMENTS THEREOF FOR TREATMENT, PREVENTION, OR INHIBITION OF PHOTOPHOBIA

Figure 1A
Antibody Variable Heavy Chain Protein Features
Sequence

Name	FR1	CDR1	FR2	CDR2
Ab10	QSVESGGRRLVTPGTPPLTLTCTVSGIDLN	SYMT	WVRQAPGKGLEWIG	FIDAGGJAYYASWAKG
Ab20	QSVESGGRRLVTPGTPPLTLTCTVSGIDLN	SYYS	WVRQAPGKGLEWIG	FIDTGSAYYATWAKG

(57) Abstract: This invention relates to methods of screening for anti-PACAP antibodies, or anti-PACAP receptor antibodies, and antigen binding fragments thereof, for potential use in treating or preventing PACAP-associated photophobia or light aversion, and therapeutic compositions containing and methods of using anti-PACAP antibodies, or anti-PACAP receptor antibodies, and antigen binding fragments thereof.



- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
- Published:**
- *with international search report (Art. 21(3))*
- *with sequence listing part of description (Rule 5.2(a))*

USE OF ANTI-PACAP ANTIBODIES AND ANTIGEN BINDING FRAGMENTS
THEREOF FOR TREATMENT, PREVENTION, OR INHIBITION OF PHOTOPHOBIA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 62/148,550, filed April 16, 2015, U.S. Provisional Application Ser. No. 62/148,557, filed April 16, 2015, U.S. Provisional Application Ser. No. 62/148,562, filed April 16, 2015, U.S. Provisional Application Ser. No. 62/148,596, filed April 16, 2015, U.S. Provisional Application Ser. No. 62/148,643, filed April 16, 2015, U.S. Provisional Application Ser. No. 62/148,583, filed April 16, 2015, U.S. Provisional Application Ser. No. 62/148,640, filed April 16, 2015, each of which is hereby incorporated by reference in its entirety.

SEQUENCE DISCLOSURE

[0002] This application includes as part of its disclosure an electronic sequence listing text file named "43257o6401.txt", having a size of 98,314 bytes and created on February 25, 2016, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0003] This invention generally pertains to *in vivo* screening assays for identification of agents able to treat or prevent photophobia, as well as antibodies and antigen binding fragments thereof, preferably humanized, chimerized, and human antibodies and antigen binding fragments thereof, and compositions containing such antibodies and antigen binding fragments thereof, wherein such antibodies and antigen binding fragments thereof specifically bind to Pituitary Adenylate Cyclase-Activating Polypeptide ("PACAP") and therapeutic and diagnostic uses for the antibodies, antigen binding fragments, and compositions thereof.

BACKGROUND

[0004] Pituitary Adenylate Cyclase-Activating Polypeptide ("PACAP") is a member of the secretin/vasoactive intestinal peptide ("VIP")/growth hormone-releasing hormone ("GHRH") family. PACAP is a multifunctional vasodilatory peptide that exists in two α -amidated active forms, one with 38 amino acids (PACAP38; SEQ ID NO: 1241) and the other with 27 amino

acids (PACAP27; SEQ ID NO: 1242). Both peptides have the same N-terminal 27 amino acids and are synthesized from the same precursor protein, preproPACAP (See, Moody et al., *Curr. Opin. Endocrinol. Diabetes Obes.*, 18(1):61-67, 2011). PACAP38 is the more prevalent active form, representing up to 90% of PACAP forms in mammalian tissues (See, Kaiser and Russo, *Neuropeptides*, 47:451-461, 2013). The sequence of PACAP38 is identical in all mammals and differs from the avian and amphibian orthologs by only one amino acid (See, Vaudry et al., *Pharmacol. Rev.*, 52:269-324, 2000). The secretin/VIP/GHRH family includes mammalian peptide histidine methionamide ("PHM"), secretin, glucagon, glucagon-like peptide-1 ("GLP1"), glucagon-like peptide-2 ("GLP2"), glucose-dependent-insulinotropic polypeptide ("GIP"), and growth-hormone-releasing-factor ("GRF"). PACAP27 has 68% sequence identity to VIP at the amino acid level (See, Vaudry et al. 2000).

[0005] PACAP is widely distributed in the brain and peripheral organs, e.g., the endocrine system, gonads, sympathetic neurons, respiratory system, gastrointestinal tract, cardiovascular system, and urogenital tracts (See, Schytz et al., *Neurotherapeutics*, 7:191-196, 2010). In particular, PACAP is expressed throughout the nervous system, including a presence in the trigeminovascular system, trigeminal ganglia, spinal cord, hypothalamus, and pituitary. PACAP has roles in neurodevelopment, neuroprotection, neuromodulation, neurogenic inflammation, and nociception with multiple actions (See, Kaiser and Russo (2013)).

[0006] Consistent with its widespread distribution, PACAP exerts pleiotropic effects including modulation of neurotransmitter release, vasodilation, bronchodilation, and activation of intestinal motility, increase of insulin and histamine secretion, as well as stimulation of cell proliferation and/or differentiation. PACAP has been shown to act as a hormone, a neurohormone, a neurotransmitter, and a trophic factor in a number of tissues (See, Vaudry et al., *Pharmacological Rev.*, 52(2):269-324, 2000).

[0007] The biological effects of PACAP are mediated via three different G-protein coupled receptors: PAC1-R, vasoactive intestinal peptide receptor type 1 ("VPAC1-R"), and vasoactive intestinal peptide receptor type 2 ("VPAC2-R"). These receptors are expressed in diverse tissues. PAC1-R is particularly abundant in the nervous system (e.g., olfactory bulb, thalamus, hypothalamus, cerebellum, and spinal dorsal horn), pituitary, and adrenal glands. By contrast, VPAC1-R and VPAC2-R are expressed mainly in the lung, liver, and testis, although they have been detected in other tissues as well. VPAC1-R expression has been detected in the nervous system (e.g., cerebral cortex and hippocampus), smooth muscle cells of lung, liver, intestine, megakaryocytes, and platelets. VPAC1-R associates with receptor-

associated membrane protein ("RAMP", specifically RAMP2) (See, Christopoulos et al., *J. Biol. Chem.*, 278:3293-3297, 2002). VPAC2-R expression profile includes the nervous (e.g., thalamus, hippocampus, brain stem, and dorsal root ganglia ("DRG")), cardiovascular system, gastrointestinal system, pancreas, and reproductive systems (See, Usdin et al., *Endocrin.*, 135:2662-2680, 1994; Sheward et al., *Neurosci.*, 67:409-418, 1995).

[0008] PAC1-R is selective for PACAP38 and PACAP27. In particular, PAC1-R binds to PACAP with 100-1000-fold greater affinity than VIP, i.e., $K_D \sim 0.5$ nM for PACAP27/PACAP38 vs. $K_D \sim 500$ nM for VIP. Conversely, VPAC1-R and VPAC2-R have equal affinities for PACAP and VIP ($K_D \sim 1$ nM) (See Schytz et al. (2010)).

[0009] Upon activation, these receptors are all capable of causing downstream production of cyclic adenosine monophosphate ("cAMP"), and/or activation of phospholipase C ("PLC"), and/or modulation of phospholipase D ("PLD"). In particular, PAC1-R is coupled to dual signal transduction pathways acting through cAMP and Ca^{2+} , whereas VPAC1-R and VPAC2-R are coupled principally to adenylyl cyclase. PAC1-R is coupled to G_s protein, which activates adenylyl cyclase to form cAMP that in turn activates protein kinase A. PAC1-R also couples to G_q and thereby activates PLC, which produces inositol phosphate, which increases cytosolic calcium release from intra-cellular calcium stores. There is some evidence for a role of PAC1-R in PLD activation (See McCulloch et al., *Ann. N. Y. Acad. Sci.*, 921:175-185, 2000). Another PACAP signaling pathway results in the elevation of intra-cellular sodium levels via activation of nonselective cation channels (See Roy et al., *American Journal of Physiology: Regulatory, Integrative and Comparative Physiology*, 304(12):R1070-R1084, 2013).

[0010] PACAP is hypothesized to play a role in a multitude of diseases and disorders, including but not limited to migraine, headache, and pain, though such a role for PACAP has not been clinically demonstrated. Migraines are believed to have a neurovascular component. Migraines affect approximately 10% of the adult population in the U.S. and are typically accompanied by intense headaches. Approximately 20-30% of migraine sufferers experience aura, comprising focal neurological phenomena that precede and/or accompany the event. A role for PACAP in migraine has been suggested by several observations: (1) plasma levels of PACAP are elevated during migraine attacks (ictal), as compared to interictal levels, in humans (see, Tuka et al., *Cephalalgia*, 33(13):1085-1095, 2013); (2) an infusion of PACAP38 triggered headaches in healthy subjects, and headaches followed by migraine-like attacks in migraineurs (see, Schytz et al., *Brain*, 132:16-25 2009; and Amin et al., *Brain*, 137:779-794, 2014, respectively); (3) PACAP-induced vasodilation may play a role in

neurogenic inflammation (*see*, Kaiser and Russo, *Neuropeptides*, 47:451-461, 2013); and (4) PACAP-induced migraines are associated with photophobia, phonophobia, nausea, and respond to triptans (*see*, Amin et al., *Brain*, 32:140-149 2012). PACAP has also been shown to induce vasodilation, photophobia, as well as mast cell degranulation and neuronal activation (*See*, Markovics et al., *Neurobiology of Disease*, 45:633-644 2012; Baun et al., *Cephalalgia*, 32(4):337-345, 2012; Chan et al., *Pharmacology & Therapeutics*, 129:332-351, 2011).

[0011] One effective treatment for migraines is the administration of triptans, which are a family of tryptamine-based drugs, including sumatriptan and rizatriptan. Members of this family have an affinity for multiple serotonin receptors, including 5-HT_{1B}, 5-HT_{1D}, and 5-HT_{1F}. Members of this family of drugs selectively constrict cerebral vessels, but also cause vasoconstrictive effects on coronary vessels (*See* Durham, *New Eng. J. Med.*, 350 (11):1073-75, 2004). There is a theoretical risk of coronary spasm in patients with established heart disease following administration, and cardiac events after taking triptans in rare instances may occur. Accordingly, they are contraindicated for some patients with coronary vascular disease.

[0012] Similarly, pain may often be addressed through the administration of certain narcotics or non-steroidal anti-inflammatory drugs ("NSAIDs"). However, the administration of these treatments often has negative consequences. NSAIDs have the potential to cause kidney failure, intestinal bleeding, and liver dysfunction. Narcotics have the potential to cause nausea, vomiting, impaired mental functioning, and addiction. Therefore, it is desirable to identify alternative treatments for pain in order to avoid certain of these negative consequences.

[0013] PACAP may also be involved in diseases and disorders other than migraine, headache, and pain. For example, PACAP may correlate to or even play a causal role in anxiety disorders (WO 2012/106407); thrombocytopenia (WO 2004/062684); and inflammatory skin diseases (WO 2010/007175). PACAP and PAC1-R polymorphisms are associated with post-traumatic stress syndrome ("PTSD") in females, major depressive disorder, and generalized anxiety disorder, suggesting a role for PACAP in these conditions. Further, supporting a role for PACAP in thrombocytopenia, trisomy 18 patients have excess PACAP and exhibit defective megakaryocyte maturation (*See*, Schytz et al. 2010; and Moody et al., *Curr. Opin. Endocrinol. Diabetes Obes.*, 18(1):61-67, 2011).

[0014] Also, PACAP and other neuropeptides, such as Calcitonin Gene-Related Peptide ("CGRP"), substance P, neurokinin A, bradykinin, and endothelin-1, are expressed in the

lower urinary tract (“LUT”) (*see*, Arms and Vizzard, *Handbook Exp. Pharmacol.*, 202:395-423 2011) and reportedly may play a role in LUT dysfunction and urinary tract disorders such as urinary tract infection (“UTI”), abnormal voiding, urinary urgency, nocturia, urinary incontinence, overactive bladder, and the pain associated with such conditions.

[0015] PACAP and PACAP receptors have also been suggested to modulate inflammatory and neuropathic pain and have been implicated in both pronociception and antinociception (*See*, Davis-Taber et al., *J. Pain*, 9(5):449-56 2008). PACAP has also been reported to be required for spinal desensitization and the induction of neuropathic pain (*See*, Mabuchi et al., *J. Neurosci.*, 24(33):7283-91, 2004). Additionally, morphine withdrawal behavior is reportedly modified in PACAP-receptor deficient mice further suggesting the role of PACAP in morphine withdrawal anxiolytic response (*See*, Martin et al., *Mol. Brain Res.*, 110(1):109-18 2003).

BRIEF SUMMARY OF THE INVENTION

[0016] In one aspect, the present invention in general relates to a method of screening for an antibody or antigen binding fragment that may be suitable for use in treating or preventing Pituitary Adenylate Cyclase-Activating Peptide (PACAP)-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, in a subject in need thereof, which may comprise:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering PACAP to the at least one first test subject and the at least one second test subject;
- (iii) further administering to the at least one first test subject one or more anti-PACAP antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, or an antigen binding fragment of any of the foregoing;
- (iv) comparing the response of the at least one first test subject and at least one second test subject to light; and
- (v) based on this comparison, identifying one or more antibodies or antigen binding fragments thereof that yield a decreased light aversion or decreased photophobia in the at least one first test subject as compared with the at least one second test subject, thereby identifying an antibody or antigen binding fragment suitable for use in treating or preventing

PACAP-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion in a subject in need thereof.

[0017] In certain embodiments, the invention embraces a method of administering one or more antibodies or antigen binding fragments may comprise administering at least one anti-PACAP antibody or antigen binding fragment thereof. In another embodiment, the invention relates to a method of administering one or more antibodies or antigen binding fragments that may comprise administering at least one anti-PAC1-R antibody or antigen binding fragment thereof. The invention may also generally pertain to a method wherein the efficacy of the one or more antibodies or antigen binding fragments for inhibiting PACAP-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, may be confirmed in a human subject. Moreover, another aspect of the invention relates to a method wherein at least one first test subject and at least one second test subject may be different subjects.

[0018] Furthermore, the invention generally embraces a method of screening for an antibody or antigen binding fragment thereof that may be suitable for use in treating or preventing Pituitary Adenylate Cyclase-Activating Peptide (PACAP)-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, in a subject in need thereof, which may comprise:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering to the at least one first test subject one or more anti-PACAP antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, preferably at least one anti-PACAP antibody and/or at least one anti-PAC1-R antibody, or an antigen binding fragment of any of the foregoing;
- (iii) administering PACAP to the at least one first test subject and the at least one second test subject;
- (iv) comparing the response of the at least one first test subject and at least one second test subject to light; and
- (v) based on this comparison, identifying antibodies or antigen binding fragments that yield decreased photophobia or decreased light aversion in the at least one first test subject as compared with the at least one second test subject, identifying an antibody or antigen binding fragment suitable for use in treating or preventing PACAP-associated photophobia or light

aversion, or identifying an antibody or antigen binding fragment suitable for precluding the onset of PACAP-associated photophobia or light aversion, in a subject in need thereof.

[0019] Moreover, the invention relates to a method wherein administering one or more antibody or antigen binding fragments may comprise administering one or more anti-PACAP antibodies or antigen binding fragments thereof. Furthermore, one aspect of the invention generally pertains to a method wherein administering the one or more antibody or antigen binding fragments may comprise administering one or more anti-PAC1-R antibodies or antigen binding fragments thereof. In another embodiment, the invention embraces a method wherein the efficacy of one or more antibodies or antigen binding fragments for inhibiting PACAP-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, may be confirmed in a human subject. Additionally, the invention relates to a method wherein the at least one first test subject and/or the at least one second test subject of any of the methods disclosed herein may be a mammal, e.g., wherein the at least one first test subject and/or at least one second test subject may be a mouse, monkey, rabbit, human, rat, guinea pig, dog, or hamster. Furthermore, said monkey may be a macaque, marmoset, tamarin, spider monkey, owl monkey, vervet monkey, squirrel monkey, or baboon. Additionally, the invention generally relates to a method wherein the at least one first test subject of any of the methods disclosed herein or at least one second test subject of any of the methods disclosed herein may be a mouse, e.g., a CD1 mouse. The invention also embraces any of the methods disclosed herein wherein the identified antibody or antigen binding fragment thereof may specifically bind PACAP.

[0020] In an additional embodiment, the invention relates to a method that may comprise adapting the identified antibody or antigen binding fragment for use in treating a subject who may suffer from one or more of migraine, hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, secondary headaches due to an underlying structural problem in the head or neck, cranial neuralgia, sinus headaches, allergy-induced headaches, headache, or other migraine condition. Additionally, said subject of any of the methods disclosed herein may have an ocular disorder associated with photophobia that may be selected from one or more of achromatopsia, aniridia, photophobia caused by an anticholinergic drug, aphakia (absence of the lens of the eye), buphthalmos (abnormally narrow angle between the cornea and iris), cataracts, cone dystrophy, congenital abnormalities of the eye, viral conjunctivitis ("pink eye"), corneal abrasion, corneal dystrophy, corneal ulcer, disruption of the corneal epithelium, ectopia lentis, endophthalmitis, eye trauma caused by disease, injury, or infection such as chalazion, episcleritis, glaucoma,

keratoconus, or optic nerve hypoplasia, hydrophthalmos, or congenital glaucoma Iritis, optic neuritis, pigment dispersion syndrome, pupillary dilation (naturally or chemically induced), retinal detachment, scarring of the cornea or sclera, and uveitis. Also, said subject of any of the methods disclosed herein may have a nervous-system-related or neurological condition associated with photophobia selected from one or more of autism spectrum disorders, chiari malformation, dyslexia, encephalitis including myalgic encephalomyelitis (chronic fatigue syndrome), meningitis, subarachnoid hemorrhage, tumor of the posterior cranial fossa, ankylosing spondylitis, albinism, ariboflavinosis, benzodiazepines (long term use of or withdrawal from benzodiazepines), chemotherapy, chikungunya infection, cystinosis, Ehlers-Danlos syndrome, hangover, influenza infection, infectious mononucleosis, magnesium deficiency, mercury poisoning, migraine, rabies, and tyrosinemia type II (Richner-Hanhart syndrome). Furthermore, said subject of any of the methods disclosed herein may have a photophobia associated disorder that may be selected from one or more of migraine (with or without aura), iritis, uveitis, meningitis, depression, bipolar disorder, cluster headache or another trigeminal autonomic cephalalgia or blepharospasm, depression, post-traumatic stress syndrome (PTSD) traumatic brain injury, and agoraphobia. In a further embodiment, the invention relates to a method wherein the at least one first subject and/or at least one second subject may suffer from migraine headaches. Yet another embodiment of the invention relates to a method wherein the one or more antibodies or antigen binding fragments thereof may be for use in combination with another active agent for treating migraine. Also, the invention generally pertains to a method wherein the identified antibody or antigen binding fragment thereof may be for use as a monotherapy. For example, said antibody or antigen binding fragment thereof may be for use in combination with another active agent effective for treating migraine, wherein antibody and active agent may be for joint or separate administration. Also, said antibody or fragment thereof may be for use in treating subjects suffering from migraines, in combination with one or more of an analgesic, a triptan, a topiramate, a dihydroergotamine, and an opioid.

[0021] The invention also embraces any of the methods disclosed herein wherein anti-PACAP antibodies or antigen binding fragments thereof identified in the disclosed methods, comprise human, humanized, or chimerized anti-PACAP antibodies or antigen binding fragments, which comprise (a) a variable heavy chain comprising a CDR1 sequence consisting of SEQ ID NO: 404; a CDR2 sequence consisting of SEQ ID NO: 406; and a CDR3 sequence consisting of SEQ ID NO: 408; and/or (b) a variable light chain comprising a CDR1 sequence consisting of SEQ ID NO: 424; a CDR2 sequence consisting of SEQ ID

NO: 426; and a CDR3 sequence consisting of SEQ ID NO: 428. In a more specific embodiment, selected anti-PACAP antibodies and antigen binding fragments may comprise (a) a variable heavy chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 402, and/or (b) a variable light chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 422. In another specific embodiment, selected anti-PACAP antibodies and antigen binding fragments may comprise (a) a variable heavy chain having the amino acid sequence of SEQ ID NO: 402, and/or (b) a variable light chain having the amino acid sequence of SEQ ID NO: 422. In another specific embodiment, selected anti-PACAP antibodies and antigen binding fragments may comprise (a) a heavy chain having the amino acid sequence of SEQ ID NO: 401, and/or (b) a light chain having the amino acid sequence of SEQ ID NO: 421.

[0022] The invention also embraces any of the methods disclosed herein wherein anti-PACAP antibodies and antigen binding fragments thereof identified by the disclosed methods, preferably human, humanized, or chimerized anti-PACAP antibodies or antigen binding fragments, may comprise (a) a variable heavy chain comprising a CDR1 sequence consisting of SEQ ID NO: 444; a CDR2 sequence consisting of SEQ ID NO: 446; and a CDR3 sequence consisting of SEQ ID NO: 448; and/or (b) a variable light chain comprising a CDR1 sequence consisting of SEQ ID NO: 464; a CDR2 sequence consisting of SEQ ID NO: 466; and a CDR3 sequence consisting of SEQ ID NO: 468. In a further specific embodiment, selected anti-PACAP antibodies and antigen binding fragments thereof may comprise (a) a variable heavy chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 442, and/or (b) a variable light chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 462. In another specific embodiment, selected anti-PACAP antibodies and antigen binding fragments thereof may comprise (a) a variable heavy chain having the amino acid sequence of SEQ ID NO: 442, and/or (b) a variable light chain having the amino acid sequence of SEQ ID NO: 462. In another specific embodiment, selected anti-PACAP antibodies and antigen binding fragments thereof may comprise (a) a heavy chain having the amino acid sequence of SEQ ID NO: 441, and/or (b) a light chain having the amino acid sequence of SEQ ID NO: 461.

[0023] Additionally, another aspect of the invention generally relates to any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may comprise: a light chain and/or a heavy chain, which has a framework (FR) region and one or more

Complementary Determining Region(s) (CDR), and wherein one or more of the FR or CDR residues in the light chain and/or heavy chain may be substituted with another amino acid residue. Also, the invention pertains to any of the methods disclosed herein wherein the antibody or fragment thereof may be a humanized antibody or fragment thereof; and/or wherein the antibody or fragment thereof may be a chimeric antibody or fragment thereof; and/or wherein the antibody or fragment thereof may comprise a single chain antibody or fragment thereof. Said chimeric antibody or fragment thereof according to the invention may comprise a human Fc, e.g., wherein the human Fc may be derived from IgG1, IgG2, IgG3, or IgG4.

[0024] Furthermore, the invention generally pertains to any of the methods disclosed herein wherein anti-PACAP antibodies or fragments thereof may comprise a polypeptide sequence that may have at least 90% or greater homology to two of the polypeptide sequences of the invention. Additionally, the invention relates to any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may comprise a polypeptide sequence having at least 95% or greater homology to any one of the polypeptide sequences of the invention.

[0025] Moreover, another aspect of the invention embraces any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may bind to PACAP with a binding affinity (K_D) of less than or equal to 5×10^{-5} M, 10^{-5} M, 5×10^{-6} M, 10^{-6} M, 5×10^{-7} M, 10^{-7} M, 5×10^{-8} M, 10^{-8} M, 5×10^{-9} M, 10^{-9} M, 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, 10^{-12} M, 5×10^{-13} M, or 10^{-13} M, as determined by ELISA, bio-layer interferometry ("BLI"), KINEXA, or surface plasmon resonance at 25°C or 37°C. Furthermore, the invention embraces a method wherein the anti-PACAP antibody or fragment thereof may bind to PACAP with a K_D that may be less than about 100 nM, less than about 40 nM, less than about 1 nM, less than about 100 pM, less than about 50 pM, or less than about 25 pM, and/or wherein the anti-PACAP antibody or fragment thereof may bind to PACAP with a K_D that may be between about 10 pM and about 100 pM.

[0026] Another embodiment of the invention relates to any of the methods disclosed herein wherein the antibody or fragment thereof may be entirely non-glycosylated, or may lack N-glycosylation, or may contain only mannose residues. An additional embodiment of the invention pertains to any of the methods disclosed herein wherein the antibody or fragment thereof may contain an Fc region that may be modified to alter effector function, half-life, proteolysis, and/or glycosylation. The invention additionally embraces any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may specifically bind to circulating soluble PACAP molecules *in vivo*. An additional embodiment of the invention

encompasses any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may specifically bind to PACAP27 and/or PACAP38.

[0027] In yet another embodiment, the invention embraces any of the methods disclosed herein wherein the affinity of said anti-PACAP antibody or fragment thereof for PACAP may be at least 10-fold, 30-fold, 100-fold, 300-fold, 1000-fold, 3000-fold, 10000-fold, 30000-fold, 100000-fold, 300000-fold, 1000000-fold, 3000000-fold, 10000000-fold, 30000000-fold or more stronger than the affinity of said anti-PACAP antibody and antigen binding fragment to VIP. Also, the invention pertains to any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may (a) inhibit or neutralize at least one biological effect elicited by PACAP; (b) neutralize or inhibit PACAP activation of at least one of PAC1-R, VPAC1-R and/or VPAC2-R; (c) neutralize or inhibit PACAP activation of each of PAC1-R, VPAC1-R and VPAC2-R; (d) neutralize or inhibit PACAP activation of PAC1-R; (e) inhibits PACAP binding to at least one of PAC1-R, VPAC1-R and/or VPAC2-R; (f) inhibits PACAP binding to each of PAC1-R, VPAC1-R and/or VPAC2-R; (g) inhibits PACAP binding to PAC1-R; and/or (h) inhibits PACAP-induced cAMP production. Additionally, the invention encompasses any of the methods disclosed herein wherein the anti-PACAP antibody or fragment thereof may inhibit the association of PACAP with one or more PACAP receptors including PAC-1R, VPAC1-R, and/or VPAC2-R.

[0028] An additional embodiment of the invention embraces any of the methods disclosed herein wherein the antibody or fragment thereof may be administered intramuscularly, subcutaneously, intravenously, rectally, by infusion, orally, transdermally, or by inhalation. Also, the invention relates to any of the methods disclosed herein wherein the antibody or fragment thereof may be administered intravenously. Also, the invention encompasses any of the methods disclosed herein wherein the antibody or fragment thereof may be administered with an additional therapeutic agent or regimen selected from anti-histamines, anti-inflammatory agents, and antibiotics. Also, another embodiment of the invention pertains to any of the methods disclosed herein wherein the antibody or fragment thereof may be directly or indirectly attached to a detectable label or therapeutic agent. The invention further relates to any of the methods disclosed herein wherein the antibody or fragment thereof may further comprise an effector moiety. Said effector moiety may be a detectable moiety or a functional moiety, e.g., wherein said detectable moiety may be a fluorescent dye, an enzyme, a substrate, a bioluminescent material, a radioactive material, or a chemiluminescent material, or said functional moiety may be streptavidin, avidin, biotin, a cytotoxin, a cytotoxic agent, or a radioactive material.

[0029] Another aspect of the invention generally relates to a method of assessing the potential *in vivo* efficacy of a candidate anti-Pituitary Adenylate Cyclase-Activating Peptide (PACAP) antibody, an anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibody, and antigen binding fragment thereof for treating PACAP-associated photophobia or light aversion, that may comprise determining whether the antibody or fragment thereof may inhibit or diminish light aversion behavior in a rodent administered PACAP, as compared to a rodent administered PACAP in the presence of one or more of the candidate anti-PACAP, anti-PAC1-R antibody or fragment thereof. For example, said method of assessment may be used to assess whether the antibody or fragment thereof may be effective for treatment of a neurological condition characterized by increased PACAP levels, and/or said method of assessment may be used to assess whether the antibody or fragment thereof may be effective for treatment of migraine, menstrual migraine, or chronic migraine. Additionally, said method of assessment may be used to assess whether the antibody or fragment thereof may be effective for treatment of migraines (with or without aura), weight loss, cancer or tumors, angiogenesis associated with cancer or tumor growth, angiogenesis associated with cancer or tumor survival, hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, general headaches, headache-free migraine, abdominal migraine, hot flashes, chronic paroxysmal hemicrania, secondary headaches caused by an underlying structural problem in the head or neck, cranial neuralgia, sinus headaches, allergy-induced headaches or allergy-induced migraines, pain, inflammatory pain, post-operative incision pain, complex regional pain syndrome, cancer pain, primary or metastatic bone cancer pain, fracture pain, osteoporotic fracture pain, pain resulting from burn, osteoporosis, gout joint pain, pain associated with sickle cell crises, nociceptive pain, hepatocellular carcinoma, breast cancer, liver cirrhosis, neurogenic pain, neuropathic pain, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, menstrual pain, ovarialgia, reflex sympathetic dystrophy, neurogenic pain, osteoarthritis or rheumatoid arthritis pain, lower back pain, diabetic neuropathy, sciatica, visceral pain associated with gastro-esophageal reflux, dyspepsia, irritable bowel syndrome, inflammatory bowel disease, Crohn's disease, ileitis, ulcerative colitis, renal colic, dysmenorrhea, cystitis, menstrual period, labor, menopause, prostatitis, or pancreatitis.

[0030] An additional embodiment of the invention relates to any of the methods disclosed herein wherein any of said methods may further comprise administering an additional active agent selected from a beta-blocker, flunarizine, valproic acid, topiramate, amitriptyline, venlafaxine, gabapentin, naproxen, butterbur root, vitamin B2, and/or magnesium. Also, said

additional active agent may be selected from agonists, antagonists, and modulators of TNF- α , IL-2, IL-4, IL-6, IL-10, IL-12, IL-13, IL-18, IFN- α , IFN- γ , BAFF, CXCL13, IP-10, VEGF, EPO, EGF, HRG, Hepatocyte growth Factor (HGF), hepcidin, antibodies reactive against any of the foregoing, and antibodies reactive against any of their receptors. Yet another embodiment of the invention embraces any of the methods disclosed herein wherein any of said methods may further comprise administering analgesics, anti-histamines, antipyretics, anti-inflammatories, antibiotics, antivirals, and/or anti-cytokine agents.

[0031] An additional embodiment of the invention relates to any of the methods disclosed herein wherein any of said methods may further comprise administering an active agent that may be selected from one or more of the following: 2-arylpropionic acids, aceclofenac, acemetacin, acetylsalicylic acid, alclofenac, alminoprofen, amoxiprin, ampyrone, arylalkanoic acids, azapropazone, benorylate/benorilate, benoxaprofen, bromfenac, carprofen, celecoxib, choline magnesium salicylate, clofezone, COX-2 inhibitors, dexibuprofen, dexketoprofen, diclofenac, diflunisal, droxicam, ethenzamide, etodolac, etoricoxib, faislamine, fenamic acids, fenbufen, fenoprofen, flufenamic acid, flunoxaprofen, flurbiprofen, ibuprofen, ibuproxam, indomethacin, indoprofen, kebuzone, ketoprofen, ketorolac, lomoxicam, loxoprofen, lumiracoxib, magnesium salicylate, meclofenamic acid, mefenamic acid, meloxicam, metamizole, methyl salicylate, mofebutazone, nabumetone, naproxen, N-arylanthranilic acids, Nerve Growth Factor (NGF), oxametacin, oxaprozin, oxicams, oxyphenbutazone, oxytocin, parecoxib, phenazone, phenylbutazone, phenylbutazone, piroxicam, pirprofen, profens, proglumetacin, pyrazolidine derivatives, rofecoxib, salicyl salicylate, salicylamide, salicylates, substance P, sulfinpyrazone, sulindac, suprofen, tenoxicam, tiaprofenic acid, tolfenamic acid, tolmetin, and valdecoxib.

[0032] Additionally, the invention relates to any of the methods disclosed herein wherein any of said methods may further comprise administering an anti-histamine active agent that may be selected from one or more of the following: acrivastine, astemizole, azatadine, azelastine, betastastine, brompheniramine, buclizine, cetirizine, cetirizine analogues, chlorpheniramine, clemastine, CS 560, cyproheptadine, desloratadine, dexchlorpheniramine, ebastine, epinastine, fexofenadine, HSR 609, hydroxyzine, levocabastine, loratidine, methscopolamine, mizolastine, norastemizole, phenindamine, promethazine, pyrilamine, terfenadine, and tranilast. Moreover, the invention encompasses any of the methods disclosed herein where any of said methods may further comprise administering an antibiotic active agent that may be selected from one or more of the following: amikacin, aminoglycosides, amoxicillin, ampicillin, ansamycins, arspenamine, azithromycin, azlocillin, aztreonam, bacitracin,

carbacephem, carbapenems, carbenicillin, cefaclor, cefadroxil, cefalexin, cefalothin, cefalotin, cefamandole, cefazolin, cefdinir, cefditoren, cefepime, cefixime, cefoperazone, cefotaxime, cefoxitin, cefpodoxime, cefprozil, ceftazidime, ceftibuten, ceftizoxime, ceftobiprole, ceftriaxone, cefuroxime, cephalosporins, chloramphenicol, cilastatin, ciprofloxacin, clarithromycin, clindamycin, cloxacillin, colistin, co-trimoxazole, dalfopristin, demeclocycline, dicloxacillin, dirithromycin, doripenem, doxycycline, enoxacin, ertapenem, erythromycin, ethambutol, flucloxacillin, fosfomycin, furazolidone, fusidic acid, gatifloxacin, geldanamycin, gentamicin, glycopeptides, herbimycin, imipenem, isoniazid, kanamycin, levofloxacin, lincomycin, linezolid, lomefloxacin, loracarbef, macrolides, mafenide, meropenem, methicillin, metronidazole, mezlocillin, minocycline, monobactams, moxifloxacin, mupirocin, nafcillin, neomycin, netilmicin, nitrofurantoin, norfloxacin, ofloxacin, oxacillin, oxytetracycline, paromomycin, penicillin, penicillins, piperacillin, platensimycin, polymyxin B, polypeptides, prontosil, pyrazinamide, quinolones, quinupristin, rifampicin, rifampin, roxithromycin, spectinomycin, streptomycin, sulfacetamide, sulfamethizole, sulfanilamide, sulfasalazine, sulfisoxazole, sulfonamides, teicoplanin, telithromycin, tetracycline, tetracyclines, ticarcillin, tinidazole, tobramycin, trimethoprim, trimethoprim-sulfamethoxazole, troleandomycin, trovafloxacin, and vancomycin.

[0033] Also, the invention relates to any of the methods disclosed herein wherein any of said methods may further comprise administering an active agent that may be selected from: aldosterone, beclomethasone, betamethasone, corticosteroids, cortisol, cortisone acetate, deoxycorticosterone acetate, dexamethasone, fludrocortisone acetate, glucocorticoids, hydrocortisone, methylprednisolone, prednisolone, prednisone, steroids, and triamcinolone, and combinations thereof. An additional embodiment of the invention pertains to any of the methods disclosed herein wherein any of said methods may further comprise administering an active agent that may be selected from: ibuprofen, naproxen, sumatriptan, paracetamol/acetaminophen, caffeine, a triptan, a corticosteroid, an anti-mimetic, and combinations thereof.

[0034] Another aspect of the invention generally encompasses a method of screening for antibodies or antigen binding fragments that may decrease or inhibit light-induced pain signaling through intrinsically photosensitive retinal ganglion cells ("ipRGCs"), that may comprise:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering PACAP to the first test subject and the second test subject;

(iii) administering to the first test subject one or more of anti-Pituitary Adenylate Cyclase-Activating Peptide (PACAP) antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, preferably an anti-PACAP antibody or anti-PAC1-R antibody, or an antigen binding fragment of any of the foregoing;

(iv) comparing the response of the at least one first test subject and at least one second test subject to light; and

(v) based on this comparison identifying one or more antibodies that decrease or inhibit light-induced pain signaling through intrinsically photosensitive retinal ganglion cells ("ipRGCs").

[0035] An additional embodiment of the invention relates to a method of screening for a test substance that may treat or prevent photophobia or light aversion in a subject in need thereof by decreasing or inhibiting light-induced pain signaling through intrinsically photosensitive retinal ganglion cells ("ipRGCs"), that may comprise:

(i) providing at least one first test subject and at least one second test subject;

(ii) administering PACAP to the first test subject and the second test subject;

(iii) administering to the first test subject one or more of anti-Pituitary Adenylate Cyclase-Activating Peptide (PACAP) antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, preferably an anti-PACAP antibody or anti-PAC1-R antibody, or an antigen binding fragment of any of the foregoing;

(iv) comparing the response of the at least one first test subject and at least one second test subject to light; and

(v) based on this comparison, identifying one or more antibodies or antigen binding fragments thereof that may be useful for treating or preventing light-induced pain signaling through ipRGCs.

[0036] An aspect of the present invention in general relates to anti-PACAP antibodies and antigen binding fragments thereof, preferably human, humanized, or chimerized anti-human PACAP antibodies or antibody fragments thereof that may antagonize, inhibit, neutralize or block at least one biological effect associated with human PACAP.

[0037] Moreover, the invention pertains to anti-PACAP antibodies and antigen binding fragments thereof that may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof that specifically compete for binding to human PACAP with an

antibody that may be selected from the group consisting of Ab10 and Ab20, or an antigen-binding fragment thereof.

[0038] Additionally, the anti-PACAP antibodies and antigen binding fragments of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments that may specifically bind to at least one linear or conformational epitope bound by an anti-PACAP antibody that may be selected from the group consisting of Ab10 and Ab20, or an antigen-binding fragment thereof. The epitope may be identified by alanine scanning, e.g., as disclosed in Example 12 or another art-recognized method.

[0039] Also, in another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof which bind to the identical epitopes as any one of Ab10 or Ab20, or an antigen-binding fragment thereof. The epitope may be identified by alanine scanning, e.g., as disclosed in Example 12 or another art-recognized method.

[0040] In a further embodiment of the invention, the anti-PACAP antibodies or antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments which may specifically bind to an epitope on human PACAP or a fragment or variant thereof containing the corresponding amino acid residues wherein said epitope includes one or more of the following:

- (i) at least one of residues 19, 22, 23 and 27 of human PACAP;
- (ii) at least one of residues 19, 22, 23, 24 and 27 of human PACAP;
- (iii) at least two of the residues of any one of (i)-(ii);
- (iv) at least three of the residues of any one of (i)-(ii);
- (v) at least four of the residues of any one of (i)-(ii); and
- (v) all five of the residues of (ii).

[0041] In a specific embodiment of the invention, anti-PACAP antibodies or antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments which specifically bind to an epitope on human PACAP, or a fragment or variant thereof that may contain the corresponding amino acid residues that may include residues 19, 22, 23 and 27 of human PACAP. Also, in another embodiment of the invention, the anti-PACAP antibodies or antigen binding fragments thereof may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof, which specifically bind to an epitope on human PACAP (or a fragment or variant thereof that may contain the corresponding amino acid residues that may be present in human wild-type PACAP38) but not human wild-type human PACAP27. The epitope may be

identified by alanine scanning, e.g., as disclosed in Example 12 or another art-recognized method.

[0042] In an additional embodiment of the invention, anti-PACAP antibodies or antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof which may specifically bind to an epitope on human PACAP or a fragment or variant thereof that contain the corresponding amino acid residues, wherein said epitope may consist of the residues of (i)-(ii) as described above. The epitope may be identified by alanine scanning, e.g., as disclosed in Example 12 or another art-recognized method.

[0043] Another aspect of the invention also embraces anti-PACAP antibodies or antigen binding fragments thereof that may include human, humanized or chimerized anti-PACAP antibodies or antibody fragment which specifically bind to an epitope on human PACAP (or a fragment or variant thereof containing the corresponding amino acid residues) that may be present in human wild-type PACAP38 and in human wild-type human PACAP27.

[0044] Additionally, the anti-PACAP antibodies or antigen binding fragments thereof may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof, which may specifically bind to human wild-type human PACAP38 but which may not bind or appreciably bind to human wild-type human PACAP27. In another embodiment of the invention, the anti-PACAP antibodies and antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof which may have a K_D for human PACAP38 which may be at least 10, 100, 1000, 10,000 or 100,000 fold lower (stronger) than the K_D of said antibody or antibody fragment to human PACAP27.

[0045] In another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof which do not bind to or do not appreciably bind to human Vasoactive Intestinal Peptide ("VIP"). Said anti-PACAP antibodies or antibody fragments thereof may have a K_D for human PACAP which may be at least 10, 100, 1000, 10,000 or 100,000 fold lower (stronger) than the K_D of said antibody or antibody fragment to human VIP.

[0046] In embodiments of the invention, the human, humanized or chimerized anti-PACAP antibody or antibody fragment as disclosed herein, may inhibit or neutralize at least one biological effect elicited by human PACAP.

[0047] In another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof that may comprise one or more of the following properties: (a) inhibit, block or prevent PACAP activation of at least one of PAC1 receptor ("PAC1-R"), vasoactive intestinal peptide receptor type 1 ("VPAC1-R"), and/or vasoactive intestinal peptide receptor type 2 ("VPAC2-R"); (b) inhibit, block or prevent PACAP activation of each of PAC1-R, VPAC1-R, and VPAC2-R; (c) inhibit, block or prevent PACAP activation of PAC1-R; (d) capable of inhibiting PACAP binding to at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; (e) are capable of inhibiting PACAP binding to each of PAC1-R, VPAC1-R, and/or VPAC2-R; (f) are capable of inhibiting PACAP binding to PAC1-R-expressing cells; (g) are capable of inhibiting PACAP binding to VPAC1-R -expressing cells; (h) may be capable of inhibiting PACAP binding to VPAC2-R -expressing cells; (i) inhibit PACAP binding to the cell surface, e.g. via a glycosaminoglycan ("GAG"); (j) do not inhibit PACAP-mediated binding of such antibody to the cell surface, e.g., via a GAG; (k) inhibit PACAP-mediated binding of such antibody to the cell surface, e.g., via a glycosaminoglycan ("GAG"); (l) inhibit, block or prevent PACAP-induced cAMP production; (m) when administered to a subject reduce PACAP-induced vasodilation; and/or (n) when administered to a subject reduces PACAP-induced photophobia, mast cell degranulation and/or neuronal activation.

[0048] The invention may also pertain to anti-PACAP antibodies and antigen binding fragments thereof that may be preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments which may be substantially non-immunogenic in human subjects. The invention may also relates to anti-PACAP antibodies and antigen binding fragments thereof that may be preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, which may be suitable for treating a human subject having an acute, episodic or chronic condition associated with increased vasodilation, photophobia, mast cell degranulation and/or neuronal activation.

[0049] Another embodiment of the invention relates to anti-PACAP antibodies and antigen binding fragments thereof that may be preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments that specifically bind to the same or overlapping linear or conformational epitope(s) and/or may compete for binding to the same or overlapping linear or conformational epitope(s) on human PACAP as an anti-PACAP antibody that may be selected from Ab10 or Ab20. Yet another embodiment of the invention relates to anti-PACAP antibodies and antigen binding fragments thereof, preferably human,

humanized or chimerized anti-PACAP antibodies or antibody fragments, that may specifically bind to the same or overlapping linear or conformational epitope(s) on human PACAP as an anti-PACAP antibody that may be selected from Ab10 or Ab20. Said epitope as described herein bound by said antibody or antibody fragment of the invention may be identified by alanine scanning, e.g., as disclosed in Example 12 or another art-recognized method.

[0050] The invention may also embody anti-PACAP antibodies and antigen binding fragments thereof that may be preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments that may comprise at least 2 complementarity determining regions ("CDRs") of an anti-PACAP antibody that may be selected from Ab10 or Ab20, preferably including the V_H CDR3 and/or the V_L CDR3. Another additional embodiment of the invention may include anti-PACAP antibodies and antigen binding fragments thereof that may be preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments that may comprise at least 3, at least 4, at least 5, or all 6 CDRS of an anti-PACAP antibody that may be selected from Ab10 or Ab20. In instances where all 6 CDRs may not be present, preferably at least the V_H CDR3 and the V_L CDR3 may be present.

[0051] In another embodiment of the invention, anti-PACAP antibodies and antigen binding fragments thereof, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments thereof, may comprise a sequence variant of any of the antibodies or antibody fragments of the invention that may contain one or more modifications that may putatively alter binding affinity or immunogenicity.

[0052] In a specific embodiment, the anti-PACAP antibodies and antigen binding fragments thereof according to the invention, are human, humanized, or chimerized anti-PACAP antibodies or antigen binding fragments thereof, and comprise (a) a variable heavy chain comprising a CDR1 sequence consisting of SEQ ID NO: 404; a CDR2 sequence consisting of SEQ ID NO: 406; and a CDR3 sequence consisting of SEQ ID NO: 408; and/or (b) a variable light chain comprising a CDR1 sequence consisting of SEQ ID NO: 424; a CDR2 sequence consisting of SEQ ID NO: 426; and a CDR3 sequence consisting of SEQ ID NO: 428. Alternatively, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a variable heavy chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 402, and/or (b) a variable light chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 422. In another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof comprise (a) a variable heavy chain having the amino

acid sequence of SEQ ID NO: 402, and/or (b) a variable light chain having the amino acid sequence of SEQ ID NO: 422. More specifically, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a heavy chain having the amino acid sequence of SEQ ID NO: 401, and/or (b) a light chain having the amino acid sequence of SEQ ID NO: 421.

[0053] In another specific embodiment, the anti-PACAP antibodies and antigen binding fragments thereof according to the invention, are human, humanized, or chimerized anti-PACAP antibodies or antigen binding fragments thereof, and comprise (a) a variable heavy chain comprising a CDR1 sequence consisting of SEQ ID NO: 444; a CDR2 sequence consisting of SEQ ID NO: 446; and a CDR3 sequence consisting of SEQ ID NO: 448; and/or (b) a variable light chain comprising a CDR1 sequence consisting of SEQ ID NO: 464; a CDR2 sequence consisting of SEQ ID NO: 466; and a CDR3 sequence consisting of SEQ ID NO: 468. Alternatively, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a variable heavy chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 442, and/or (b) a variable light chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 462. In another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof and comprise (a) a variable heavy chain having the amino acid sequence of SEQ ID NO: 442, and/or (b) a variable light chain having the amino acid sequence of SEQ ID NO: 462. More specifically, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a heavy chain having the amino acid sequence of SEQ ID NO: 441, and/or (b) a light chain having the amino acid sequence of SEQ ID NO: 461.

[0054] Additionally, the anti-PACAP antibodies and antigen binding fragments of the invention may include human, humanized or chimerized anti-PACAP antibodies or antibody fragments wherein the antibodies or antibody fragments may be selected from the group consisting of scFvs, camelbodies, nanobodies, Immunoglobulin New Antigen Receptor ("IgNAR"), fragment antigen binding ("Fab") fragments, Fab' fragments, MetMab like antibodies, monovalent antibody fragments, and F(ab')₂ fragments. In another embodiment, the anti-PACAP antibodies and antigen binding fragments of the invention, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, may substantially or entirely lack N-glycosylation and/or O-glycosylation. Also, the invention embraces an embodiment of the invention wherein the anti-PACAP antibodies and antigen binding fragments of the invention, preferably human, humanized or chimerized anti-PACAP

antibodies or antibody fragments, may comprise a human constant domain, e.g. that of an IgG1, IgG2, IgG3, or IgG4 antibody or fragment thereof.

[0055] An additional embodiment of the invention relates to anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, wherein said antibodies or antibody fragments may comprise an Fc region that may have been modified to alter at least one of effector function, half-life, proteolysis, or glycosylation, e.g., wherein the Fc region may contain one or more mutations that may alter or eliminate N- and/or O-glycosylation.

[0056] In yet another embodiment of the invention, anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, may bind to PACAP with a binding affinity (K_D) of less than or equal to 5×10^{-5} M, 10^{-5} M, 5×10^{-6} M, 10^{-6} M, 5×10^{-7} M, 10^{-7} M, 5×10^{-8} M, 10^{-8} M, 5×10^{-9} M, 10^{-9} M, 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, 10^{-12} M, 5×10^{-13} M, or 10^{-13} M, e.g., as may be determined by ELISA, bio-layer interferometry ("BLI"), KINEXA or surface plasmon resonance at 25° or 37°C. Also, another embodiment of the invention pertains to anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, wherein said antibodies or antibody fragments may bind to PACAP with a binding affinity (K_D) of less than or equal to 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, or 10^{-12} M. Additionally, the anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, of the invention may include anti-PACAP antibodies or antibody fragments which may bind to PACAP with an off-rate (k_{off}) of less than or equal to $5 \times 10^{-4} \text{ s}^{-1}$, 10^{-4} s^{-1} , $5 \times 10^{-5} \text{ s}^{-1}$, or 10^{-5} s^{-1} .

[0057] Another embodiment of the invention relates to anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, wherein said antibodies and antibody fragments may be directly or indirectly attached to a detectable label or therapeutic agent. An additional embodiment of the invention pertains to anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments that when administered to a subject may inhibit or neutralize at least one biological effect elicited by PACAP. The anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, of the invention may bind to PACAP27 and/or PACAP38 and may block PACAP27 and/or PACAP38 binding to PAC1-R, VPAC1-R, and/or VPAC2-R; may bind to PACAP27 and/or PACAP38

and may block PACAP27 and/or PACAP38 binding to each of PAC1-R, VPAC1-R, and VPAC2-R; and/or may bind to PACAP27 and/or PACAP38 and may block PACAP27 and/or PACAP38 binding to PAC1-R-expressing cells, VPAC1-R-expressing cells, and/or VPAC2-R-expressing cells.

[0058] In another embodiment of the invention, the anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, of the invention may neutralize or inhibit PACAP activation of at least one of PAC1-R, VPAC1-R, or VPAC2-R; may neutralize or inhibit PACAP activation of each of PAC1-R, VPAC1-R, and VPAC2-R; may neutralize or inhibit PACAP activation of PAC1-R; may be capable of inhibiting or preventing PACAP binding to at least one of PAC1-R, VPAC1-R, or VPAC2-R; may be capable of inhibiting or preventing PACAP binding to each of PAC1-R, VPAC1-R, and VPAC2-R; may be capable of inhibiting or preventing PACAP binding to PAC1-R-expressing cells, VPAC1-R-expressing cells, and/or VPAC2-R-expressing cells; may inhibit or block PACAP-induced cAMP production; may, when administered to a subject, reduce PACAP-induced vasodilation, photophobia, mast cell degranulation and/or neuronal activation.

[0059] In yet another embodiment of the invention, anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, may bind to PACAP with a K_D that may be less than about 100 nM; with a K_D that may be less than about 40 nM; with a K_D that may be less than about 100 pM; with a K_D that may be less than about 50 pM; with a K_D that may be less than about 25 pM; or with a K_D that may be between about 10 pM and about 100 pM. The invention also embraces anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, that may have stronger binding affinity for PACAP as compared to VIP and/or that may not bind to VIP, e.g., wherein said antibodies or antibody fragments thereof may have an affinity to PACAP that may be at least 10-fold, 30-fold, 100-fold, 300-fold, 1000-fold, 3000-fold, 10000-fold, 30000-fold, 100000-fold, 300000-fold, 1000000-fold, 3000000-fold, 10000000-fold, 30000000-fold or more stronger than the affinity of said antibody or antibody fragment to VIP.

[0060] In another embodiment, the invention pertains to anti-PACAP antibodies and antigen binding fragments, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, that may be attached to at least one effector moiety, e.g., wherein said effector moiety may comprise a chemical linker. In another embodiment, the invention pertains to anti-PACAP antibodies and antigen binding fragments, preferably human,

humanized or chimerized anti-PACAP antibodies or antibody fragments that may be attached to one or more detectable moieties, e.g., wherein said detectable moieties may comprise a fluorescent dye, enzyme, substrate, bioluminescent material, radioactive material, chemiluminescent moiety, and/or mixtures thereof. Also, the anti-PACAP antibodies and antigen binding fragments of the invention, preferably human, humanized or chimerized anti-PACAP antibodies or antibody fragments, may be attached to one or more functional moieties.

[0061] Another embodiment of the invention relates to anti-idiotypic antibodies that may be produced against anti-PACAP antibodies or antibody fragments, wherein said anti-idiotypic antibodies optionally may neutralize one or more biological effects of the anti-PACAP antibody to which it may bind. Said embodiment of the invention may also be related to a method of using said anti-idiotypic antibody to monitor the *in vivo* levels of said anti-PACAP antibody or antibody fragment in a subject or to neutralize the *in vivo* effects of said anti-PACAP antibody in a subject.

[0062] In yet another embodiment, the invention pertains to a composition that may be suitable for therapeutic, prophylactic, or a diagnostic use, whereby the composition may comprise a therapeutically, prophylactically or diagnostically effective amount of at least one anti-PACAP antibody or antibody fragment or anti-idiotypic antibody, e.g., wherein the composition may be suitable for administration via injection, topical, oral, inhalation or transdermal; may be suitable for subcutaneous, intravenous, intramuscular, topical, oral, inhalatory, intranasal, intrabuccal, vaginal, anal, transdermal, intraperitoneal, or intrathecal administration; and/or wherein the composition may be suitable for subcutaneous intravenous or intramuscular administration. The invention also embraces an embodiment of the invention wherein said composition of at least one anti-PACAP antibody or antibody fragment or anti-idiotypic antibody may be lyophilized; and/or wherein said composition may comprise a pharmaceutically acceptable diluent, carrier, solubilizer, emulsifier, preservative, or mixture thereof. Said composition of the invention may further comprise at least one other active agent, e.g., wherein the other active agent may be selected from the group consisting of a chemotherapeutic, an analgesic, an anti-inflammatory, an immunosuppressant, a cytokine, an antiproliferative, an antiemetic and/or a cytotoxin. Said composition may also be lyophilized, stabilized, and/or formulated for administration by injection.

[0063] A further embodiment of the invention embraces an isolated nucleic acid sequence or nucleic acid sequences that may encode an anti-PACAP antibody or antibody fragment or anti-idiotypic antibody, and wherein said isolated nucleic acid sequence or nucleic acid

sequences may be contained within a vector or vectors. Additionally, in an embodiment of the invention, a host cell may comprise said isolated nucleic acid sequence or sequences, wherein said host cell may be a mammalian, bacterial, fungal, yeast, avian, amphibian, plant or insect cell; and/or said host cell may be a filamentous fungus or a yeast. Wherein said host cell may be a yeast cell, the yeast may be selected from the following genera: *Arxiozyma*; *Ascobotryozyma*; *Citeromyces*; *Debaryomyces*; *Dekkera*; *Eremothecium*; *Issatchenkia*; *Kazachstania*; *Kluyveromyces*; *Kodamaea*; *Lodderomyces*; *Pachysolen*; *Pichia*; *Saccharomyces*; *Saturnispora*; *Tetrapisispora*; *Torulaspora*; *Williopsis*; and *Zygosaccharomyces*; or the yeast may be genus *Pichia*. In an embodiment of the invention, the yeast host cell may be selected from *Pichia pastoris*, *Pichia methanolica* and *Hansenula polymorpha* (*Pichia angusta*). Additionally, said host cell may be a filamentous fungus or a yeast or may be a CHO cell.

[0064] The invention also relates to a method of expressing an anti-PACAP antibody or antibody fragment that may comprise culturing any of but not limited to the host cells disclosed herein under conditions that may provide for expression of said antibody or antibody fragment. Additionally, the invention pertains to said method wherein the host cell may be a yeast cell or CHO cell that may stably express and secrete said antibody or antibody fragment. For example, said yeast cell may be a polyploid yeast that may be made by a method that may comprise: (i) introducing at least one expression vector containing one or more heterologous polynucleotides encoding said antibody operably linked to a promoter and a signal sequence into a haploid yeast cell; (ii) producing by mating or spheroplast fusion a polyploid yeast from said first and/or second haploid yeast cell; (iii) selecting polyploid yeast cells that stably express said antibody; and (iv) producing stable polyploid yeast cultures from said polyploid yeast cells that stably express said antibody into the culture medium; and said polyploid yeast may be of the genus *Pichia*. Additionally in another embodiment, the invention embraces a method of expressing an anti-PACAP antibody or antibody fragment that may comprise culturing a host cell wherein said host cell may be a mammalian cell, e.g., a CHO cell.

[0065] Additionally, the invention pertains to a method that may block, inhibit, block or neutralize one or more biological effects associated with PACAP in a subject that may comprise administering to said subject a therapeutically or prophylactically effective amount of a human, humanized or chimerized anti-PACAP antibody or antibody fragment that may antagonize, inhibit, neutralize or block at least one biological effect associated with human PACAP. Another aspect of the invention relates to a method that may block, inhibit, or

neutralize one or more biological effects associated with PACAP in a subject that may comprise administering to said subject a therapeutically or prophylactically effective amount of a human, humanized or chimerized anti-PACAP antibody or antibody fragment that may antagonize, inhibit, neutralize or block at least one biological effect associated with human PACAP and that may not substantially interact with (bind) VIP.

[0066] Another aspect of the invention generally relates to a method that may block, inhibit, or neutralize one or more biological effects, e.g., vasomotor effects, associated with PACAP in a subject that may comprise administering to a subject a therapeutically or prophylactically effective amount of a human, humanized or chimerized anti-PACAP antibody or antibody fragment that may comprise one or more of the following: inhibits, blocks or neutralizes at least one biological effect elicited by PACAP; neutralizes or inhibits PACAP activation of at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; inhibits, blocks or neutralizes PACAP activation of each of PAC1-R, VPAC1-R, and VPAC2-R; neutralizes or inhibits PACAP activation of PAC1-R; inhibits PACAP binding to at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; inhibits PACAP binding to each of PAC1-R, VPAC1-R, and/or VPAC2-R; inhibits PACAP binding to PAC1-R-expressing cells; inhibits PACAP binding to VPAC1-R and/or VPAC2-R-expressing cells; does not inhibit PACAP-mediated binding of such antibody to the cell surface, e.g., via a glycosaminoglycan ("GAG"); inhibits PACAP binding to the cell surface, e.g. via a glycosaminoglycan ("GAG"); inhibits PACAP-induced cAMP production; and/or, when administered to a subject, may reduce PACAP-induced vasodilation, photophobia, mast cell degranulation and/or neuronal activation.

[0067] Another embodiment of the invention relates to method that may block, inhibit, or neutralize vasodilation, e.g., vasodilation of the dural arteries, which may be associated with or may be elicited by PACAP in a subject that may comprise administering to a subject a therapeutically or prophylactically effective amount of a human, humanized or chimerized anti-PACAP antibody or antibody fragment that may block, inhibit, or neutralize vasodilation associated with, or elicited by PACAP.

[0068] Yet another embodiment of the invention pertains to a method that may treat or prevent the onset, frequency, severity or duration of headache or migraine, e.g., wherein said headache or migraine may be selected from migraine with aura, migraine without aura, hemiplegic migraine, cluster headache, migrainous neuralgia, chronic headache, chronic migraine, medication overuse headache, and tension headache, in a subject that may comprise administering to a subject in need thereof an effective amount of a human, humanized or chimerized anti-human PACAP antibody or antibody fragment that may elicit

one or more of the following effects: inhibits or neutralizes at least one biological effect elicited by PACAP; neutralizes or inhibits PACAP activation of at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; neutralizes or inhibits PACAP activation of each of PAC1-R, VPAC1-R, and VPAC2-R; neutralizes or inhibits PACAP activation of PAC1-R; inhibits PACAP binding to at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; inhibits PACAP binding to each of PAC1-R, VPAC1-R, and/or VPAC2-R; inhibits PACAP binding to PAC1-R-expressing cells; inhibits PACAP binding to VPAC1-R and/or VPAC2-R-expressing cells; inhibits PACAP-mediated binding of such antibody to the cell surface, e.g., via a GAG; inhibits PACAP binding to the cell surface, e.g. via a glycosaminoglycan ("GAG"); inhibits PACAP-induced cyclic adenosine monophosphate ("cAMP") production; and/or, when administered to a subject, reduces PACAP-induced vasodilation, photophobia, mast cell degranulation and/or neuronal activation.

[0069] Another embodiment of the invention relates to a method of treating a human subject that may have an acute, episodic or chronic condition that may be associated with at least one of increased vasodilation, photophobia, mast cell degranulation and neuronal activation or a combination of said conditions that may comprise administering to a subject in need thereof an effective amount of an antagonistic human, humanized or chimerized anti-human PACAP antibody or antibody fragment.

[0070] In yet another embodiment, the invention relates to a method that may block, inhibit, or neutralize one or more biological effects associated with PACAP in a subject that may comprise administering to a subject in need thereof an effective amount of a human, humanized or chimerized anti-PACAP antibody or antigen binding fragment that may antagonize, inhibit, neutralize, or block at least one biological effect associated with human PACAP. Also, an embodiment of the invention encompasses a method that may block, inhibit, or neutralize one or more biological effects associated with PACAP in a subject that may comprise administering to a subject in need thereof an effective amount of a human, humanized, or chimerized anti-PACAP antibody or antigen binding fragment that may antagonize, inhibit, neutralize, or block at least one biological effect associated with human PACAP and that may not substantially interact with (bind) VIP.

[0071] In another embodiment, the invention relates to a method that may block, inhibit, or neutralize one or more biological effects associated with PACAP in a subject that may comprise administering to a subject in need thereof an effective amount of a human, humanized, or chimerized anti-PACAP antibody or antigen binding fragment that (a) inhibits or neutralizes at least one biological effect elicited by PACAP; (b) neutralizes or inhibits

PACAP activation of at least one of PAC1 receptor ("PAC1-R"), vasoactive intestinal peptide receptor type 1 ("VPAC1-R"), and/or vasoactive intestinal peptide receptor type 2 ("VPAC2-R"); (c) neutralizes or inhibits PACAP activation of each of PAC1-R, VPAC1-R, and VPAC2-R; (d) neutralizes or inhibits PACAP activation of PAC1-R; (e) inhibits PACAP binding to at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; (f) inhibits PACAP binding to each of PAC1-R, VPAC1-R, and/or VPAC2-R; (g) may be capable of inhibiting PACAP binding to PAC1-R-expressing cells; (h) inhibits PACAP binding to the cell surface, e.g., via a glycosaminoglycan ("GAG") (i) inhibits PACAP-mediated binding of such antibody to the cell surface, e.g. via a GAG; (j) inhibits PACAP-induced cyclic adenosine monophosphate ("cAMP") production; and/or (k) when administered to the subject reduces PACAP-induced vasodilation, photophobia, mast cell degranulation and/or neuronal activation.

[0072] Moreover, an embodiment of the invention pertains to a method of treating or preventing the onset, frequency, severity or duration of headache or migraine, e.g., wherein the headache or migraine may be selected from migraine with aura, migraine without aura, hemiplegic migraine, cluster headache, migrainous neuralgia, chronic headache, chronic migraine, medication overuse headache, and tension headache, in a subject that may comprise administering to a subject in need thereof an effective amount of a human, humanized, or chimerized anti-human PACAP antibody or antigen binding fragment that (a) inhibits or neutralize at least one biological effect elicited by PACAP; (b) neutralizes or inhibits PACAP activation of at least one of PAC1 receptor ("PAC1-R"), vasoactive intestinal peptide receptor type 1 ("VPAC1-R"), and/or vasoactive intestinal peptide receptor type 2 ("VPAC2-R"); (c) neutralizes or inhibits PACAP activation of each of PAC1-R, VPAC1-R, and VPAC2-R; (d) neutralizes or inhibits PACAP activation of PAC1-R; (e) may be capable of inhibiting PACAP binding to at least one of PAC1-R, VPAC1-R, and/or VPAC2-R; (f) inhibits PACAP binding to each of PAC1-R, VPAC1-R, and/or VPAC2-R; (g) inhibits PACAP binding to PAC1-R-expressing cells; (h) inhibits PACAP binding to the cell surface, e.g., via a glycosaminoglycan ("GAG"); (i) inhibits PACAP-mediated binding of such antibody to the cell surface, e.g. via a GAG; (j) inhibits PACAP-induced cyclic adenosine monophosphate ("cAMP") production; and/or (k) when administered to the subject reduces PACAP-induced vasodilation, photophobia, mast cell degranulation and/or neuronal activation.

[0073] A further embodiment of the invention encompasses a method of treating a human subject that may have an acute, episodic or chronic condition associated with at least one of

increased vasodilation, photophobia, mast cell degranulation and neuronal activation or a combination of any of above that may comprise administering to a subject in need thereof an effective amount of an antagonistic human, humanized or chimerized anti-human PACAP antibody or antigen binding fragment.

[0074] The invention also pertains to any of the methods disclosed herein that may include the administration of anti-PACAP antibody or antigen binding fragment of the invention, and wherein said anti-PACAP antibody may be a human antibody or antigen binding fragment; and/or wherein the anti-PACAP antibody may be a humanized antibody or antigen binding fragment; and/or wherein the anti-PACAP antibody may be a chimeric antibody or antigen binding fragment.

[0075] Another embodiment of the invention also relates to a method wherein an anti-PACAP antibody or antibody fragment of the invention may bind to PACAP27 and/or PACAP38 and may block PACAP27 and/or PACAP38 binding to PAC1-R, VPAC1-R, and/or VPAC2-R. Another embodiment of the invention pertains to a method wherein said anti-PACAP antibody or antibody fragment may bind to PACAP27 and/or PACAP38 and may block PACAP27 and/or PACAP38 binding to each of PAC1-R, VPAC1-R, and VPAC2-R. Yet another embodiment of the invention relates to a method wherein said anti-PACAP antibody or antibody fragment may bind to PACAP27 and/or PACAP38 and may block PACAP27 and/or PACAP38 binding to PAC1-R-expressing cells. Additionally, said anti-PACAP antibody or antibody fragment of the invention may have an affinity to PACAP that may be at least 10-fold, 30-fold, 100-fold, 300-fold, 1000-fold, 3000-fold, 10000-fold, 30000-fold, 100000-fold, 300000-fold, 1000000-fold, 3000000-fold, 10000000-fold, 30000000-fold or more stronger than the affinity of said antibody or antibody fragment to VIP.

[0076] The invention embraces a method that may block, inhibit, block or neutralize one or more biological effects associated with PACAP in a subject that may comprise administering to said subject a therapeutically or prophylactically effective amount of a human, humanized or chimerized anti-PACAP antibody or antibody fragment that may antagonize, inhibit, neutralize or blocks at least one biological effect associated with human PACAP, and wherein said subject may have a condition selected from the group consisting of migraine with aura, migraine without aura, hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, general headaches, hot flush, photophobia, chronic paroxysmal hemicrania, secondary headaches due to an underlying structural problem in the head, secondary headaches due to an underlying structural problem in the

neck, cranial neuralgia, sinus headaches, headache associated with sinusitis, allergy-induced headaches, allergy-induced migraines, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, reflex sympathetic dystrophy, pain, chronic pain, inflammatory pain, post-operative incision pain, post-surgical pain, trauma-related pain, lower back pain, eye pain, tooth pain, complex regional pain syndrome, cancer pain, primary or metastatic bone cancer pain, fracture pain, osteoporotic fracture pain, pain resulting from burn, gout joint pain, pain associated with sickle cell crises, pain associated with temporomandibular disorders, cirrhosis, hepatitis, neurogenic pain, neuropathic pain, nociceptive pain, visceral pain, menstrual pain, ovarialgia, osteoarthritis pain, rheumatoid arthritis pain, diabetic neuropathy, sciatica, dyspepsia, irritable bowel syndrome, inflammatory bowel disease, Crohn's disease, ileitis, ulcerative colitis, renal colic, dysmenorrhea, cystitis, interstitial cystitis, menstrual period, labor, menopause, pancreatitis, schizophrenia, depression, post-traumatic stress disorder ("PTSD"), anxiety disorders, autoimmune diabetes, Sjögren's syndrome, multiple sclerosis, overactive bladder, bronchial hyperreactivity, asthma, stroke, bronchitis, bronchodilation, emphysema, chronic obstructive pulmonary disease ("COPD"), inflammatory dermatitis, adenocarcinoma in glandular tissue, blastoma in embryonic tissue of organs, carcinoma in epithelial tissue, leukemia in tissues that form blood cells, lymphoma in lymphatic tissue, myeloma in bone marrow, sarcoma in connective or supportive tissue, adrenal cancer, AIDS-related lymphoma, anemia, bladder cancer, bone cancer, brain cancer, breast cancer, carcinoid tumors, cervical cancer, chemotherapy, colon cancer, cytopenia, endometrial cancer, esophageal cancer, gastric cancer, head cancer, neck cancer, hepatobiliary cancer, kidney cancer, leukemia, liver cancer, lung cancer, lymphoma, Hodgkin's disease, non-Hodgkin's, nervous system tumors, oral cancer, ovarian cancer, pancreatic cancer, prostate cancer, rectal cancer, skin cancer, stomach cancer, testicular cancer, thyroid cancer, urethral cancer, cancer of bone marrow, multiple myeloma, tumors that metastasize to the bone, tumors infiltrating the nerve and hollow viscus, tumors near neural structures, acne vulgaris, atopic dermatitis, urticaria, keloids, hypertrophic scars and rosacea, endothelial dysfunction, Raynaud's syndrome, coronary heart disease ("CHD"), coronary artery disease ("CAD"), heart failure, peripheral arterial disease ("PAD"), diabetes, pulmonary hypertension ("PH"), connective tissue disorder, allergic dermatitis, psoriasis, pruritus, neurogenic cutaneous redness, erythema, sarcoidosis, shock, sepsis, opiate withdrawal syndrome, morphine tolerance, and epilepsy. Additionally, said subject may have a condition selected from the group consisting of migraine, headache and a pain associated disease or condition, wherein said headache or migraine may selected from the group

consisting of migraine with aura, migraine without aura, hemiplegic migraine, cluster headache, migrainous neuralgia, chronic headache, chronic migraine, medication overuse headache, and tension headache. Also, said subject may have an ocular disorder associated with photophobia selected from the group consisting of achromatopsia, aniridia, photophobia caused by an anticholinergic drug, aphakia, buphthalmos, cataracts, cone dystrophy, congenital abnormalities of the eye, viral conjunctivitis, corneal abrasion, corneal dystrophy, corneal ulcer, disruption of the corneal epithelium, ectopia lentis, endophthalmitis, eye trauma caused by disease, eye trauma caused by injury, eye trauma caused by infection, chalazion, episcleritis, glaucoma, keratoconus, optic nerve hypoplasia, hydrophthalmos, congenital glaucoma iritis, optic neuritis, pigment dispersion syndrome, pupillary dilation, retinal detachment, scarring of the cornea, sclera and uveitis. Further, said subject may have a nervous system-related or neurological condition associated with photophobia selected from the group consisting of autism spectrum disorders, Chiari malformation, dyslexia, encephalitis, meningitis, subarachnoid hemorrhage, tumor of the posterior cranial fossa, ankylosing spondylitis, albinism, ariboflavinosis, benzodiazepines, chemotherapy, chikungunya, cystinosis, Ehlers-Danlos syndrome, hangover, influenza, infectious mononucleosis, magnesium deficiency, mercury poisoning, migraine, rabies, and tyrosinemia type II. Additionally, said subject may have a photophobia associated disorder selected from the group consisting of migraine with aura, migraine without aura, iritis, uveitis, meningitis, depression, bipolar disorder, cluster headache or another trigeminal autonomic cephalalgia ("TAC") or blepharospasm, depression, agoraphobia and bipolar disorder.

[0077] The invention additionally embraces any of the methods disclosed herein wherein an antibody of any of the methods disclosed herein may be a human, humanized, or chimerized anti-PACAP antibody or antigen binding fragment, and/or wherein the epitope bound by said antibody of any of the methods disclosed herein may be identified by alanine scanning.

[0078] The invention also embraces any of the methods disclosed herein wherein the method relates to an antibody or antibody fragment that may be a human, humanized, or chimerized anti-PACAP antibody or antibody fragment; and/or wherein the antibody or antibody fragment may be a human, humanized, or chimerized anti-PACAP antibody or antibody fragment; and/or wherein the antibody or antibody fragment may be an anti-PACAP antibody or antibody fragment that may comprise the same CDRs as an anti-PACAP antibody that may be selected from Ab10 or Ab20.

[0079] The invention additionally embraces any of the methods disclosed herein wherein the anti-PACAP antibody or antigen binding fragment may comprise at least 3 CDRs; at least 4

CDRs; at least 5 CDRs; or all 6 CDRs of an anti-PACAP antibody that may be selected from Ab10 or Ab20.

[0080] The invention also embraces any of the methods disclosed herein wherein the anti-PACAP antibodies and antigen binding fragments thereof according to the invention, are human, humanized, or chimerized anti-PACAP antibodies or antigen binding fragments thereof, and comprise (a) a variable heavy chain comprising a CDR1 sequence consisting of SEQ ID NO: 404; a CDR2 sequence consisting of SEQ ID NO: 406; and a CDR3 sequence consisting of SEQ ID NO: 408; and/or (b) a variable light chain comprising a CDR1 sequence consisting of SEQ ID NO: 424; a CDR2 sequence consisting of SEQ ID NO: 426; and a CDR3 sequence consisting of SEQ ID NO: 428. Alternatively, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a variable heavy chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 402, and/or (b) a variable light chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 422. In another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof comprise (a) a variable heavy chain having the amino acid sequence of SEQ ID NO: 402, and/or (b) a variable light chain having the amino acid sequence of SEQ ID NO: 422. More specifically, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a heavy chain having the amino acid sequence of SEQ ID NO: 401, and/or (b) a light chain having the amino acid sequence of SEQ ID NO: 421.

[0081] The invention also embraces any of the methods disclosed herein wherein the anti-PACAP antibodies and antigen binding fragments thereof according to the invention, are human, humanized, or chimerized anti-PACAP antibodies or antigen binding fragments thereof, and comprise (a) a variable heavy chain comprising a CDR1 sequence consisting of SEQ ID NO: 444; a CDR2 sequence consisting of SEQ ID NO: 446; and a CDR3 sequence consisting of SEQ ID NO: 448; and/or (b) a variable light chain comprising a CDR1 sequence consisting of SEQ ID NO: 464; a CDR2 sequence consisting of SEQ ID NO: 466; and a CDR3 sequence consisting of SEQ ID NO: 468. Alternatively, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a variable heavy chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 442, and/or (b) a variable light chain comprising an amino acid sequence with at least 80, 85, 90, 95, 96, 97, 98, or 99% sequence identity to SEQ ID NO: 462. In another embodiment, the anti-PACAP antibodies and antigen binding fragments thereof and comprise (a) a variable heavy chain having the amino acid sequence of SEQ ID

NO: 442, and/or (b) a variable light chain having the amino acid sequence of SEQ ID NO: 462. More specifically, the anti-PACAP antibodies and antigen binding fragments thereof can comprise (a) a heavy chain having the amino acid sequence of SEQ ID NO: 441, and/or (b) a light chain having the amino acid sequence of SEQ ID NO: 461.

[0082] The invention also relates to any of the methods disclosed herein wherein the anti-PACAP antibodies or antibody fragments may be selected from the group consisting of scFvs, camelbodies, nanobodies, Immunoglobulin New Antigen Receptor ("IgNAR"), fragment antigen binding ("Fab") fragments, Fab' fragments, MetMab like antibodies, monovalent antibody fragments, and F(ab')₂ fragments. Additionally, the invention relates to any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may substantially or entirely lack N-glycosylation and/or O-glycosylation. Also, the invention pertains to any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may comprise a human constant domain, e.g., that of an IgG1, IgG2, IgG3, or IgG4 antibody.

[0083] Another aspect of the invention pertains to any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may comprise an Fc region that may have been modified to alter at least one of effector function, half-life, proteolysis, or glycosylation, e.g., the Fc region may contain one or more mutations that may alter or eliminate N- and/or O-glycosylation.

[0084] A further aspect of the invention relates to any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may bind to PACAP with a binding affinity (K_D) of less than or equal to 5×10^{-5} M, 10^{-5} M, 5×10^{-6} M, 10^{-6} M, 5×10^{-7} M, 10^{-7} M, 5×10^{-8} M, 10^{-8} M, 5×10^{-9} M, 10^{-9} M, 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, 10^{-12} M, 5×10^{-13} M, or 10^{-13} M. Also, said anti-PACAP antibody or antibody fragment of any of the methods disclosed herein may bind to PACAP with a binding affinity (K_D) of less than or equal to 5×10^{10} M, 10^{10} M, 5×10^{11} M, 10^{11} M, 5×10^{12} M, or 10^{12} M. Another embodiment of the invention pertains any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may bind to PACAP with an off-rate (k_{off}) of less than or equal to $5 \times 10^{-4} \text{ s}^{-1}$, 10^{-4} s^{-1} , $5 \times 10^{-5} \text{ s}^{-1}$, or 10^{-5} s^{-1} .

[0085] Moreover, the invention embraces any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may be directly or indirectly attached to a detectable label or therapeutic agent. Also, the invention relates to any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may bind to PACAP with a K_D that may be less than about 100 nM, less than about 40 nM, less than

about 1 nM, less than about 100 pM, less than about 50 pM, or less than about 25 pM. Also, the invention embraces any of the methods disclosed herein wherein the anti-PACAP antibody or antibody fragment may bind to PACAP with a K_D that may be between about 10 pM and about 100 pM. The invention further pertains to any of the methods disclosed herein wherein the method may further comprise administering separately or co-administering another agent, e.g., wherein the other agent may be selected from a chemotherapeutic, an analgesic, an anti-inflammatory, an immunosuppressant, a cytokine, an antiproliferative, an antiemetic or a cytotoxin. Also, the invention embraces any of the methods disclosed herein wherein the other therapeutic agent may be an analgesic, and said analgesic may be a non-steroidal anti-inflammatory drug ("NSAID"), an opioid analgesic, another antibody or a non-antibody biologic, and further wherein said other antibody may be an anti-NGF antibody or antibody fragment; and/or may be an anti- Calcitonin Gene-Related Peptide ("CGRP") antibody or antibody fragment and/or an anti-CGRP receptor antibody or antibody fragment. The invention also pertains to any of the methods disclosed herein wherein said NSAID may be a cyclooxygenase 1 and/or cyclooxygenase 2 inhibitor.

[0086] In another embodiment of the invention, an anti-PACAP antibody or antibody fragment or a method as disclosed herein may inhibit the effects of PACAP on vasodilation; and/or may inhibit the effects of PACAP on cAMP production; and/or may inhibit the effects of PACAP on PLC resulting in reduced Ca^{++} and PLD levels; and/or may inhibit the effects of PACAP on adenylate cyclase activity; and/or may inhibit the effects of PACAP on its binding to any or all of PAC1-R, VPAC1-R or VPAC2-R; and/or may inhibit the effects of PACAP on neurodevelopment; may inhibit the effects of PACAP on neuroprotection; and/or may inhibit the effects of PACAP on neuromodulation; and/or may inhibit the effects of PACAP on neurogenic inflammation; and/or may inhibit the effects of PACAP on nociception; and/or may modulate the interaction of PACAP with binding the cell surface, e.g. via at least one GAG, e.g., wherein at least one said GAG may comprise one or more of heparin, chondroitin, keratin, and hyaluronic acid, and further wherein said antibody or antibody fragment or method may block or inhibit receptor-independent cellular uptake of PACAP38 and/or PACAP27 and/or may inhibit or may block GAG-dependent uptake of PACAP38 and/or PACAP27 by cells.

[0087] A further embodiment of the invention relates to method of therapy or prophylaxis that may comprise the administration of an anti-PACAP antibody or antibody fragment of the invention. Additionally, the invention pertains to a composition that may be used in human therapy that may contain an anti-PACAP antibody or antibody fragment of the invention.

Said composition may contain another active agent, e.g., wherein the other agent may be selected from a chemotherapeutic, an analgesic, an anti-inflammatory, an immunosuppressant, a cytokine, an antiproliferative, an antiemetic or a cytotoxin. Wherein said other agent may be an analgesic, said analgesic may be a NSAID, an opioid analgesic, another antibody or a non-antibody biologic. When said other agent may be an analgesic that may be another antibody, the other antibody may be an anti-NGF antibody or antibody fragment, and/or the other antibody may be an anti- Calcitonin Gene-Related Peptide ("CGRP") antibody or antibody fragment and/or an anti-CGRP receptor antibody or antibody fragment. Wherein said other agent may be a NSAID, said NSAID may be a cyclooxygenase 1 and/or cyclooxygenase 2 inhibitor; and/or said NSAID may be selected from the group consisting of (1) propionic acid derivatives including ibuprofen, naproxen, naprosyn, diclofenac, and ketoprofen; (2) acetic acid derivatives including tolmetin and sulindac; (3) fenamic acid derivatives including mefenamic acid and meclofenamic acid; (4) biphenylcarboxylic acid derivatives including diflunisal and flufenisal; and (5) oxicams including piroxim, sudoxicam, and isoxicam. Wherein said other agent may be an opioid analgesic, said opioid analgesic may be selected from the group consisting of codeine, dihydrocodeine, diacetylmorphine, hydrocodone, hydromorphone, levorphanol, oxymorphone, alfentanil, buprenorphine, butorphanol, fentanyl, sufentanil, meperidine, methadone, nalbuphine, propoxyphene, pentazocine, and pharmaceutically acceptable salts thereof; and/or said opioid analgesic may be morphine or a morphine derivative or pharmaceutically acceptable salt thereof; and/or said opioid analgesic and an anti-PACAP antibody or antigen binding fragment according to the invention may increase the analgesic effect as compared to either the opioid analgesic or the anti-PACAP antibody or antigen binding fragment administered alone.

[0088] In another embodiment of the invention, an anti-PACAP antibody or fragment or composition according to the invention, wherein the anti-PACAP antibody or fragment and another active agent may be combined therewith or may be administered in combination, may elicit a synergistic or additive effect on the treatment or prevention of a PACAP associated effect, e.g., migraine or on pain. The invention additionally embraces the anti-PACAP antibody or fragment or composition according the invention that may be used in therapy or diagnosis, e.g., migraine treatment or prophylaxis. A further embodiment of the invention relates to anti-PACAP antibody or fragment or composition according to the invention that may be used for potentially treating one or more of hot flush, migraine with or without aura,

hemiplegic migraine, cluster headache, migrainous neuralgia, chronic headache, chronic migraine, medication overuse headache or tension headache.

[0089] Another embodiment of the invention pertains anti-PACAP antibody or fragment or composition according to the invention that may be used for ameliorating, controlling, reducing incidence of, or delaying the development or progression of headache, e.g., migraine with or without aura, hemiplegic migraine, cluster headache, migrainous neuralgia, chronic headache, chronic migraine, medication overuse headache or tension headache. In an embodiment of the invention, the use may be for a subject who may have previously received or may be receiving an anti-CGRP antibody or antibody fragment and/or an anti-CGRP receptor antibody or antibody fragment, and further wherein said subject may be a migraineur who may not have adequately responded to anti-CGRP antibody or antibody fragment and/or anti-CGRP receptor antibody or antibody fragment treatment; and/or wherein said subject may have previously received at least one anti-CGRP antibody or antibody fragment and/or anti-CGRP receptor antibody or antibody fragment administration that may have elicited an immune response to the anti-CGRP antibody or antibody fragment and/or anti-CGRP receptor antibody or antibody fragment.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0090] FIG. 1A-1B provides the polypeptide sequences of the variable region heavy chain for antibodies Ab10 and Ab20 (SEQ ID NOs: 402 and 442, respectively) aligned by their framework regions (FR) and complementarity determining regions (CDRs).

[0091] FIG. 2A-2B provide the polypeptide sequences of the variable region light chain for antibodies Ab10 and Ab20 (SEQ ID NOs: 422 and 462, respectively) aligned by their framework regions (FR), and complementarity determining regions (CDRs).

[0092] FIG. 3A-3E provide the polynucleotide sequences encoding the variable region heavy chain for antibodies Ab10 and Ab20 (SEQ ID NOs: 412 and 452, respectively) aligned by their framework regions (FR), and complementarity determining regions (CDRs).

[0093] FIG. 4A-E provide the polynucleotide sequences encoding the variable region light chain for antibodies Ab10 and Ab20 (SEQ ID NOs: 432 and 472, respectively) aligned by their framework regions (FR), and complementarity determining regions (CDRs).

[0094] FIG. 5 provides the polypeptide sequence coordinates for certain antibody heavy chain protein sequence features including the variable region and complementarity determining regions (CDRs) of the heavy chain for antibodies Ab10 and Ab20.

[0095] FIG. 6 provides the polypeptide sequence coordinates for certain antibody heavy chain protein sequence features including the constant region and framework regions (FR) of the heavy chain for antibodies Ab10 and Ab20.

[0096] FIG. 7 provides the polypeptide sequence coordinates for certain antibody light chain protein sequence features including the variable region and complementarity determining regions (CDRs) of the light chain for antibodies Ab10 and Ab20.

[0097] FIG. 8 provides the polypeptide sequence coordinates for certain antibody light chain protein sequence features including the constant region and framework regions (FR) of the light chain for antibodies Ab10 and Ab20.

[0098] FIG. 9 provides the polynucleotide sequence coordinates for certain antibody heavy chain DNA sequence features including the variable region and complementarity determining regions (CDRs) of the heavy chain for antibodies Ab10 and Ab20.

[0099] FIG. 10 provides the polynucleotide sequence coordinates for certain antibody heavy chain DNA sequence features including the constant region and framework regions (FR) of the heavy chain for antibodies Ab10 and Ab20.

[0100] FIG. 11 provides the polynucleotide sequence coordinates for certain antibody light chain DNA sequence features including the variable region and complementarity determining regions (CDRs) of the light chain for antibodies Ab10 and Ab20.

[0101] FIG. 12 provides the polynucleotide sequence coordinates for certain antibody light chain DNA sequence features including the constant region and framework regions (FR) of the light chain for antibodies Ab10 and Ab20.

[0102] FIG. 13 provides representative data showing a reduction in vasodilation obtained by administering Ab1.H following PACAP38 administration in a rabbit model, relative to a vehicle control, obtained following the protocol in Example 7 *infra*.

[0103] FIG. 14 provides representative data showing a reduction in vasodilation obtained by administering Ab10 following PACAP38 administration in a rabbit model, relative to an isotype antibody control, obtained following the protocol in Example 8 *infra*.

[0104] FIG. 15A provides epitope binning data for labeled Ab1 and unlabeled Ab10 obtained following the protocol in Example 9 *infra*.

[0105] FIG. 15B provides epitope binning data for unlabeled Ab1 and labeled Ab10 obtained following the protocol in Example 9 *infra*.

[0106] FIG. 16 provides representative data showing the *in vivo* effect of the administration of PACAP and an anti-PACAP antibody Ab1.H in a rodent photophobia model, which model detects the amount of time treated animals (mice) spend in the light per 5 minute intervals

compared to appropriate control animals obtained following the protocol in Example 11 *infra*.

[0107] FIG. 17 provides representative data showing the *in vivo* effect of the administration of PACAP and anti-PACAP antibody Ab1.H in a rodent photophobia animal model, which detects the average amount of time treated animals (mice) spend in the light compared to appropriate control animals obtained following the protocol in Example 11 *infra*.

[0108] FIG. 18 provides representative data showing the *in vivo* effect of the administration of PACAP and an anti-PACAP antibody Ab10.H in a rodent photophobia model, which model detects the amount of time treated animals (mice) spend in the light compared to appropriate control animals obtained following the protocol in Example 11 *infra*.

[0109] FIG. 19A-H provides representative data showing Ab10 (FIG. 19A), Ab20 (FIG. 19B), Ab21 (FIG. 19C), Ab1.H (FIG. 19D), Ab10.H (FIG. 19E), Ab21.H (FIG. 19F), Ab22 (FIG. 19G), and Ab23 (FIG. 19H) binding to PAC1-R-expressing PC-12 cells in the presence of PACAP38 obtained following the protocol in Example 6 *infra*. The dashed line in FIG. 19A represents a no PACAP and no antibody control.

DETAILED DESCRIPTION

Definitions

[0110] It is to be understood that this invention is not limited to the particular methodology, protocols, cell lines, animal species or genera, and reagents described, as such may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention, which will be limited only by the appended claims. As used herein the singular forms "a", "and", and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a cell" includes a plurality of such cells and reference to "the protein" includes reference to one or more proteins and equivalents thereof known to those skilled in the art, and so forth. All technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs unless clearly indicated otherwise.

[0111] *Pituitary Adenylate Cyclase-Activating Polypeptide (PACAP)*: As used herein, unless stated otherwise PACAP includes any mammalian form of PACAP, and in particular encompasses the following *Homo sapiens* PACAP27 and *Homo sapiens* PACAP38 amino acid sequences:

[0112] PACAP38:

[0113] HSDGIFTDSYSRYRKQMAVKKYLA AVL GKRYKQRVKNK (SEQ ID NO: 1241), wherein the C-terminal lysine is amidated; but also any mutants, splice variants, isoforms, orthologs, homologs, and variants of this sequence.

[0114] PACAP27:

[0115] HSDGIFTDSYSRYRKQMAVKKYLA AVL (SEQ ID NO: 1242), wherein the C-terminal leucine is amidated; but also any mutants, splice variants, isoforms, orthologs, homologs, and variants of this sequence.

[0116] "Photophobia" herein refers to a symptom of abnormal intolerance to visual perception of light, sometimes additionally defined by abnormal or irrational fear of light, or by presence of actual physical photosensitivity of the eyes. In the present invention photophobia includes in particular light aversion associated with migraine, cluster headaches and other neurological causes of light aversive behavior that can trigger a migraine or cluster headache. Patients/subjects can develop photophobia as a result of several different medical conditions, related to the eye or the nervous system. Photophobia can be caused by an increased response to light starting at any step in the visual system such as: (i) too much light entering the eye, (ii) too much light can enter the eye if it is damaged, such as with corneal abrasion and retinal damage, or if a pupil(s) is unable to normally constrict (seen with damage to the oculomotor nerve), (iii) overstimulation of the photoreceptors in the retina, (iv) excessive electric impulses to the optic nerve, and (v) excessive response in the central nervous system.

[0117] "Effective treatment or prevention of photophobia" herein refers to inhibiting light aversive behavior or photophobia or inhibiting the onset of light aversive behavior or photophobia in a subject in need thereof, e.g., a subject having an active migraine attack or cluster headache or a subject prone to migraine or cluster headaches, or one of the other photophobia-associated disorders identified herein after administration of an effective amount of an anti-PACAP antibody or antigen binding fragment thereof according to the invention. The treatment may be effected as a monotherapy or in association with another active agent such as topiramate or dihydroergotamine by way of example.

[0118] The term "migraine" refers to a complex and disabling neurological disorder that may progress during four stages: prodrome, aura, headache, and postdrome. A migraine is defined by the International Headache Society as a headache that lasts for 4-72 hours and is characterized by at least two of the following: unilateral localization, pulsating quality, moderate to severe pain intensity; and aggravation by movement such as walking. In

addition, the headache must be accompanied by at least one of the following: nausea and/or vomiting, photophobia, or phonophobia. A migraine may also be accompanied by aura, which typically precedes the headache during the premonition or prodrome phase, and often results in visual changes, e.g., a scintillating scotoma that moves across the visual field. The prodrome may also be accompanied by other symptoms, e.g., fatigue, gastrointestinal issues, and mood changes. A migraineur is often incapacitated for extended periods of time. The postdrome is the final phase and occurs after the attack, during which time the migraineur may feel exhausted or mildly euphoric.

[0119] The term "headache" refers to pain in any region of the head. Headaches may occur on one or both sides of the head, be isolated to a certain location, radiate across the head from one point, or have a vise-like quality. A headache may be a sharp pain, throbbing sensation or dull ache. Headaches may appear gradually or suddenly, and they may last less than an hour or for several days.

[0120] The term "pain associated disease or condition" refers to any disease or condition defined, in whole or in part, by acute and/or chronic pain. Pain is generally defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. Pain may be classified as neurogenic, neuropathic, inflammatory, or nociceptive.

[0121] The term "opioid analgesic" herein refers to all drugs, natural or synthetic, with morphine-like actions. The synthetic and semi-synthetic opioid analgesics are derivatives of five chemical classes of compound: phenanthrenes; phenylheptylamines; phenylpiperidines; morphinans; and benzomorphanes, all of which are within the scope of the term. Exemplary opioid analgesics include codeine, dihydrocodeine, diacetylmorphine, hydrocodone, hydromorphone, levorphanol, oxycodone, alfentanil, buprenorphine, butorphanol, fentanyl, sufentanil, meperidine, methadone, nalbuphine, propoxyphene, and pentazocine, or pharmaceutically acceptable salts thereof.

[0122] The term "NSAID" refers to a non-steroidal anti-inflammatory compound. NSAIDs are categorized by virtue of their ability to inhibit cyclooxygenase. Cyclooxygenase 1 and cyclooxygenase 2 are two major isoforms of cyclooxygenase and most standard NSAIDs are mixed inhibitors of the two isoforms. Most standard NSAIDs fall within one of the following five structural categories: (1) propionic acid derivatives, such as ibuprofen, naproxen, naprosyn, diclofenac, and ketoprofen; (2) acetic acid derivatives, such as tolmetin and sulindac; (3) fenamic acid derivatives, such as mefenamic acid and meclofenamic acid; (4) biphenylcarboxylic acid derivatives, such as diflunisal and flufenisal; and (5) oxicams, such

as piroxim, sudoxicam, and isoxicam. Another class of NSAID has been described that selectively inhibit cyclooxygenase 2. COX-2 inhibitors have been described, e.g., in U.S. Patent Nos. 5,616,601; 5,604,260; 5,593,994; 5,550,142; 5,536,752; 5,521,213; 5,475,995; 5,639,780; 5,604,253; 5,552,422; 5,510,368; 5,436,265; 5,409,944; and 5,130,311, all of which are hereby incorporated by reference. Certain exemplary COX-2 inhibitors include celecoxib (SC-58635), DUP-697, flosulide (CGP-28238), meloxicam, 6-methoxy-2 naphthylacetic acid (6-MNA), rofecoxib, MK-966, nabumetone (prodrug for 6-MNA), nimesulide, NS-398, SC-5766, SC-58215, T-614; or combinations thereof.

[0123] As used herein, "treatment" is an approach for obtaining beneficial or desired clinical results. For purposes of this invention, beneficial or desired clinical results include, but are not limited to, one or more of the following: improvement in any aspect of PACAP-related conditions such as migraine or headache. For example in the context of headache or migraine treatment this includes lessening severity, alleviation of pain intensity, and other associated symptoms, reducing frequency of recurrence, increasing the quality of life of those suffering from the headache, and decreasing dose of other medications required to treat the headache. For migraine, other associated symptoms include, but are not limited to, nausea, vomiting, and sensitivity to light, sound, and/or movement. For cluster headache, other associated symptoms include, but are not limited to swelling under or around the eyes, excessive tears, red eye, rhinorrhea or nasal congestion, and red flushed face.

[0124] "Reducing incidence" or "prophylaxis" or "prevention" means any of reducing severity for a particular disease, condition, symptom, or disorder (the terms disease, condition, and disorder are used interchangeably throughout the application). Reduction in severity includes reducing drugs and/or therapies generally used for the condition by, for example, reducing the need for, amount of, and/or exposure to drugs or therapies. Reduction in severity also includes reducing the duration, and/or frequency of the particular condition, symptom, or disorder (including, for example, delaying or increasing time to next episodic attack in an individual).

[0125] "Ameliorating" headache or one or more symptoms of headache or migraine or other PACAP-related condition means a lessening or improvement of one or more symptoms of the condition, e.g., headache or migraine as compared to not administering an anti-PACAP antagonist antibody. "Ameliorating" also includes shortening or reduction in duration of a symptom.

[0126] As used herein, "controlling headache" or "controlling migraine" or "controlling" another PACAP-related condition refers to maintaining or reducing severity or duration of

one or more symptoms of the condition, e.g., headache or migraine or frequency of headache or migraine attacks in an individual (as compared to the level before treatment). For example, the duration or severity of head pain, or frequency of attacks is reduced by at least about any of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 100% in the individual as compared to the level before treatment. The reduction in the duration or severity of head pain, or frequency of attacks can last for any length of time, e.g., 2 weeks, 4 weeks (1 month), 8 weeks (2 months), 16 weeks (3 months), 4 months, 5 months, 6 months, 9 months, 12 months, etc.

[0127] As used therein, "delaying" the development of a PACAP-related condition such as migraine or headache means to defer, hinder, slow, retard, stabilize, and/or postpone progression of the condition or disease. This delay can be of varying lengths of time, depending on the history of the condition or disease and/or individuals being treated. As is evident to one skilled in the art, a sufficient or significant delay can, in effect, encompass prevention, in that the individual does not develop headache (e.g., migraine). A method that "delays" development of the symptom is a method that reduces probability of developing the symptom in a given time frame and/or reduces extent of the symptoms in a given time frame, when compared to not using the method. Such comparisons are typically based on clinical studies, using a statistically significant number of subjects.

[0128] "Development" or "progression" of a PACAP-related condition such as migraine or headache, preferably a condition associated with photophobia or light aversion, means initial manifestations and/or ensuing progression of the disorder or symptom or side effect of such disorder such as photophobia or light aversion. Development of headache or migraine can be detectable and assessed using standard clinical techniques as well known in the art. However, development also refers to progression that may be undetectable. For purpose of this invention, development, or progression refers to the biological course of the symptoms. "Development" includes occurrence, recurrence, and onset. As used herein "onset" or "occurrence" of a condition such as headache or migraine includes initial onset and/or recurrence.

[0129] As used herein, an "effective dosage" or "effective amount" of drug, compound, or pharmaceutical composition is an amount sufficient to effect beneficial or desired results, e.g., an amount sufficient to treat or ameliorate or prevent PACAP associate photophobia or light aversion. For prophylactic use, beneficial or desired results include results such as eliminating or reducing the risk, lessening the severity, or delaying the outset of the disease, including biochemical, histological, and/or behavioral symptoms of the disease, its

complications and intermediate pathological phenotypes presenting during development of the disease. For therapeutic use, beneficial or desired results include clinical results such as reducing pain intensity, duration, or frequency of headache attack, and decreasing one or more symptoms resulting from headache (biochemical, histological, and/or behavioral), including its complications and intermediate pathological phenotypes presenting during development of the disease, increasing the quality of life of those suffering from the disease, decreasing the dose of other medications required to treat the disease, enhancing effect of another medication, and/or delaying the progression of the disease of patients. For instance, clinical results include reducing the sensation of photophobia, light aversion, or avoidance and sensitivity to light. An effective dosage can be administered in one or more administrations. For purposes of this invention, an effective dosage of drug, compound, or pharmaceutical composition is an amount sufficient to accomplish prophylactic or therapeutic treatment either directly or indirectly. As is understood in the clinical context, an effective dosage of a drug, compound, or pharmaceutical composition may or may not be achieved in conjunction with another drug, compound, or pharmaceutical composition. Thus, an "effective dosage" may be considered in the context of administering one or more therapeutic agents, and a single agent may be considered to be given in an effective amount if, in conjunction with one or more other agents, a desirable result may be or is achieved.

[0130] A "suitable host cell" or "host cell" generally includes any cell wherein the subject anti-PACAP antibodies and antigen binding fragments thereof can be produced recombinantly using techniques and materials readily available. For example, the anti-PACAP antibodies and antigen binding fragments thereof of the present invention can be produced in genetically engineered host cells according to conventional techniques. Suitable host cells are those cell types that can be transformed or transfected with exogenous DNA and grown in culture, and include bacteria, fungal cells (e.g., yeast), and cultured higher eukaryotic cells (including cultured cells of multicellular organisms), particularly cultured mammalian cells, e.g., human or non-human mammalian cells. In an exemplary embodiment these antibodies may be expressed in CHO cells. Techniques for manipulating cloned DNA molecules and introducing exogenous DNA into a variety of host cells are disclosed by Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2nd ed., Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory Press (1989), and *Current Protocols in Molecular Biology*, Ausubel et al., editors, New York, NY: Green and Wiley and Sons (1993).

[0131] In some exemplary embodiments the antibodies may be expressed in mating competent yeast, e.g., any haploid, diploid or tetraploid yeast that can be grown in culture.

Yeast useful in fermentation expression methods may exist in a haploid, diploid, or other polyploid form. The cells of a given ploidy may, under appropriate conditions, proliferate for an indefinite number of generations in that form. Diploid cells can also sporulate to form haploid cells. Sequential mating can result in tetraploid strains through further mating or fusion of diploid strains. The present invention contemplates the use of haploid yeast, as well as diploid or other polyploid yeast cells produced, for example, by mating or spheroplast fusion. By way of example, such yeast may include members of the *Saccharomycetaceae* family, which includes the genera *Arxiozyma*; *Ascobotryozyma*; *Citeromyces*; *Debaryomyces*; *Dekkera*; *Eremothecium*; *Issatchenkia*; *Kazachstania*; *Kluyveromyces*; *Kodamaea*; *Lodderomyces*; *Pachysolen*; *Pichia*; *Saccharomyces*; *Saturnispora*; *Tetrapisispora*; *Torulasporea*; *Williopsis*; and *Zygosaccharomyces*. Other types of yeast potentially useful in the invention include *Yarrowia*; *Rhodospiridium*; *Candida*; *Hansenula*; *Filobasium*; *Sporidiobolus*; *Bullera*; *Leucosporidium* and *Filobasidella*.

[0132] In a preferred exemplary embodiment of the invention, the mating competent yeast used for antibody expression may comprise a member of the genus *Pichia*. In a further preferred exemplary embodiment of the invention, the mating competent yeast of the genus *Pichia* is one of the following species: *Pichia pastoris*, *Pichia methanolica*, and *Hansenula polymorpha* (*Pichia angusta*). In a particularly preferred embodiment of the invention, the mating competent yeast of the genus *Pichia* is the species *Pichia pastoris*.

[0133] A “selectable marker” herein refers to a gene or gene fragment that confers a growth phenotype (physical growth characteristic) on a cell receiving that gene as, for example through a transformation event. The selectable marker allows that cell to survive and grow in a selective growth medium under conditions in which cells that do not receive that selectable marker gene cannot grow. Selectable marker genes generally fall into several types, including positive selectable marker genes such as a gene that confers on a cell resistance to an antibiotic or other drug, temperature when two temperature sensitive (“ts”) mutants are crossed or a ts mutant is transformed; negative selectable marker genes such as a biosynthetic gene that confers on a cell the ability to grow in a medium without a specific nutrient needed by all cells that do not have that biosynthetic gene, or a mutagenized biosynthetic gene that confers on a cell inability to grow by cells that do not have the wild type gene; and the like. Suitable markers include but are not limited to: ZEO; G418; LYS3; MET1; MET3a; ADE1; ADE3; URA3; and the like.

[0134] An “expression vector” herein refers to DNA vectors containing elements that facilitate manipulation for the expression of a foreign protein within the target host cell, e.g.,

a bacterial, insect, yeast, plant, amphibian, reptile, avian, or mammalian cell, and most typically a yeast or mammalian cell, e.g., a CHO cell. Conveniently, manipulation of sequences and production of DNA for transformation is first performed in a bacterial host, e.g. *E. coli*, and usually vectors will include sequences to facilitate such manipulations, including a bacterial origin of replication and appropriate bacterial selection marker. Selection markers encode proteins necessary for the survival or growth of transformed host cells grown in a selective culture medium. Host cells not transformed with the vector containing the selection gene will not survive in the culture medium. Typical selection genes encode proteins that (a) confer resistance to antibiotics or other toxins, (b) complement auxotrophic deficiencies, or (c) supply critical nutrients not available from complex media. Exemplary vectors and methods for transformation of yeast are described, for example, in Burke, D., Dawson, D., & Stearns, T., *Methods in yeast genetics: a Cold Spring Harbor Laboratory course manual*, Plainview, NY: Cold Spring Harbor Laboratory Press (2000). Expression vectors for use in the methods of the invention may include yeast or mammalian specific sequences, including a selectable auxotrophic or drug marker for identifying transformed host strains. A drug marker may further be used to amplify copy number of the vector in a yeast host cell.

[0135] The polypeptide coding sequence of interest is operably linked to transcriptional and translational regulatory sequences that provide for expression of the polypeptide in the desired host cells, e.g., yeast or mammalian cells. These vector components may include, but are not limited to, one or more of the following: an enhancer element, a promoter, and a transcription termination sequence. Sequences for the secretion of the polypeptide may also be included, e.g. a signal sequence, and the like. An origin of replication, e.g., a yeast origin of replication, is optional, as expression vectors are often integrated into the host cell genome. In one embodiment of the invention, the polypeptide of interest is operably linked, or fused, to sequences providing for optimized secretion of the polypeptide from yeast diploid cells.

[0136] Nucleic acids are "operably linked" when placed into a functional relationship with another nucleic acid sequence. For example, DNA for a signal sequence is operably linked to DNA for a polypeptide if it is expressed as a preprotein that participates in the secretion of the polypeptide; a promoter or enhancer is operably linked to a coding sequence if it affects the transcription of the sequence. Generally, "operably linked" means that the DNA sequences being linked are contiguous, and, in the case of a secretory leader, contiguous and in reading frame. However, enhancers do not have to be contiguous. Linking is accomplished

by ligation at convenient restriction sites or alternatively via a PCR/recombination method familiar to those skilled in the art (GATEWAY[®] Technology; Invitrogen, Carlsbad California). If such sites do not exist, the synthetic oligonucleotide adapters or linkers are used in accordance with conventional practice.

[0137] Promoters are untranslated sequences located upstream (5') to the start codon of a structural gene (generally within about 100 to 1000 bp) that control the transcription and translation of particular nucleic acid sequences to which they are operably linked. Such promoters fall into several classes: inducible, constitutive, and repressible promoters (that increase levels of transcription in response to absence of a repressor). Inducible promoters may initiate increased levels of transcription from DNA under their control in response to some change in culture conditions, e.g., the presence or absence of a nutrient or a change in temperature.

[0138] The promoter fragment may also serve as the site for homologous recombination and integration of the expression vector into the same site in the host cell, e.g., yeast cell, genome; alternatively, a selectable marker may be used as the site for homologous recombination. *Pichia* transformation is described in Cregg et al., *Mol. Cell. Biol.*, 5:3376-3385 (1985). Suitable promoters for use in different eukaryotic and prokaryotic cells are well known and commercially available.

[0139] The polypeptides of interest may be produced recombinantly not only directly, but also as a fusion polypeptide with a heterologous polypeptide, e.g. a signal sequence or other polypeptide having a specific cleavage site at the N-terminus of the mature protein or polypeptide. In general, the signal sequence may be a component of the vector, or it may be a part of the polypeptide coding sequence that is inserted into the vector. The heterologous signal sequence selected preferably is one that is recognized and processed through one of the standard pathways available within the host cell, e.g., a mammalian cell, an insect cell, or a yeast cell. Additionally, these signal peptide sequences may be engineered to provide for enhanced secretion in expression systems. Secretion signals of interest also include mammalian and yeast signal sequences, which may be heterologous to the protein being secreted, or may be a native sequence for the protein being secreted. Signal sequences include pre-peptide sequences, and in some instances may include propeptide sequences. Many such signal sequences are known in the art, including the signal sequences found on immunoglobulin chains, e.g., K28 preprotoxin sequence, PHA-E, FACE, human MCP-1, human serum albumin signal sequences, human Ig heavy chain, human Ig light chain, and the

like. For example, see Hashimoto et. al., *Protein Eng.*, 11(2):75 (1998); and Kobayashi et. al., *Therapeutic Apheresis*, 2(4):257 (1998).

[0140] Transcription may be increased by inserting a transcriptional activator sequence into the vector. These activators are cis-acting elements of DNA, usually about from 10 to 300 bp, which act on a promoter to increase its transcription. Transcriptional enhancers are relatively orientation and position independent, having been found 5' and 3' to the transcription unit, within an intron, as well as within the coding sequence itself. The enhancer may be spliced into the expression vector at a position 5' or 3' to the coding sequence, but is preferably located at a site 5' from the promoter.

[0141] Expression vectors used in eukaryotic host cells may also contain sequences necessary for the termination of transcription and for stabilizing the mRNA. Such sequences are commonly available from 3' to the translation termination codon, in untranslated regions of eukaryotic or viral DNAs or cDNAs. These regions contain nucleotide segments transcribed as polyadenylated fragments in the untranslated portion of the mRNA.

[0142] Construction of suitable vectors containing one or more of the above-listed components employs standard ligation techniques or PCR/recombination methods. Isolated plasmids or DNA fragments are cleaved, tailored, and re-ligated in the form desired to generate the plasmids required or via recombination methods. For analysis to confirm correct sequences in plasmids constructed, the ligation mixtures are used to transform host cells, and successful transformants selected by antibiotic resistance (e.g. ampicillin or Zeocin) where appropriate. Plasmids from the transformants are prepared, analyzed by restriction endonuclease digestion, and/or sequenced.

[0143] As an alternative to restriction and ligation of fragments, recombination methods based on specific attachment ("att") sites and recombination enzymes may be used to insert DNA sequences into a vector. Such methods are described, for example, by Landy, *Ann. Rev. Biochem.*, 58:913-949 (1989); and are known to those of skill in the art. Such methods utilize intermolecular DNA recombination that is mediated by a mixture of lambda and *E. coli* - encoded recombination proteins. Recombination occurs between att sites on the interacting DNA molecules. For a description of att sites see Weisberg and Landy, *Site-Specific Recombination in Phage Lambda*, in *Lambda II*, p. 211-250, Cold Spring Harbor, NY: Cold Spring Harbor Press (1983). The DNA segments flanking the recombination sites are switched, such that after recombination, the att sites are hybrid sequences comprised of sequences donated by each parental vector. The recombination can occur between DNAs of any topology.

[0144] *Att* sites may be introduced into a sequence of interest by ligating the sequence of interest into an appropriate vector; generating a PCR product containing *att* B sites through the use of specific primers; generating a cDNA library cloned into an appropriate vector containing *att* sites; and the like.

[0145] *Folding*, as used herein, refers to the three-dimensional structure of polypeptides and proteins, where interactions between amino acid residues act to stabilize the structure. While non-covalent interactions are important in determining structure, usually the proteins of interest will have intra- and/or intermolecular covalent disulfide bonds formed by two cysteine residues. For naturally occurring proteins and polypeptides or derivatives and variants thereof, the proper folding is typically the arrangement that results in optimal biological activity, and can conveniently be monitored by assays for activity, *e.g.* ligand binding, enzymatic activity, *etc.*

[0146] In some instances, for example where the desired product is of synthetic origin, assays based on biological activity will be less meaningful. The proper folding of such molecules may be determined on the basis of physical properties, energetic considerations, modeling studies, and the like.

[0147] The expression host may be further modified by the introduction of sequences encoding one or more enzymes that enhance folding and disulfide bond formation, *i.e.* foldases, chaperonins, *etc.* Such sequences may be constitutively or inducibly expressed in the yeast host cell, using vectors, markers, *etc.* as known in the art. Preferably the sequences, including transcriptional regulatory elements sufficient for the desired pattern of expression, are stably integrated in the yeast genome through a targeted methodology.

[0148] For example, the eukaryotic protein disulfide isomerase (“PDI”) is not only an efficient catalyst of protein cysteine oxidation and disulfide bond isomerization, but also exhibits chaperone activity. Co-expression of PDI can facilitate the production of active proteins having multiple disulfide bonds. Also of interest is the expression of immunoglobulin heavy chain binding protein (“BIP”); cyclophilin; and the like. In one embodiment of the invention, each of the haploid parental strains expresses a distinct folding enzyme, *e.g.* one strain may express BIP, and the other strain may express PDI or combinations thereof.

[0149] Cultured mammalian cells are also preferred exemplary hosts for production of the disclosed anti-PACAP antibodies and antigen binding fragments thereof. As mentioned CHO cells are particularly suitable for expression of antibodies. Many procedures are known in the art for manufacturing monoclonal antibodies in mammalian cells. (See, Galfre, G. and

Milstein, C., *Methods Enzym.*, 73:3-46, 1981; Basalp et al., *Turk. J. Biol.*, 24:189-196, 2000; Wurm, F.M., *Nat. Biotechnol.*, 22:1393-1398, 2004; and Li et al., *mAbs*, 2(5):466-477, 2010). As mentioned in further detail *infra*, common host cell lines employed in mammalian monoclonal antibody manufacturing schemes include, but are not limited to, human embryonic retinoblast cell line PER.C6® (Crucell N.V., Leiden, The Netherlands), NS0 murine myeloma cells (Medical Research Council, London, UK), CV1 monkey kidney cell line, 293 human embryonic kidney cell line, BHK baby hamster kidney cell line, VERO African green monkey kidney cell line, human cervical carcinoma cell line HELA, MDCK canine kidney cells, BRL buffalo rat liver cells, W138 human lung cells, HepG2 human liver cells, MMT mouse mammary tumor cells, TRI cells, MRC5 cells, Fs4 cells, myeloma or lymphoma cells, or Chinese Hamster (*Cricetulus griseus*) Ovary (CHO) cells, and the like. Many different subclones or sub-cell lines of CHO cells known in the art that are useful and optimized for production of recombinant monoclonal antibodies, such as the DP12 (CHO K1 dhfr-) cell line, NS0 cells are a non-Ig secreting, non-light chain-synthesizing subclone of NS-1 cells that are resistant to azaguanine. Other Chinese Hamster and CHO cells are commercially available (from ATCC, etc.), including CHO-DXB11 (CHO-DUKX), CHO-pro3, CHO-DG44, CHO 1-15, CHO DP-12, Lec2, M1WT3, Lec8, pgsA-745, and the like, all of which are genetically altered to optimize the cell line for various parameters. Monoclonal antibodies are commonly manufactured using a batch fed method whereby the monoclonal antibody chains are expressed in a mammalian cell line and secreted into the tissue culture medium in a bioreactor. Medium (or feed) is continuously supplied to the bioreactor to maximize recombinant protein expression. Recombinant monoclonal antibody is then purified from the collected media. In some circumstances, additional steps are needed to reassemble the antibodies through reduction of disulfide bonds, etc. Such production methods can be scaled to be as large as 10,000 L in a single batch or more. It is now routine to obtain as much as 20 pg/cell/day through the use of such cell lines and methodologies, providing titers as high as 10 g/L or more, amounting to 15 to 100 kg from bioreactors of 10 kL to 25 kL. (Li et al., 2010). Various details of this production methodology, including cloning of the polynucleotides encoding the antibodies into expression vectors, transfecting cells with these expression vectors, selecting for transfected cells, and expressing and purifying the recombinant monoclonal antibodies from these cells are provided below.

[0150] For recombinant production of an anti-PACAP antibody or antigen binding fragment in mammalian cells, nucleic acids encoding the antibody or fragment thereof are generally inserted into a replicable vector for further cloning (amplification of the DNA) or for

expression. DNA encoding the antibody is readily isolated or synthesized using conventional procedures (e.g., by using oligonucleotide probes that are capable of binding specifically to DNAs encoding the heavy and light chains of the antibody). The vector components generally include, but are not limited to, one or more of the following: a signal sequence, an origin of replication, one or more marker genes, an enhancer element, a promoter, and a transcription termination sequence. Selection of promoters, terminators, selectable markers, vectors, and other elements is a matter of routine design within the level of ordinary skill in the art. Many such elements are known in the art and are available through commercial suppliers.

[0151] The antibodies of this invention may be produced recombinantly not only directly, but also as a fusion polypeptide with a heterologous polypeptide, which is preferably a signal sequence or other polypeptide having a specific cleavage site at the N-terminus of the mature protein or polypeptide. The homologous or heterologous signal sequence selected preferably is one that is recognized and processed (i.e., cleaved by a signal peptidase) by the host cell. In mammalian cell expression, mammalian signal sequences as well as viral secretory leaders, for example, the herpes simplex gD signal, are available.

[0152] Such expression vectors and cloning vectors will generally contain a nucleic acid sequence that enables the vector to replicate in one or more selected host cells. Typically, in cloning vectors this sequence is one that enables the vector to replicate independently of the host chromosomal DNA, and includes origins of replication or autonomously replicating sequences. Such sequences are well known for a variety of bacteria, yeast, and viruses, e.g., the origin of replication from the plasmid pBR322 is suitable for most Gram-negative bacteria, the 2 μ plasmid origin is suitable for yeast, and various viral origins (Simian Virus 40 ("SV40"), polyoma, adenovirus, vesicular stomatitis virus ("VSV"), or bovine papillomavirus ("BPV")) are useful for cloning vectors in mammalian cells. Generally, the origin of replication component is not needed for mammalian expression vectors (the SV40 origin may typically be used only because it contains the early promoter).

[0153] These vectors will also typically contain a selection gene, also termed a selectable marker. Typical selection genes encode proteins that (a) confer resistance to antibiotics or other toxins, e.g., ampicillin, neomycin, methotrexate, or tetracycline, (b) complement auxotrophic deficiencies, or (c) supply critical nutrients not available from complex media, e.g., the gene encoding D-alanine racemase for Bacilli.

[0154] One example of a selection scheme utilizes a drug to arrest growth of a host cell. Drug selection is generally used to select for cultured mammalian cells into which foreign DNA

has been inserted. Such cells are commonly referred to as "transfectants". Cells that have been cultured in the presence of the selective agent and are able to pass the gene of interest to their progeny are referred to as "stable transfectants." Examples of such dominant selection use the drugs neomycin, mycophenolic acid, and hygromycin. An exemplary selectable marker is a gene encoding resistance to the antibiotic neomycin. Selection is carried out in the presence of a neomycin-type drug, such as G-418 or the like. Those cells that are successfully transformed with a heterologous gene produce a protein conferring drug resistance and thus survive the selection regimen.

[0155] Selection systems can also be used to increase the expression level of the gene of interest, a process referred to as "amplification." Amplification of transfectants typically occurs by culturing the cells in the presence of a low level of the selective agent and then increasing the amount of selective agent to select for cells that produce high levels of the products of the introduced genes. Exemplary suitable selectable markers for mammalian cells are those that enable the identification of cells competent to take up the antibody nucleic acid, such as dihydrofolate reductase ("DHFR"), thymidine kinase, metallothionein-I and -II, preferably primate metallothionein genes, adenosine deaminase, ornithine decarboxylase, etc.

[0156] For example, an amplifiable selectable marker for mammalian cells is dihydrofolate reductase, which confers resistance to methotrexate. Other drug resistance genes (e.g. hygromycin resistance, multi-drug resistance, puromycin acetyltransferase) can also be used. Cells transformed with the DHFR selection gene are first identified by culturing all of the transformants in a culture medium that contains methotrexate ("MTX"), a competitive antagonist of DHFR. An appropriate host cell when wild-type DHFR is employed is the Chinese hamster ovary ("CHO") cell line deficient in DHFR activity.

[0157] Alternatively, host cells (particularly wild-type hosts that contain endogenous DHFR) transformed or co-transformed with DNA sequences encoding antibody, wild-type DHFR protein, and another selectable marker such as aminoglycoside 3'-phosphotransferase ("APH") can be selected by cell growth in medium containing a selection agent for the selectable marker such as an aminoglycosidic antibiotic, e.g., kanamycin, neomycin, or G-418. See U.S. Patent No. 4,965,199.

[0158] These vectors may comprise an enhancer sequence that facilitates transcription of a DNA encoding the antibody. Many enhancer sequences are known from mammalian genes (for example, globin, elastase, albumin, alpha-fetoprotein, and insulin). A frequently used enhancer is one derived from a eukaryotic cell virus. Examples thereof include the SV40 enhancer on the late side of the replication origin (bp 100-270), the cytomegalovirus early

promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers (*See, Yaniv, Nature, 297:17-18, 1982, on enhancing elements for activation of eukaryotic promoters*). The enhancer may be spliced into the vector at a position 5' or 3' to the antibody-encoding sequence, but is preferably located at a site 5' from the promoter.

[0159] Expression and cloning vectors will also generally comprise a promoter that is recognized by the host organism and is operably linked to the antibody nucleic acid. Promoter sequences are known for eukaryotes. Virtually all eukaryotic genes have an AT-rich region located approximately 25 to 30 bases upstream from the site where transcription is initiated. Another sequence found 70 to 80 bases upstream from the start of transcription of many genes is a CNCAAT region where N may be any nucleotide. At the 3' end of most eukaryotic genes is an AATAAA sequence that may be the signal for addition of the poly A tail to the 3' end of the coding sequence. All of these sequences are suitably inserted into eukaryotic expression vectors.

[0160] Antibody transcription from vectors in mammalian host cells is controlled, for example, by promoters obtained from the genomes of viruses such as polyoma virus, fowlpox virus, adenovirus (such as Adenovirus 2), BPV, avian sarcoma virus, cytomegalovirus, a retrovirus, hepatitis-B virus, and most preferably SV40, from heterologous mammalian promoters, e.g., the actin promoter or an immunoglobulin promoter, from heat-shock promoters, provided such promoters are compatible with the host cell systems.

[0161] The early and late promoters of the SV40 virus are conveniently obtained as an SV40 restriction fragment that also contains the SV40 viral origin of replication. The immediate early promoter of the human cytomegalovirus is conveniently obtained as a HindIII E restriction fragment. A system for expressing DNA in mammalian hosts using the BPV as a vector is disclosed in U.S. Patent No. 4,419,446. A modification of this system is described in U.S. Patent No. 4,601,978. *See also Reyes et al., Nature, 297:598-601 (1982) on expression of human beta-interferon cDNA in mouse cells under the control of a thymidine kinase promoter from herpes simplex virus. Alternatively, the rous sarcoma virus long terminal repeat can be used as the promoter.*

[0162] Strong transcription promoters can be used, such as promoters from SV40, cytomegalovirus, or myeloproliferative sarcoma virus. *See, e.g., U.S. Patent No. 4,956,288 and U.S. Patent Publication No. 20030103986. Other suitable promoters include those from metallothionein genes (U.S. Patent Nos. 4,579,821 and 4,601,978) and the adenovirus major late promoter. Expression vectors for use in mammalian cells include pZP-1, pZP-9, and*

pZMP21, which have been deposited with the American Type Culture Collection, 10801 University Blvd., Manassas, VA. USA under accession numbers 98669, 98668, and PTA-5266, respectively, and derivatives of these vectors.

[0163] Expression vectors used in eukaryotic host cells (yeast, fungus, insect, plant, animal, human, or a nucleated cell from other multicellular organism) will also generally contain sequences necessary for the termination of transcription and for stabilizing the mRNA. Such sequences are commonly available from the 5' and, occasionally 3', untranslated regions of eukaryotic or viral DNAs or cDNAs. These regions contain nucleotide segments transcribed as polyadenylated fragments in the untranslated portion of the mRNA encoding the antibody. One useful transcription termination component is the bovine growth hormone polyadenylation region. See WO 94/11026 and the expression vector disclosed therein.

[0164] Suitable host cells for cloning or expressing the subject antibodies include prokaryote, yeast, or higher eukaryote cells described above. However, interest has been greatest in vertebrate cells, and propagation of vertebrate cells in culture has become a routine procedure. Examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-1 (ATCC No. CRL 1650); and COS-7, ATCC CRL 1651); human embryonic kidney line (293 or 293 cells subcloned for growth in suspension culture, (ATCC No. CRL 1573; Graham et al., *J. Gen. Virol.*, 36:59-72 (1977)); baby hamster kidney cells (BHK, ATCC CCL 10, ATCC No. CRL 1632; BHK 570, ATCC No. CRL 10314); CHO cells (CHO-K1, ATCC No. CCL 61; CHO-DG44, Urlaub et al., *Proc. Natl. Acad. Sci. USA*, 77:4216-4220 (1980)); mouse sertoli cells (TM4, Mather, *Biol. Reprod.*, 23:243-251 (1980)); monkey kidney cells (CV1 ATCC CCL 70); African green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HELA, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse mammary tumor (MMT 060562, ATCC CCL51); TRI cells (Mather et al., *Annals N.Y. Acad. Sci.*, 383:44-68 (1982)); MRC 5 cells; FS4 cells; and a human hepatoma line (Hep G2). Additional suitable cell lines are known in the art and available from public depositories such as the American Type Culture Collection, Manassas, VA.

[0165] Host cells are transformed with the above-described expression or cloning vectors for antibody production and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences as discussed *supra*.

[0166] The mammalian host cells used to produce the antibody of this invention may be cultured in a variety of media. Commercially available media such as Ham's F10 (Sigma-Aldrich Corporation, St. Louis, MO), Minimal Essential Medium ("MEM" (Sigma-Aldrich Corporation, St. Louis, MO), Roswell Park Memorial Institute-1640 medium ("RPMI-1640", Sigma-Aldrich Corporation, St. Louis, MO), and Dulbecco's Modified Eagle's Medium ("DMEM" Sigma-Aldrich Corporation, St. Louis, MO) are suitable for culturing the host cells. In addition, any of the media described in Ham et al., *Meth. Enz.*, 58:44 (1979), Barnes et al., *Anal. Biochem.*, 102:255 (1980), U.S. Patent Nos. 4,767,704; 4,657,866; 4,927,762; 4,560,655; or 5,122,469; WO 90/03430; WO 87/00195; or U.S. Patent Reexam No. 30,985 can be used as culture media for the host cells. Any of these media may be supplemented as necessary with hormones and/or other growth factors (such as insulin, transferrin, or epidermal growth factor), salts (such as sodium chloride, calcium, magnesium, and phosphate), buffers (such as HEPES), nucleotides (such as adenosine and thymidine), antibiotics (such as Gentamycin drug), trace elements (defined as inorganic compounds usually present at final concentrations in the micromolar range), and glucose or an equivalent energy source. Any other necessary supplements may also be included at appropriate concentrations that would be known to those skilled in the art. The culture conditions, such as temperature, pH, and the like, are those previously used with the host cell selected for expression, and will be apparent to the ordinarily skilled artisan. Methods of development and optimization of media and culture conditions are known in the art (See, Gronemeyer et al., *Bioengineering*, 1(4):188-212, 2014).

[0167] After culture conditions are optimized and a preferred cell line clone is selected, these cells are cultured (either adherent cells or suspension cultures) most typically in a batch-fed process in a bioreactor (many models are commercially available) that involves continuously feeding the cell culture with medium and feed, optimized for the particular cell line chosen and selected for this purpose. (See, Butler, M., *Appl. Microbiol. Biotechnol.*, 68:283-291, 2005; and Kelley, B., *mAb*, 1(5):443-452, 2009). Perfusion systems are also available in which media and feed are continuously supplied to the culture while the same volume of media is being withdrawn from the bioreactor. (Wurm, 2004). Synthetic media, also commercially available, are available for growing cells in a batch-fed culture, avoiding the possibility of contamination from outside sources, such as with the use of animal components, such as bovine serum albumin, etc. However, animal-component-free hydrolysates are commercially available to help boost cell density, culture viability and productivity. (Li et al., 2010). Many studies have been performed in an effort to optimize cell

culture media, including careful attention to head space available in roller bottles, redox potentials during growth and expression phases, presence of reducing agents to maintain disulfide bonds during production, etc. (See, for instance, Hutterer et al., *mAbs*, 5(4):608-613, 2013; and Mullan et al., *BMC Proceed.*, 5(Suppl 8):P110, 2011). Various methodologies have been developed to address the possibility of harmful oxidation during recombinant monoclonal antibody production. (See, for example, U.S. Patent No. 8,574,869). Cultured cells may be grown by feeding nutrients continuously or as separately administered amounts. Often various process parameters such as cell concentration, pH, temperature, CO₂, dO₂, osmolality, amount of metabolites such as glucose, lactate, glutamine and glutamate, and the like, are monitored by the use of probes during the cell growth either on-line by direct connection to calibrated analyzers or off-line by intervention of operators. The culturing step also typically involves ensuring that the cells growing in culture maintain the transfected recombinant genes by any means known in the art for cell selection.

[0168] Following fermentation, i.e., upon reaching maximum cell growth and recombinant protein expression, the culturing step is typically followed by a harvesting step, whereby the cells are separated from the medium and a harvested cell culture media is thereby obtained. (See, Liu et al., *mAbs*, 2(5):480-499, 2010). Typically various purification steps, involving column chromatography and the like, follow culturing to separate the recombinant monoclonal antibody from cell components and cell culture media components. The exact purification steps needed for this phase of the production of recombinant monoclonal antibodies depends on the site of expression of the proteins, i.e., in the cytosol of the cells themselves, or the more commonly preferred route of protein excreted into the cell culture medium. Various cell components may be separated using techniques known in the art such as differential centrifugation techniques, gravity-based cell settling, and/or size exclusion chromatograph/filtration techniques that can include tangential flow micro-filtration or depth filtration. (See, Pollock et al., *Biotechnol. Bioeng.*, 110:206-219, 2013, and Liu et al., 2010). Centrifugation of cell components may be achieved on a large scale by use of continuous disk stack centrifuges followed by clarification using depth and membrane filters. (See, Kelley, 2009). Most often, after clarification, the recombinant protein is further purified by Protein A chromatography due to the high affinity of Protein A for the Fc domain of antibodies, and typically occurs using a low pH/acidification elution step (typically the acidification step is combined with a precautionary virus inactivation step). Flocculation and/or precipitation steps using acidic or cationic polyelectrolytes may also be employed to separate animal cells in suspension cultures from soluble proteins. (Liu et al., 2010). Lastly, anion- and cation-

exchange chromatography, hydrophobic interaction chromatograph ("HIC"), hydrophobic charge induction chromatograph (HCIC), hydroxyapatite chromatography using ceramic hydroxyapatite ($\text{Ca}_5(\text{PO}_4)_3\text{OH}$)₂, and combinations of these techniques are typically used to polish the solution of recombinant monoclonal antibody. Final formulation and concentration of the desired monoclonal antibody may be achieved by use of ultracentrifugation techniques. Purification yields are typically 70 to 80%. (Kelley, 2009).

[0169] The terms "*desired protein*" or "*desired antibody*" are used interchangeably and refer generally to a parent antibody specific to a target, i.e., PACAP or a chimeric or humanized antibody or a binding portion thereof derived therefrom as described herein. The term "antibody" is intended to include any polypeptide chain-containing molecular structure with a specific shape that fits to and recognizes an epitope, where one or more non-covalent binding interactions stabilize the complex between the molecular structure and the epitope. The archetypal antibody molecule is the immunoglobulin, and all types of immunoglobulins, IgG, IgM, IgA, IgE, IgD, etc., from all sources, e.g. human, rodent, rabbit, cow, sheep, pig, dog, other mammals, chicken, other avians, etc., are considered to be "antibodies." A preferred source for producing antibodies useful as starting material according to the invention is rabbits. Examples thereof include chimeric antibodies, human antibodies and other non-human mammalian antibodies, humanized antibodies, single chain antibodies (such as scFvs), camelbodies, nanobodies, IgNAR (single-chain antibodies which may be derived from sharks, for example), small-modular immunopharmaceuticals ("SMIPs"), and antibody fragments such as Fabs, Fab', F(ab')₂, and the like (See Streltsov et al., *Protein Sci.*, 14(11):2901-9 (2005); Greenberg et al., *Nature*, 374(6518):168-73 (1995); Nuttall et al., *Mol. Immunol.*, 38(4):313-26 (2001); Hamers-Casterman et al., *Nature*, 363(6428):446-8 (1993); Gill et al., *Curr. Opin. Biotechnol.*, (6):653-8 (2006)).

[0170] For example, antibodies or antigen binding fragments thereof may be produced by genetic engineering. In this technique, as with other methods, antibody-producing cells are sensitized to the desired antigen or immunogen. The messenger RNA isolated from antibody producing cells is used as a template to make cDNA using PCR amplification. A library of vectors, each containing one heavy chain gene and one light chain gene retaining the initial antigen specificity, is produced by insertion of appropriate sections of the amplified immunoglobulin cDNA into the expression vectors. A combinatorial library is constructed by combining the heavy chain gene library with the light chain gene library. This results in a library of clones that co-express a heavy and light chain (resembling the Fab fragment or antigen binding fragment of an antibody molecule). The vectors that carry these genes are co-

transfected into a host cell. When antibody gene synthesis is induced in the transfected host, the heavy and light chain proteins self-assemble to produce active antibodies that can be detected by screening with the antigen or immunogen.

[0171] Antibody coding sequences of interest include those encoded by native sequences, as well as nucleic acids that, by virtue of the degeneracy of the genetic code, are not identical in sequence to the disclosed nucleic acids, and variants thereof. Variant polypeptides can include amino acid ("aa") substitutions, additions, or deletions. The amino acid substitutions can be conservative amino acid substitutions or substitutions to eliminate non-essential amino acids, such as to alter a glycosylation site, or to minimize misfolding by substitution or deletion of one or more cysteine residues that are not necessary for function. Variants can be designed so as to retain or have enhanced biological activity of a particular region of the protein (*e.g.*, a functional domain, catalytic amino acid residues, *etc.*). Variants also include fragments of the polypeptides disclosed herein, particularly biologically active fragments and/or fragments corresponding to functional domains. Techniques for *in vitro* mutagenesis of cloned genes are known. Also included in the subject invention are polypeptides that have been modified using ordinary molecular biological techniques so as to improve their resistance to proteolytic degradation or to optimize solubility properties or to render them more suitable as a therapeutic agent.

[0172] Chimeric antibodies may be made by recombinant means by combining the V_L and V_H regions, obtained from antibody producing cells of one species with the constant light and heavy chain regions from another. Typically chimeric antibodies utilize rodent or rabbit variable regions and human constant regions, in order to produce an antibody with predominantly human domains. The production of such chimeric antibodies is well known in the art, and may be achieved by standard means (as described, *e.g.*, in U.S. Patent No. 5,624,659, incorporated herein by reference in its entirety). It is further contemplated that the human constant regions of chimeric antibodies of the invention may be selected from IgG1, IgG2, IgG3, and IgG4 constant regions.

[0173] Humanized antibodies are engineered to contain even more human-like immunoglobulin domains, and incorporate only the complementarity determining regions of the animal-derived antibody. This is accomplished by carefully examining the sequence of the hyper-variable loops of the variable regions of the monoclonal antibody and fitting them to the structure of the human antibody chains. Although facially complex, the process is straightforward in practice. See, *e.g.*, U.S. Patent No. 6,187,287, incorporated fully herein by reference.

[0174] In addition to entire immunoglobulins (or their recombinant counterparts), immunoglobulin fragments comprising the epitope binding site (e.g., Fab', F(ab')₂, or other fragments) may be synthesized. "Fragment" or minimal immunoglobulins may be designed utilizing recombinant immunoglobulin techniques. For instance "Fv" immunoglobulins for use in the present invention may be produced by synthesizing a fused variable light chain region and a variable heavy chain region. Combinations of antibodies are also of interest, e.g. diabodies, which comprise two distinct Fv specificities. In another embodiment of the invention, small molecule immunopharmaceuticals ("SMIPs"), camelbodies, nanobodies, and IgNAR are encompassed by immunoglobulin fragments.

[0175] Immunoglobulins and fragments thereof may be modified post-translationally, e.g. to add effector moieties such as chemical linkers, detectable moieties, such as fluorescent dyes, enzymes, toxins, substrates, bioluminescent materials, radioactive materials, chemiluminescent moieties, and the like, or specific binding moieties, such as streptavidin, avidin, or biotin, and the like may be utilized in the methods and compositions of the present invention. Examples of additional effector molecules are provided *infra*.

[0176] A polynucleotide sequence "corresponds" to a polypeptide sequence if translation of the polynucleotide sequence in accordance with the genetic code yields the polypeptide sequence (i.e., the polynucleotide sequence "encodes" the polypeptide sequence), one polynucleotide sequence "corresponds" to another polynucleotide sequence if the two sequences encode the same polypeptide sequence.

[0177] A "heterologous" region or domain of a DNA construct is an identifiable segment of DNA within a larger DNA molecule that is not found in association with the larger molecule in nature. Thus, when the heterologous region encodes a mammalian gene, the DNA flanking the gene usually does not flank the mammalian genomic DNA in the genome of the source organism. Another example of a heterologous region is a construct where the coding sequence itself is not found in nature (e.g., a cDNA where the genomic coding sequence contains introns or synthetic sequences having codons different than the native gene). Allelic variations or naturally-occurring mutational events do not give rise to a heterologous region of DNA as defined herein.

[0178] A "coding sequence" is an in-frame sequence of codons that correspond to or encode a protein or peptide sequence. Two coding sequences correspond to each other if the sequences or their complementary sequences encode the same amino acid sequences. A coding sequence in association with appropriate regulatory sequences may be transcribed and translated into a polypeptide. A polyadenylation signal and transcription termination

sequence will usually be located 3' to the coding sequence. A "promoter sequence" is a DNA regulatory region capable of initiating transcription of a downstream (3' direction) coding sequence, and typically contain additional sites for binding of regulatory molecules, e.g., transcription factors, that affect the transcription of the coding sequence. A coding sequence is "under the control" of the promoter sequence or "operatively linked" to the promoter when RNA polymerase binds the promoter sequence in a cell and transcribes the coding sequence into mRNA, which is then in turn translated into the protein encoded by the coding sequence.

[0179] The general structure of antibodies in vertebrates now is well understood. See Edelman, G. M., *Ann. N.Y. Acad. Sci.*, 190:5 (1971). Antibodies consist of two identical light polypeptide chains of molecular weight approximately 23,000 daltons (the "light chain"), and two identical heavy chains of molecular weight 53,000-70,000 (the "heavy chain"). The four chains are joined by disulfide bonds in a "Y" configuration wherein the light chains bracket the heavy chains starting at the mouth of the "Y" configuration. The "branch" portion of the "Y" configuration is designated the F_{ab} region; the stem portion of the "Y" configuration is designated the F_C region. The amino acid sequence orientation runs from the N-terminal end at the top of the "Y" configuration to the C-terminal end at the bottom of each chain. The N-terminal end possesses the variable region having specificity for the antigen that elicited it, and is approximately 100 amino acids in length, there being slight variations between light and heavy chain and from antibody to antibody.

[0180] The variable region is linked in each chain to a constant region that extends the remaining length of the chain and that within a particular class of antibody does not vary with the specificity of the antibody (i.e., the antigen eliciting it). There are five known major classes of constant regions that determine the class of the immunoglobulin molecule (IgG, IgM, IgA, IgD, and IgE corresponding to γ , μ , α , δ , and ϵ (gamma, mu, alpha, delta, or epsilon) heavy chain constant regions). The constant region or class determines subsequent effector function of the antibody, including activation of complement (*see* Kabat, E. A., *Structural Concepts in Immunology and Immunochemistry*, 2nd Ed., p. 413-436, New York, NY: Holt, Rinehart, Winston (1976)), and other cellular responses (*see* Andrews et al., *Clinical Immunology*, pp. 1-18, W. B. Sanders, Philadelphia, PA (1980); Kohl et al., *Immunology*, 48:187 (1983)); while the variable region determines the antigen with which it will react. Light chains are classified as either κ (kappa) or λ (lambda). Each heavy chain class can be prepared with either kappa or lambda light chain. The light and heavy chains are covalently bonded to each other, and the "tail" portions of the two heavy chains are bonded to

each other by covalent disulfide linkages when the immunoglobulins are generated either by hybridomas or by B-cells.

[0181] The expression "variable region" or "VR" refers to the domains within each pair of light and heavy chains in an antibody that are involved directly in binding the antibody to the antigen. Each heavy chain has at one end a variable domain (V_H) followed by a number of constant domains. Each light chain has a variable domain (V_L) at one end and a constant domain at its other end; the constant domain of the light chain is aligned with the first constant domain of the heavy chain, and the light chain variable domain is aligned with the variable domain of the heavy chain.

[0182] The expressions "complementarity determining region," "hypervariable region," or "CDR" refer to one or more of the hyper-variable or complementarity determining regions ("CDRs") found in the variable regions of light or heavy chains of an antibody (*See* Kabat et al., *Sequences of Proteins of Immunological Interest*, 4th ed., Bethesda, MD: U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health (1987)). These expressions include the hypervariable regions as defined by Kabat et al., (*Sequences of Proteins of Immunological Interest*, NIH Publication No. 91-3242, Bethesda, MD: U.S. Dept. of Health and Human Services, National Institutes of Health (1983)) or the hypervariable loops in 3-dimensional structures of antibodies (Chothia and Lesk, *J. Mol. Biol.*, 196:901-917 (1987)). The CDRs in each chain are held in close proximity by framework regions ("FRs") and, with the CDRs from the other chain, contribute to the formation of the antigen binding site. Within the CDRs there are select amino acids that have been described as the selectivity determining regions ("SDRs") that represent the critical contact residues used by the CDR in the antibody-antigen interaction (*see* Kashmiri et al., *Methods*, 36(1):25-34 (2005)).

[0183] An "epitope" or "binding site" is an area or region on an antigen to which an antigen-binding peptide (such as an antibody) specifically binds. A protein epitope may comprise amino acid residues directly involved in the binding (also called immunodominant component of the epitope) and other amino acid residues, which are not directly involved in the binding, such as amino acid residues that are effectively blocked by the specifically antigen binding peptide (in other words, the amino acid residue is within the "footprint" of the specifically antigen binding peptide). The term epitope herein includes both types of amino acid binding sites in any particular region of PACAP, i.e., PACAP38 and PACAP27, that specifically binds to an anti-PACAP antibody. PACAP may comprise a number of different epitopes, which may include, without limitation, (1) linear peptide antigenic determinants, (2) conformational antigenic determinants that consist of one or more non-

contiguous amino acids located near each other in a mature PACAP conformation; and (3) post-translational antigenic determinants that consist, either in whole or part, of molecular structures covalently attached to a PACAP protein such as carbohydrate groups. In particular, the term "epitope" includes the specific residues in a protein or peptide, e.g., PACAP, which are involved in the binding of an antibody to such protein or peptide as determined by known and accepted methods such as alanine scanning techniques. Such methods are exemplified herein.

[0184] The phrase that an antibody (e.g., first antibody) binds "substantially" or "at least partially" the same epitope as another antibody (e.g., second antibody) means that the epitope binding site for the first antibody comprises at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or more of the amino acid residues on the antigen that constitutes the epitope binding site of the second antibody. Also, that a first antibody binds substantially or partially the same or overlapping epitope as a second antibody means that the first and second antibodies compete in binding to the antigen, as described above. Thus, the term "binds to substantially the same epitope or determinant as" a monoclonal antibody means that an antibody "competes" with the antibody.

[0185] The phrase "binds to the same or overlapping epitope or determinant as" an antibody of interest means that an antibody "competes" with said antibody of interest for at least one, (e.g., at least 2, at least 3, at least 4, at least 5) or all residues on PACAP to which said antibody of interest specifically binds. The identification of one or more antibodies that bind(s) to substantially or essentially the same epitope as the monoclonal antibodies described herein can be readily determined using alanine scanning. Additionally, any one of variety of immunological screening assays in which antibody competition can be assessed. A number of such assays are routinely practiced and well known in the art (see, e.g., U.S. Patent No. 5,660,827, issued Aug. 26, 1997, which is specifically incorporated herein by reference). It will be understood that actually determining the epitope to which an antibody described herein binds is not in any way required to identify an antibody that binds to the same or substantially the same or overlapping epitope as the monoclonal antibody described herein.

[0186] For example, where the test antibodies to be examined are obtained from different source animals, or are even of a different Ig isotype, a simple competition assay may be employed in which the control antibody is mixed with the test antibody and then applied to a sample containing PACAP. Protocols based upon ELISAs, radioimmunoassays, Western blotting, and the use of BIACORE® (GE Healthcare Life Sciences, Marlborough, MA) analysis are suitable for use in such simple competition studies.

[0187] In certain embodiments, the control anti-PACAP antibody is pre-mixed with varying amounts of the test antibody (e.g., in ratios of about 1:1, 1:2, 1:10, or about 1:100) for a period of time prior to applying to the PACAP38 or PACAP27 antigen sample. In other embodiments, the control and varying amounts of test antibody can simply be added separately and admixed during exposure to the PACAP38 or PACAP27 antigen sample. As long as bound antibodies can be distinguished from free antibodies (e.g., by using separation or washing techniques to eliminate unbound antibodies) and control antibody from the test antibody (e.g., by using species specific or isotype specific secondary antibodies or by specifically labeling the control antibody with a detectable label) it can be determined if the test antibody reduces the binding of the control antibody to the PACAP38 or PACAP27 antigens, indicating that the test antibody recognizes substantially the same epitope as the control anti-PACAP antibody. The binding of the (labeled) control antibody in the presence of a completely irrelevant antibody (that does not bind PACAP) can serve as the control high value. The control low value can be obtained by incubating the labeled control antibody with the same but unlabeled control antibody, where competition would occur and reduce binding of the labeled antibody. In a test assay, a significant reduction in labeled antibody reactivity in the presence of a test antibody is indicative of a test antibody that recognizes substantially the same epitope, i.e., one that competes with the labeled control antibody. For example, any test antibody that reduces the binding of the control antibody to PACAP38 or PACAP27 by at least about 50%, such as at least about 60%, or more preferably at least about 70% (e.g., about 65-100%), at any ratio of test antibody between about 1:1 or 1:10 and about 1:100 is considered to be an antibody that binds to substantially the same or overlapping epitope or determinant as the control antibody.

[0188] Preferably, such test antibody will reduce the binding of the control antibody to PACAP38 or PACAP27 antigen preferably at least about 50%, at least about 60%, at least about 80%, or at least about 90% (e.g., about 95%) of the binding of the control antibody observed in the absence of the test antibody.

[0189] A simple competition assay in which a test antibody is applied at saturating concentration to a surface onto which PACAP38 or PACAP27 is immobilized also may be advantageously employed. The surface in the simple competition assay is preferably a BIACORE® (GE Healthcare Life Sciences, Marlborough, MA) chip (or other media suitable for surface plasmon resonance ("SPR") analysis). The binding of a control antibody that binds PACAP38 or PACAP27 to the PACAP-coated surface is measured. This binding to the PACAP38- or PACAP27-containing surface of the control antibody alone is compared with

the binding of the control antibody in the presence of a test antibody. A significant reduction in binding to the PACAP38- or PACAP27-containing surface by the control antibody in the presence of a test antibody indicates that the test antibody recognizes substantially the same epitope as the control antibody such that the test antibody "competes" with the control antibody. Any test antibody that reduces the binding of control antibody by at least about 20% or more, at least about 40%, at least about 50%, at least about 70%, or more, can be considered to be an antibody that binds to substantially the same epitope or determinant as the control antibody. Preferably, such test antibody will reduce the binding of the control antibody to PACAP38 or PACAP27 by at least about 50% (e.g., at least about 60%, at least about 70%, or more). It will be appreciated that the order of control and test antibodies can be reversed; i.e. the control antibody can be first bound to the surface and then the test antibody is brought into contact with the surface thereafter in a competition assay. Preferably, the "sandwich-style" binding assay exemplified in Example 9 *infra* is used. Alternatively, the antibody having greater affinity for PACAP38 or PACAP27 antigen is bound to the PACAP38- or PACAP27-containing surface first, as it will be expected that the decrease in binding seen for the second antibody (assuming the antibodies are competing) will be of greater magnitude. Further examples of such assays are provided in e.g., Saunal and Regenmortel, *J. Immunol. Methods*, 183:33-41 (1995), the disclosure of which is incorporated herein by reference.

[0190] In addition, whether an antibody binds the same or overlapping epitope(s) on PACAP as another antibody or the epitope bound by a test antibody may in particular be determined using a Western-blot based assay. In this assay a library of peptides corresponding to the antigen bound by the antibody, the PACAP protein, is made, that comprise overlapping portions of the protein, typically 10-25, 10-20, or 10-15 amino acids long. These different overlapping amino acid peptides encompassing the PACAP sequence are synthesized and covalently bound to a PEPSPOTSTM nitrocellulose membrane (JPT Peptide Technologies, Berlin, Germany). Blots are then prepared and probed according to the manufacturer's recommendations.

[0191] Essentially, the immunoblot assay then detects by fluorometric means what peptides in the library bind to the test antibody and thereby can identify what residues on the antigen, i.e., PACAP, interact with the test antibody. (See U.S. Patent No. 7,935,340, incorporated by reference herein).

[0192] Various epitope mapping techniques are known in the art. By way of example, X-ray co-crystallography of the antigen and antibody; NMR; SPR (e.g., at 25° or 37°C); array-

based oligo-peptide scanning (or “pepscan analysis”); site-directed mutagenesis (e.g., alanine scanning); mutagenesis mapping; hydrogen-deuterium exchange; phage display; and limited proteolysis are all epitope mapping techniques that are well known in the art (See, e.g., *Epitope Mapping Protocols: Second Edition, Methods in Molecular Biology*, editors Mike Schutkowski and Ulrich Reineke, 2nd Ed., New York, NY: Humana Press (2009), and *Epitope Mapping Protocols, Methods in Molecular Biology*, editor Glenn Morris, 1st Ed., New York, NY: Humana Press (1996), both of which are herein incorporated by referenced in their entirety).

[0193] The identification of one or more antibodies that bind(s) to substantially or essentially the same epitope as the monoclonal antibodies described herein, e.g., Ab10 or Ab20, can be readily determined using any one of variety of immunological screening assays in which antibody competition can be assessed. A number of such assays are routinely practiced and well known in the art (see, e.g., U.S. Patent No. 5,660,827, issued Aug. 26, 1997, which is incorporated herein by reference). It will be understood that determining the epitope to which an antibody described herein binds is not in any way required to identify an antibody that binds to the same or substantially the same epitope as the monoclonal antibody described herein.

[0194] For example, where the test antibodies to be examined are obtained from different source animals, or are even of a different Ig isotype, a simple competition assay may be employed in which the control antibody (one of Ab10 or Ab20, for example) is mixed with the test antibody and then applied to a sample containing either or both PACAP38 and PACAP27, each of which is known to be bound by Ab10 or Ab20. Protocols based upon ELISAs, radioimmunoassays, Western blotting, and BIACORE® (GE Healthcare Life Sciences, Marlborough, MA) analysis (as described in the Examples section herein) are suitable for use in such simple competition studies.

[0195] In certain embodiments, the method comprises pre-mixing the control antibody with varying amounts of the test antibody (e.g., in ratios of about 1:1, 1:2, 1:10, or about 1:100) for a period of time prior to applying to the PACAP antigen sample. In other embodiments, the control and varying amounts of test antibody can be added separately and admixed during exposure to the PACAP antigen sample. As long as bound antibodies can be distinguished from free antibodies (e.g., by using separation or washing techniques to eliminate unbound antibodies) and control antibody from the test antibody (e.g., by using species specific or isotype specific secondary antibodies or by specifically labelling the control antibody with a detectable label), the method can be used to determine that the test antibody reduces the

binding of the control antibody to the PACAP antigen, indicating that the test antibody recognizes substantially the same epitope as the control antibody (e.g., Ab10 or Ab20). The binding of the (labeled) control antibody in the presence of a completely irrelevant antibody (that does not bind PACAP) can serve as the control high value. The control low value can be obtained by incubating the labeled control antibody with the same but unlabeled control antibody, where competition would occur and reduce binding of the labeled antibody. In a test assay, a significant reduction in labeled antibody reactivity in the presence of a test antibody is indicative of a test antibody that recognizes substantially the same epitope, i.e., one that competes with the labeled control antibody. For example, any test antibody that reduces the binding of Ab10 or Ab20 to both of PACAP38 and PACAP27 antigens by at least about 50%, such as at least about 60%, or more preferably at least about 70% (e.g., about 65-100%), at any ratio of control Ab10 or Ab20:test antibody or Ab10 or Ab20:test antibody between about 1:1 or 1:10 and about 1:100 is considered to be an antibody that binds to substantially the same epitope or determinant as Ab10 or Ab20, respectively. Preferably, such test antibody will reduce the binding of Ab10 or Ab20 to at least one, preferably each, of the PACAP38 and PACAP27 antigens preferably at least about 50%, at least about 60%, at least about 80% or at least about 90% (e.g., about 95%) of the binding of Ab10 or Ab20 observed in the absence of the test antibody. These methods can be adapted to identify and/or evaluate antibodies that compete with other control antibodies.

[0196] A simple competition assay in which a test antibody is applied at saturating concentration to a surface onto which either PACAP38 or PACAP27, or both, are immobilized also may be advantageously employed. The surface in the simple competition assay is preferably of a media suitable for OCTET® and/or PROTEON®. The binding of a control antibody (e.g., Ab10 or Ab20) to the PACAP-coated surface is measured. This binding to the PACAP-containing surface of the control antibody alone is compared with the binding of the control antibody in the presence of a test antibody. A significant reduction in binding to the PACAP-containing surface by the control antibody in the presence of a test antibody indicates that the test antibody recognizes substantially the same epitope as the control antibody such that the test antibody "competes" with the control antibody. Any test antibody that reduces the binding of control antibody (such as Ab10 or Ab20) to both of PACAP38 and PACAP27 antigens by at least about 20% or more, at least about 40%, at least about 50%, at least about 70%, or more, can be considered to be an antibody that binds to substantially the same epitope or determinant as the control antibody (e.g., Ab10 or Ab20). Preferably, such test antibody will reduce the binding of the control antibody (e.g., Ab10 or

Ab20) to the PACAP antigen by at least about 50% (e.g., at least about 60%, at least about 70%, or more). It will be appreciated that the order of control and test antibodies can be reversed; i.e. the control antibody can be first bound to the surface and then the test antibody is brought into contact with the surface thereafter in a competition assay. Preferably, the antibody having higher affinity for PACAP38 and PACAP27 is bound to the PACAP-containing surface first, as it will be expected that the decrease in binding seen for the second antibody (assuming the antibodies are competing) will be of greater magnitude. Further examples of such assays are provided in, e.g., Saunal and Regenmortel, *J. Immunol. Methods*, 183:33-41 (1989), the disclosure of which is incorporated herein by reference.

[0197] Determination of whether an antibody, antigen binding fragment thereof, or antibody derivative binds within one of the epitope regions defined above can be carried out in ways known to the person skilled in the art. In another example of such mapping/characterization methods, an epitope region for an anti-PACAP antibody may be determined by epitope "footprinting" using chemical modification of the exposed amines/carboxyls in the PACAP38 and PACAP27 protein. One specific example of such a foot-printing technique is the use of hydrogen-deuterium exchange detected by mass spectrometry ("HXMS"), wherein a hydrogen/deuterium exchange of receptor and ligand protein amide protons, binding, and back exchange occurs, wherein the backbone amide groups participating in protein binding are protected from back exchange and therefore will remain deuterated. Relevant regions can be identified at this point by peptic proteolysis, fast microbore high-performance liquid chromatography separation, and/or electrospray ionization mass spectrometry (See, e.g., Ehring H., *Analytical Biochemistry*, 267(2):252-259 (1999) and Engen, J. R. & Smith, D. L., *Anal. Chem.*, 73:256A-265A (2001)). Another example of a suitable epitope identification technique is nuclear magnetic resonance epitope mapping ("NMR"), where typically the position of the signals in two-dimensional NMR spectra of the free antigen and the antigen complexed with the antigen binding peptide, such as an antibody, are compared. The antigen typically is selectively isotopically labeled with ^{15}N so that only signals corresponding to the antigen and no signals from the antigen binding peptide are seen in the NMR-spectrum. Antigen signals originating from amino acids involved in the interaction with the antigen binding peptide typically will shift position in the spectra of the complex compared to the spectra of the free antigen, and the amino acids involved in the binding can be identified that way, See, e.g., *Ernst Schering Res. Found. Workshop*, (44):149-67 (2004); Huang et al., *J. Mol. Biol.*, 281(1):61-67 (1998); and Saito and Patterson, *Methods*, 9(3):516-24 (1996)). Epitope mapping/characterization also can be performed using mass spectrometry

("MS") methods (See, e.g., Downard, *J. Mass Spectrom.*, 35(4):493-503 (2000) and Kiselar and Downard, *Anal. Chem.*, 71(9):1792-801 (1999)).

[0198] Protease digestion techniques also can be useful in the context of epitope mapping and identification. Antigenic determinant-relevant regions/sequences can be determined by protease digestion, e.g. by using trypsin in a ratio of about 1:50 to PACAP38 or PACAP27 overnight ("o/n") digestion at 37°C and pH 7-8, followed by mass spectrometry ("MS") analysis for peptide identification. The peptides protected from trypsin cleavage by the anti-PACAP antibody can subsequently be identified by comparison of samples subjected to trypsin digestion and samples incubated with antibody and then subjected to digestion by e.g. trypsin (thereby revealing a footprint for the antibody). Other enzymes like chymotrypsin or pepsin can be used in similar epitope characterization methods. Moreover, enzymatic digestion can provide a quick method for analyzing whether a potential antigenic determinant sequence is within a region of PACAP in the context of a PACAP-binding polypeptide. If the polypeptide is not surface exposed, it is most likely not relevant in terms of immunogenicity/antigenicity (See, e.g., Manca, *Ann. Ist. Super. Sanità.*, 27(1):15-9 (1991) for a discussion of similar techniques).

[0199] Site-directed mutagenesis is another technique useful for characterization of a binding epitope. For example, in "alanine-scanning" site-directed mutagenesis (also known as alanine scanning, alanine scanning mutagenesis, alanine scanning mutations, combinatorial alanine scanning, or creation of alanine point mutations, for example), each residue within a protein segment is replaced with an alanine residue (or another residue such as valine where alanine is present in the wild-type sequence) through such methodologies as direct peptide or protein synthesis, site-directed mutagenesis, the GENEART™ Mutagenesis Service (Thermo Fisher Scientific, Waltham, MA U.S.A.) or shotgun mutagenesis, for example. A series of single point mutants of the molecule is thereby generated using this technique; the number of mutants generated is equivalent to the number of residues in the molecule, each residue being replaced, one at a time, by a single alanine residue. Alanine is generally used to replace native (wild-type) residues because of its non-bulky, chemically inert, methyl functional group that can mimic the secondary structure preferences that many other amino acids may possess. Subsequently, the effects replacing a native residue with an alanine has on binding affinity of an alanine scanning mutant and its binding partner can be measured using such methods as, but not limited to, SPR binding experiments. If a mutation leads to a significant reduction in binding affinity, it is most likely that the mutated residue is involved in binding. Monoclonal antibodies specific for structural epitopes (i.e., antibodies that do not bind the

unfolded protein) can be used as a positive control for binding affinity experiments to verify that the alanine-replacement does not influence the overall tertiary structure of the protein (as changes to the overall fold of the protein may indirectly affect binding and thereby produce a false positive result). See, e.g., Clackson and Wells, *Science*, 267:383-386 (1995); Weiss *et al.*, *Proc. Natl. Acad. Sci. USA*, 97(16):8950-8954 (2000); and Wells, *Proc. Natl. Acad. Sci. USA*, 93:1-6 (1996). In Example 12 alanine scanning methods are used to identify the specific epitope or residues of PACAP which specifically interact with the anti-PACAP antibodies disclosed herein.

[0200] Electron microscopy can also be used for epitope "footprinting". For example, Wang *et al.*, *Nature*, 355:275-278 (1992) used coordinated application of cryoelectron microscopy, three-dimensional image reconstruction, and X-ray crystallography to determine the physical footprint of a Fab-fragment on the capsid surface of native cowpea mosaic virus.

[0201] Other forms of "label-free" assay for epitope evaluation include SPR (sold commercially as the BIACORE® system, GE Healthcare Life Sciences, Marlborough, MA) and reflectometric interference spectroscopy ("RifS") (See, e.g., Fagerstam *et al.*, *Journal of Molecular Recognition*, 3:208-14 (1990); Nice *et al.*, *J. Chromatogr.*, 646:159-168 (1993); Leipert *et al.*, *Angew. Chem. Int. Ed.*, 37:3308-3311 (1998); Kroger *et al.*, *Biosensors and Bioelectronics*, 17:937-944 (2002)).

[0202] The expressions "framework region" or "FR" refer to one or more of the framework regions within the variable regions of the light and heavy chains of an antibody (See Kabat *et al.*, *Sequences of Proteins of Immunological Interest*, 4th edition, Bethesda, MD: U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health (1987)). These expressions include those amino acid sequence regions interposed between the CDRs within the variable regions of the light and heavy chains of an antibody.

[0203] The term "Fc region" is used to define a C-terminal region of an immunoglobulin heavy chain. The "Fc region" may be a native sequence Fc region or a variant Fc region. Although the boundaries of the Fc region of an immunoglobulin heavy chain might vary, the human IgG heavy chain Fc region is usually defined to stretch from an amino acid residue at position Cys226, or from Pro230, to the carboxyl-terminus thereof. The numbering of the residues in the Fc region is that of the EU index as in Kabat. Kabat *et al.*, *Sequences of Proteins of Immunological Interest*, 5th edition, Bethesda, MD: U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health (1991). The Fc region of an immunoglobulin generally comprises two constant domains, CH2 and CH3.

[0204] The terms "Fc receptor" and "FcR" describe a receptor that binds to the Fc region of an antibody. The preferred FcR is a native sequence human FcR. Moreover, a preferred FcR is one that binds an IgG antibody (a gamma receptor) and includes receptors of the FcγRI, FcγRII, and FcγRIII subclasses, including allelic variants and alternatively spliced forms of these receptors. FcγRII receptors include FcγRIIA (an "activating receptor") and FcγRIIB (an "inhibiting receptor"), which have similar amino acid sequences that differ primarily in the cytoplasmic domains thereof. FcRs are reviewed in Ravetch and Kinet, *Ann. Rev. Immunol.*, 9:457-92 (1991); Capel et al., *Immunomethods*, 4:25-34 (1994); and de Haas et al., *J. Lab. Clin. Med.*, 126:330-41 (1995). "FcR" also includes the neonatal receptor, FcRn, which is responsible for the transfer of maternal IgGs to the fetus (Guyer et al., *J. Immunol.*, 117:587 (1976); and Kim et al., *J. Immunol.*, 24:249 (1994)), and which primarily functions to modulate and/or extend the half-life of antibodies in circulation. To the extent that the disclosed anti-PACAP antibodies are aglycosylated, as a result of the expression system and/or sequence, the subject antibodies are expected to bind FcRn receptors, but not to bind (or to minimally bind) Fcγ receptors.

[0205] A "functional Fc region" possesses at least one effector function of a native sequence Fc region. Exemplary "effector functions" include C1q binding; complement dependent cytotoxicity ("CDC"); Fc receptor binding; antibody-dependent cell-mediated cytotoxicity ("ADCC"); phagocytosis; down-regulation of cell surface receptors (e.g. B cell receptor ("BCR")), etc. Such effector functions generally require the Fc region to be combined with a binding domain (e.g. an antibody variable domain) and can be assessed using various assays known in the art for evaluating such antibody effector functions.

[0206] A "native sequence Fc region" comprises an amino acid sequence identical to the amino acid sequence of an Fc region found in nature. A "variant Fc region" comprises an amino acid sequence that differs from that of a native sequence Fc region by virtue of at least one amino acid modification, yet retains at least one effector function of the native sequence Fc region. Preferably, the variant Fc region has at least one amino acid substitution compared to a native sequence Fc region or to the Fc region of a parent polypeptide, e.g. from about one to about ten amino acid substitutions, and preferably from about one to about five amino acid substitutions in a native sequence Fc region or in the Fc region of the parent polypeptide. The variant Fc region herein will preferably possess at least about 80% sequence identity with a native sequence Fc region and/or with an Fc region of a parent polypeptide, and most preferably at least about 90% sequence identity therewith, more preferably at least about

95%, at least about 96%, at least about 97%, at least about 98%, or at least about 99% sequence identity therewith.

Anti-PACAP Antibodies and Binding Fragments Thereof Having Binding Affinity for PACAP

[0207] PACAP is a multifunctional vasodilatory peptide with expression throughout the central nervous system ("CNS") and periphery. PACAP is a member of the secretin/VIP/GRH family. PACAP exists in two α -amidated active forms, PACAP38 (SEQ ID NO: 1241) and PACAP27 (SEQ ID NO: 1242). Herein, the term "PACAP" includes either or both of PACAP38 and PACAP27 unless expressly indicated otherwise. PACAP is highly conserved between species.

[0208] In humans, PACAP is derived from a 176 amino acid precursor protein (preproPACAP) and the gene is located on chromosome 18p11, with PACAP38 encoded for by exon 5 (Vaudry et al., *Pharmacol. Rev.*, 61:283-357 (2009)). PreproPACAP contains an N-terminal 24 amino acid signal protein, a 29 amino acid PACAP-related peptide and PACAP in the C-terminal domain. The precursor is metabolized by prohormone convertase enzymes into biologically active PACAP38 and PACAP27.

[0209] VIP (SEQ ID NO: 1243) belongs to the same protein family as PACAP and shares high homology with PACAP, i.e., VIP and PACAP27 have 68% sequence homology at the amino acid level, as well as similar overall secondary structure, i.e. long alpha-helical structures at the C-terminus.

[0210] PACAP's actions are mediated via three different G-protein coupled receptors: PAC1-R, VPAC1-R, and VPAC2-R. VPAC1-R can associate with all of the receptor-associated membrane proteins ("RAMPs", Kaiser & Russo, *Neuropeptides* 47: 451-461 (2013)). PAC1-R is selective for PACAP, whereas VPAC1-R and VPAC2-R bind to both VIP and PACAP with high affinity. PAC1-R binds to PACAP with 100-1000-fold higher affinity than VIP, i.e., $K_D \sim 0.5$ nM for PACAP27/PACAP38 vs. $K_D \sim 500$ nM for VIP. Conversely, VPAC1-R and VPAC2-R have equal affinities for PACAP and VIP ($K_D \sim 1$ nM) (See Schytz et al. (2010)). All three receptors are widely expressed in both peripheral tissues and in the CNS, with PAC1-R predominantly expressed in the CNS, most abundantly in the olfactory bulb, thalamus, hypothalamus, the dentate gyrus of the hippocampus and in granule cells of the cerebellum (Hashimoto et al., *J. Comp. Neurol.*, 371:567-577 (1996); Shioda et al., *Neurosci. Res.*, 28:345-354 (1997)).

[0211] Activation of the PAC1-R, VPAC1-R, and/or VPAC2-R results in increased adenylate cyclase activity and, thus, increased cAMP production. However, PACAP receptors can also mediate their effects through PLC, leading to increased Ca^{2+} levels, and PLD.

[0212] PACAP has a wide range of biological effects, including a role in neurodevelopment, neuroprotection, neuromodulation, neurogenic inflammation, and nociception. PACAP is also reported to interact with glycosaminoglycans ("GAGs"). GAGs are long, unbranched polysaccharides composed of repeating disaccharide units, such as heparin, chondroitin, keratin, and hyaluronic acid. It has been shown that the cellular uptake of PACAP is dependent on the expression of GAG proteins and that PACAP bound to sulfated GAGs. Particularly, it was determined that PACAP38 binding to GAGs was capable of inducing receptor-independent cellular uptake of PACAP38. This study further demonstrated that a random coil-to- α -helix transition in PACAP38 was essential for GAG-dependent uptake of PACAP38, as a mutant PACAP38 that could not undergo the structural transition was not internalized by GAG-containing cell lines as efficiently as the wild-type form of PACAP38 (Neree et al., *FEBS Lett.*, 588(24):4590-4596, 2014). In a follow up study, it was determined that PACAP's ability to cluster GAGs, i.e., heparin, was directly related to its ability to function as a cell penetrating peptide ("CPP"). It is hypothesized that this activity is attributable to the heparin-binding, or Cardin-Weintraub, motif found in secretin/glucagon/GHRH family members, such as PACAP (Neree et al., *Int. J. Mol. Sci.*, 16:27391-27400, 2015). Interestingly, Neree et al. (2015) presented data demonstrating that PACAP38 was able to cluster sulfated GAGs *in vitro*. These data suggested that the observed clustering effect is important for the GAG-mediated cellular uptake of PACAP38, as other peptides, such as glucagon, displayed higher binding affinities for sulfated GAGs (heparin) but are not internalized by cells as efficiently as PACAP38. Further, it is reported that in *in vitro* studies in which cells are exposed to PACAP, cartilage formation is increased, including cartilage matrix that is rich in sulphated GAG proteins, consistent with its putative protective role expressed during various cellular stress responses (Juhász et al., *PLoS ONE*, 9(3):e91541, 2014). Using cell types that lack PACAP-specific receptors on their plasma membranes, such as CHO-K1 cells, Doan et al. presented data demonstrating the ability of such cells to engage in receptor-independent cellular uptake of various forms of fluorescently-labeled PACAP38 and PACAP27 (Doan et al., *Biochem. Biophys. Acta*, 1823:940-949, 2012).

[0213] The present invention provides exemplary antibodies or antigen binding fragments thereof that bind PACAP, including human PACAP. Other antibodies or antigen binding

fragments thereof that bind PACAP, including those having different CDRs, and epitopic specificity may be obtained using the disclosure of the present specification, and using methods that are generally known in the art. Such antibodies and antigen binding fragments thereof antagonize the biological effects of PACAP *in vivo* and therefore are useful in treating or preventing PACAP-related conditions including, for example, headache, migraine, pain, photophobia, hot flush, PTSD, and anxiety disorders. In preferred embodiments, the antibody or antigen binding fragment thereof according to the invention comprises one or more CDRs, a V_L chain and/or V_H chain of the anti-PACAP antibodies and antigen binding fragments thereof described herein.

[0214] In some embodiments, an anti-PACAP antibody or antigen binding fragment thereof according to the invention will interfere with, block, reduce, or modulate the interaction between PACAP and its receptor(s) (e.g., PAC1-R, VPAC1-R, and VPAC2-R). In some instances an anti-PACAP antibody or antigen binding fragment thereof according to the invention is “neutralizing”, e.g., it totally prevents the specific interaction of PACAP with PAC1-R, VPAC1-R, and/or VPAC2-R. In some embodiments, the antibody or antigen binding fragment thereof neutralizes PACAP, e.g., by remaining bound to PACAP in a location and/or manner that prevents PACAP from specifically binding to PAC1-R, VPAC1-R, and/or VPAC2-R.

[0215] In some embodiments, the antibody or antigen binding fragment thereof according to the invention is capable of inhibiting PACAP-mediated activity (including binding to PAC1-R-expressing cells). In some embodiments, the antibody or antigen binding fragment thereof according to the invention are humanized, such as humanized rabbit antibodies to PACAP.

[0216] As mentioned, the anti-PACAP antibodies or antigen binding fragments thereof according to the invention have a variety of uses. For example, the subject antibodies and fragments can be useful in therapeutic applications, as well as diagnostically in binding assays. The subject anti-PACAP antibodies or antigen binding fragments thereof are useful for affinity purification of PACAP, in particular human PACAP or its ligands and in screening assays to identify other antagonists of PACAP activity. Some of the antibodies or antigen binding fragments thereof are useful for inhibiting binding of PACAP to PAC1-R, VPAC1-R, and/or VPAC2-R, or inhibiting PACAP-mediated activities and/or biological effects.

[0217] As used herein, the term “one or more biological effects associated with PACAP” refers to any biological effect mediated, induced, or otherwise attributable to PACAP, e.g., binding properties, functional properties, and other properties of biological significance. Non-

limiting exemplary biological effects of PACAP include PACAP binding to PAC1-R, VPAC1-R, and/or VPAC2-R; PACAP activating PAC1-R, VPAC1-R, and/or VPAC2-R-mediated signaling; PACAP-mediated increase in cAMP production; PACAP-mediated increase in PLC activity; PACAP-mediated increase in PLD activity; PACAP-mediated increase in Ca^{2+} levels; and PACAP-mediated vasodilation, photophobia, mast cell degranulation, and/or neuronal activation. The subject anti-PACAP antibodies are capable of inhibiting one, a combination of, or all of these exemplary PACAP biological activities. For example, the anti-PACAP antibodies and antigen binding fragments thereof provided herein are capable of inhibiting PACAP-induced vasodilation (*see* Example 7 and Example 8).

[0218] The antibody or antigen binding fragment thereof according to the invention can be used in a variety of therapeutic applications. For example, in some embodiments the anti-PACAP antibody or antigen binding fragment thereof are useful for treating conditions associated with PACAP, such as, but not limited to, migraine (with or without aura), hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, general headaches, hot flush, photophobia, chronic paroxysmal hemicrania, secondary headaches due to an underlying structural problem in the head or neck, cranial neuralgia, sinus headaches (e.g., headache associated with sinusitis), allergy-induced headaches or migraines, pain, chronic pain, neuroinflammatory or inflammatory pain, post-operative incision pain, post-surgical pain, trauma-related pain, eye pain, tooth pain, complex regional pain syndrome, cancer pain (e.g., primary or metastatic bone cancer pain), fracture pain, osteoporotic fracture pain, pain resulting from burn, gout joint pain, pain associated with sickle cell crises, pain associated with temporomandibular disorders, cirrhosis, hepatitis, neurogenic pain, neuropathic pain, nociceptive pain, visceral pain, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, menstrual pain, ovarialgia, reflex sympathetic dystrophy, osteoarthritis or rheumatoid arthritis pain, lower back pain, diabetic neuropathy, sciatica, dyspepsia, irritable bowel syndrome, inflammatory bowel disease, Crohn's disease, ileitis, ulcerative colitis, renal colic, dysmenorrhea, cystitis, interstitial cystitis, menstrual period, labor, menopause, pancreatitis, schizophrenia, depression, PTSD, anxiety disorders, diabetes, autoimmune diabetes, endothelial dysfunction, ischemia, Raynaud's syndrome, coronary heart disease ("CHD"), coronary artery disease ("CAD"), heart failure, peripheral arterial disease ("PAD"), pulmonary hypertension ("PH"), connective tissue disorders, stroke, Sjögren's syndrome, multiple sclerosis, bronchial hyperreactivity, asthma, bronchitis, bronchodilation, emphysema, chronic obstructive pulmonary disease ("COPD"), inflammatory dermatitis, adenocarcinoma in glandular tissue, blastoma in

embryonic tissue of organs, carcinoma in epithelial tissue, leukemia in tissues that form blood cells, lymphoma in lymphatic tissue, myeloma in bone marrow, sarcoma in connective or supportive tissue, adrenal cancer, AIDS-related lymphoma, anemia, bladder cancer, bone cancer, brain cancer, breast cancer, carcinoid tumors, cervical cancer, chemotherapy, colon cancer, cytopenia, endometrial cancer, esophageal cancer, gastric cancer, head cancer, neck cancer, hepatobiliary cancer, kidney cancer, leukemia, liver cancer, lung cancer, lymphoma, Hodgkin's disease, non-Hodgkin's, nervous system tumors, oral cancer, ovarian cancer, pancreatic cancer, prostate cancer, rectal cancer, skin cancer, stomach cancer, testicular cancer, thyroid cancer, urethral cancer, cancer of bone marrow, multiple myeloma, tumors that metastasize to the bone, tumors infiltrating the nerve and hollow viscus, tumors near neural structures, acne vulgaris, atopic dermatitis, urticaria, keloids, hypertrophic scars and rosacea, allergic dermatitis, psoriasis, pruritus, neurogenic cutaneous redness, erythema, weight loss, anorexia, sarcoidosis, shock, sepsis, opiate withdrawal syndrome, morphine tolerance, epilepsy, LUT disorders such as urinary tract infection, abnormal voiding, urinary urgency, nocturia, urinary incontinence, overactive bladder, and for preventing or alleviating the pain associated with such LUT conditions.

[0219] Specific examples of visceral pain, i.e., pain associated with the viscera, or the internal organs of the body include pain that affects organs such as e.g., the heart, lungs, reproductive organs, bladder, ureters, the digestive organs, liver, pancreas, spleen, and kidneys. Conditions associated therewith include by way of example pancreatitis, labor, abdominal surgery associated with ileus, cystitis, menstrual period, or dysmenorrhea. Likewise, kidney pain, epigastric pain, pleural pain, and painful biliary colic, appendicitis pain may all be considered to be visceral pain. Substernal pain or pressure from early myocardial infarction is also visceral. Diseases of the stomach, duodenum or colon can cause visceral pain. Commonly encountered gastrointestinal ("GI") disorders that cause visceral pain include functional bowel disorder ("FBD") and inflammatory bowel disease ("IBD"). Such GI disorders may further include gastro-esophageal reflux, dyspepsia, irritable bowel syndrome ("IBS") and functional abdominal pain syndrome ("FAPS"), and, with respect to IBD, Crohn's disease, ileitis, and ulcerative colitis.

[0220] The subject anti-PACAP antibodies and antigen binding fragments thereof may be used alone or in association with other active agents or drugs, including other biologics, to treat any subject in which blocking, inhibiting, or neutralizing the *in vivo* effect of PACAP or blocking or inhibiting the interaction of PACAP and its receptors, PAC1-R, VPAC1-R, and VPAC2-R, is therapeutically desirable.

[0221] Exemplary anti-PACAP antibodies and antigen binding fragments thereof according to the invention, and the specific CDRs thereof are identified in this section. For convenience, each exemplified antibody or antigen binding fragment thereof, and corresponding sequences are separately identified by a specific nomenclature, i.e., Ab10 or Ab20.

[0222] The anti-PACAP antibodies and antigen binding fragments thereof comprising the invention have binding affinity for PACAP, wherein the binding affinity comprises anti-PACAP antibodies or antigen binding fragments thereof specifically binding to PACAP38 and PACAP27, but not binding VIP, and/or antibodies or antigen binding fragments thereof specifically binding to PACAP38, but not binding to PACAP27 or VIP, and/or antibodies or antigen binding fragments thereof specifically binding to a linear and/or conformational epitope within PACAP38 and/or PACAP27. More specifically, the epitopes of PACAP38 and/or PACAP27 to which antagonistic anti-PACAP antibodies or antigen binding fragments thereof according to the invention bind will include those which are identified in Example 12 or residues thereof (as determined by use of alanine scanning) and/or other epitopic identification methods.

[0223]

Anti-PACAP Antibody Polypeptide Sequences

Antibody Ab10

[0224] In one embodiment, the invention includes the use or administration of antibodies and antigen binding fragments having binding specificity to PACAP that possess a heavy chain sequence comprising the sequence of SEQ ID NO: 401 which consists of the heavy chain variable region of SEQ ID NO: 402 linked to the heavy chain constant region of SEQ ID NO: 410.

[0225] In one embodiment, the invention includes the use or administration of antibodies and antigen binding fragments having binding specificity to PACAP that contain a variable heavy chain sequence comprising the sequence set forth below:

QSVEESGGRLVTPGTPLTLTCTVSGIDLNSYYMTWVRQAPGKGLEWIGFIDAGGDAY
YASWAKGRFTISKTSSTTVDLKITSPTTEDTATYFCARDLDLWGQGTLTVSS

(SEQ ID NO: 402).

[0226] In another embodiment, the invention includes the use of antibodies and antigen binding fragments thereof having binding specificity to PACAP that possess the same epitopic specificity as Ab10, and which contain a constant heavy chain sequence comprising

the polypeptide of SEQ ID NO: 1244, 1245, or 1246, or comprising the sequence set forth below:

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVL
 QSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDARVEPKSCDKTHTCPPCPAP
 ELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAK
 TKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPRE
 PQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDG
 SFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK (SEQ ID NO:
 410).

[0227] In another embodiment, the invention includes the use or administration of antibodies and antigen binding fragments having binding specificity to PACAP that contain a light chain sequence comprising the sequence of SEQ ID NO: 421 which consists of the light chain variable region of SEQ ID NO: 422 linked to the light chain constant region of SEQ ID NO: 430.

[0228] In another embodiment, the invention includes the use or administration of antibodies and antigen binding fragments having binding specificity to PACAP that contain a variable light chain sequence comprising the sequence set forth below:

AAVLTQTSPVSAAVGGTVTINCQSSSESVYGNYLAWFQQKPGQPPKLLIYEASKLES
 GVPSRFSGSGSGTQFTLTISDLQCDDAATYYCAGGDISEGVAFGGGTEVVVKR
 (SEQ ID NO: 422).

[0229] In another embodiment, the invention includes the use or administration of antibodies and antigen binding fragments thereof having binding specificity to PACAP that bind the same epitope as Ab10, and which contain a constant light chain sequence comprising the sequence set forth below:

TVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTE
 QDSKDYSLSSLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC (SEQ ID
 NO: 430).

[0230] In another embodiment, the invention includes the use or administration of antibodies and antigen binding fragments thereof having binding specificity to PACAP and that contain one, two, or three of the polypeptide sequences of SEQ ID NO: 404; SEQ ID NO: 406; and SEQ ID NO: 408, which correspond to the CDRs, or hypervariable regions, of the heavy chain sequence of SEQ ID NO: 401, or which contain the variable heavy chain sequence of SEQ ID NO: 402, and/or which further contain one, two, or three of the polypeptide sequences of SEQ ID NO: 424; SEQ ID NO: 426; and SEQ ID NO: 428, which correspond to

the CDRs, or hypervariable regions, of the light chain sequence of SEQ ID NO: 421, or which contain the variable light chain sequence of SEQ ID NO: 422, or antibodies or antigen binding fragments thereof containing combinations of sequences, which are at least 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical thereto. In another embodiment of the invention, the anti-PACAP antibodies or antigen binding fragments thereof comprise, or alternatively consist of, combinations of one or more of the exemplified variable heavy chain and variable light chain sequences, or the heavy chain and light chain sequences set forth above, or sequences that are at least 90% or 95% identical thereto.

[0231] The invention further contemplates the use or administration of anti-PACAP antibodies and antigen binding fragments thereof comprising one, two, three, or four of the polypeptide sequences of SEQ ID NO: 403; SEQ ID NO: 405; SEQ ID NO: 407; and SEQ ID NO: 409, which correspond to the FRs, or constant regions, of the heavy chain sequence of SEQ ID NO: 401, or the variable heavy chain sequence of SEQ ID NO: 402, and/or one, two, three, or four of the polypeptide sequences of SEQ ID NO: 423; SEQ ID NO: 425; SEQ ID NO: 427; and SEQ ID NO: 429, which correspond to the FRs of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422, or combinations of these polypeptide sequences, or sequences which are at least 80%, 90%, 95%, 96%, 97%, 98% or 99% identical therewith.

[0232] In another embodiment of the invention, the antibodies and antigen binding fragments thereof useful in the disclosed methods comprise, or alternatively consist of, combinations of one or more of the FRs, CDRs, the variable heavy chain and variable light chain sequences, and the heavy chain and light chain sequences set forth above, including all of them, or sequences which are at least 90% or 95% identical thereto.

[0233] In another embodiment of the invention, the anti-PACAP antibodies and antigen binding fragments useful in the disclosed methods comprise, or alternatively consist of, the polypeptide sequence of SEQ ID NO: 401, or SEQ ID NO: 402, or polypeptides that are at least 90% or 95% identical thereto. In another embodiment of the invention, the antibodies and antigen binding fragments thereof useful in the disclosed methods comprise, or alternatively consist of, the polypeptide sequence of SEQ ID NO: 421, or SEQ ID NO: 422, or polypeptides that are at least 90% or 95% identical thereto.

[0234] In a further embodiment of the invention, the antibodies and antigen binding fragments thereof useful in the disclosed methods have binding specificity to PACAP and comprise, or alternatively consist of, one, two, or three of the polypeptide sequences of SEQ ID NO: 404; SEQ ID NO: 406; and SEQ ID NO: 408, which correspond to the CDRs, or

hypervariable regions, of the heavy chain sequence of SEQ ID NO: 401, or the variable heavy chain sequence of SEQ ID NO: 402, or sequences that are at least 90%, or 95% identical thereto.

[0235] In a further embodiment of the invention, the antibodies and antigen binding fragments useful in the disclosed methods have binding specificity to PACAP and comprise, or alternatively consist of, one, two, or three of the polypeptide sequences of SEQ ID NO: 424; SEQ ID NO: 426; and SEQ ID NO: 428 which correspond to the CDRs, or hypervariable regions, of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422, or sequences that are at least 90%, or 95% identical thereto.

[0236] In a further embodiment of the invention, the antibodies and antigen binding fragments thereof useful in the disclosed methods have binding specificity to PACAP and comprise, or alternatively consist of, one, two, three, or four of the polypeptide sequences of SEQ ID NO: 403; SEQ ID NO: 405; SEQ ID NO: 407; and SEQ ID NO: 409, which correspond to the FRs, or constant regions, of the heavy chain sequence of SEQ ID NO: 401, or the variable heavy chain sequence of SEQ ID NO: 402, or sequences that are at least 90% or 95% identical thereto.

[0237] In a further embodiment of the invention, the antibodies and antigen binding fragments thereof useful in the disclosed methods have binding specificity to PACAP and comprise, or alternatively consist of, one, two, three, or four of the polypeptide sequences of SEQ ID NO: 423; SEQ ID NO: 425; SEQ ID NO: 427; and SEQ ID NO: 429, which correspond to the FRs or constant regions, of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422, or sequences that are at least 90% or 95% identical thereto.

[0238] The invention also contemplates the use or administration of anti-PACAP antibodies and antigen binding fragments thereof that include one or more of the antigen binding fragments described herein. In one embodiment of the invention, antibodies and antigen binding fragments thereof useful in the disclosed methods have binding specificity to PACAP and comprise, or alternatively consist of, one, two, three or more, including all of the following antigen binding fragments: the variable heavy chain region of SEQ ID NO: 402; the variable light chain region of SEQ ID NO: 422; the CDRs (SEQ ID NO: 404; SEQ ID NO: 406; and SEQ ID NO: 408) of the variable heavy chain region of SEQ ID NO: 402; and the CDRs (SEQ ID NO: 424; SEQ ID NO: 426; and SEQ ID NO: 428) of the variable light chain region of SEQ ID NO: 422, or sequences that are at least 90% or 95% identical thereto.

[0239] The invention also contemplates the use or administration of anti-PACAP antibodies and antigen binding fragments thereof that include one or more of the antigen binding fragments described herein. In one embodiment of the invention, antigen binding fragments of the antibodies useful in the disclosed methods have binding specificity to PACAP and comprise, or alternatively consist of, one, two, three or more, including all of the following antigen binding fragments: the variable heavy chain region of SEQ ID NO: 402; the variable light chain region of SEQ ID NO: 422; the FRs (SEQ ID NO: 403; SEQ ID NO: 405; SEQ ID NO: 407; and SEQ ID NO: 409) of the variable heavy chain region of SEQ ID NO: 402; and the FRs (SEQ ID NO: 423; SEQ ID NO: 425; SEQ ID NO: 427; and SEQ ID NO: 429) of the variable light chain region of SEQ ID NO: 422.

[0240] In another embodiment of the invention, the anti-PACAP antibody useful in the disclosed methods is Ab10, comprising, or alternatively consisting of, SEQ ID NO: 401 and SEQ ID NO: 421, or SEQ ID NO: 402 and SEQ ID NO: 422, or an antibody or antigen binding fragment comprising the CDRs of Ab10 and having at least one of the biological activities set forth herein, or is an anti-PACAP antibody that competes with Ab10 in binding PACAP, for instance an antibody containing sequences that are at least 90%, 95%, 96%, 97%, 98%, or 99% identical to that of Ab10, or an antibody that binds to the same or overlapping epitope(s) on PACAP as Ab10.

[0241] In a further embodiment of the invention, anti-PACAP antigen binding fragments useful in the disclosed methods comprise, or alternatively consist of, Fab (fragment antigen binding) fragments having binding specificity for PACAP. With respect to antibody Ab10, the Fab fragment preferably includes the variable heavy chain sequence of SEQ ID NO: 402 and the variable light chain sequence of SEQ ID NO: 422, or sequences that are at least 90%, 95%, 96%, 97%, 98%, or 99% identical thereto. This embodiment of the invention further includes the use of Fabs containing additions, deletions, and variants of SEQ ID NO: 402 and/or SEQ ID NO: 422, which retain the binding specificity for PACAP.

[0242] In one embodiment of the invention described herein, anti-PACAP Fab fragments useful in the disclosed methods can be produced by enzymatic digestion (e.g., papain) of Ab10. In another embodiment of the invention, anti-PACAP antibodies such as Ab10 or Fab fragments thereof useful in the disclosed methods can be produced via expression in mammalian cells such as CHO, NSO, or HEK 293 cells, fungal, insect, or microbial systems such as yeast cells (for example haploid or diploid yeast such as haploid or diploid *Pichia*) and other yeast strains. Suitable *Pichia* species include, but are not limited to, *Pichia pastoris*.

[0243] In an additional embodiment, the invention is further directed to the use or administration of polynucleotides encoding antibody polypeptides having binding specificity to PACAP, or PACAP receptors, including the heavy and/or light chains of Ab10 as well as fragments, variants, combinations of one or more of the FRs, CDRs, the variable heavy chain and variable light chain sequences, and the heavy chain and light chain sequences set forth above, including all of them, or sequences that are at least 90% or 95% identical thereto.

[0244] In another embodiment, the invention contemplates an isolated anti-PACAP antibody comprising a V_H polypeptide sequence selected from: SEQ ID NO: 402, SEQ ID NO: 442, or a variant thereof; and further comprising a V_L polypeptide sequence selected from: SEQ ID NO: 422, SEQ ID NO: 462, or a variant thereof, wherein one or more of the framework region residues ("FR residues") and/or CDR residues in said V_H or V_L polypeptide has been substituted with another amino acid residue resulting in an anti-PACAP antibody that specifically binds PACAP. The invention also includes humanized and chimeric forms of these antibodies. The chimeric and humanized antibodies may include an Fc derived from IgG1, IgG2, IgG3, or IgG4 constant regions.

[0245] In one embodiment of the invention, the chimeric or humanized antibodies or fragments or V_H or V_L polypeptides originate or are derived from one or more rabbit antibodies, e.g., a rabbit antibody isolated from a clonal rabbit B cell population.

[0246] In some aspects, the invention provides a vector comprising a nucleic acid molecule encoding an anti-PACAP antibody or fragment thereof as disclosed herein. In some embodiments, the invention provides a host cell comprising a nucleic acid molecule encoding an anti-PACAP antibody or fragment thereof as disclosed herein.

[0247] In some aspects, the invention provides an isolated antibody or antigen binding fragment thereof that competes for binding to PACAP with an antibody or antigen binding fragment thereof disclosed herein.

[0248] In some aspects, the invention provides a nucleic acid molecule encoding an antibody or antigen binding fragment thereof as disclosed herein.

[0249] In some aspects, the invention provides a pharmaceutical or diagnostic composition comprising at least one antibody or antigen binding fragment thereof as disclosed herein.

[0250] In some aspects, the invention provides a method for treating or preventing a condition associated with elevated PACAP levels in a subject, comprising administering to a subject in need thereof an effective amount of at least one isolated antibody or antigen binding fragment thereof as disclosed herein.

[0251] In some aspects, the invention provides a method of inhibiting binding of PACAP to PAC1-R, VPAC1-R, and/or VPAC2-R in a subject comprising administering an effective amount of at least one antibody or antigen binding fragment thereof as disclosed herein.

[0252] In some aspects, the invention provides an antibody or antigen binding fragment thereof that selectively binds to PACAP, wherein the antibody or antigen binding fragment thereof binds to PACAP with a K_D of less than or equal to 5×10^{-5} M, 10^{-5} M, 5×10^{-6} M, 10^{-6} M, 5×10^{-7} M, 10^{-7} M, 5×10^{-8} M, 10^{-8} M, 5×10^{-9} M, 10^{-9} M, 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, 10^{-12} M, 5×10^{-13} M, or 10^{-13} M; preferably, with a K_D of less than or equal to 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, or 10^{-12} M; more preferably, with a K_D that is less than about 100 pM, less than about 50 pM, less than about 40 pM, less than about 25 pM, less than about 1 pM, between about 10 pM and about 100 pM, between about 1 pM and about 100 pM, or between about 1 pM and about 10 pM. Preferably, the anti-PACAP antibody or antigen binding fragment thereof has no cross-reactivity or minimal cross-reactivity with VIP.

[0253] The inventive antibodies and antigen binding fragments thereof may be modified post-translationally to add effector moieties such as chemical linkers, detectable moieties such as for example fluorescent dyes, enzymes, substrates, bioluminescent materials, radioactive materials, and chemiluminescent moieties, or functional moieties such as for example streptavidin, avidin, biotin, a cytotoxin, a cytotoxic agent, and radioactive materials.

[0254] Antibodies and antigen binding fragments thereof may also be chemically modified to provide additional advantages such as increased solubility, stability and circulating time (*in vivo* half-life) of the polypeptide, or decreased immunogenicity (*See* U.S. Patent No. 4,179,337). The chemical moieties for derivatization may be selected from water soluble polymers such as polyethylene glycol, ethylene glycol/propylene glycol copolymers, carboxymethylcellulose, dextran, polyvinyl alcohol, and the like. The antibodies and fragments thereof may be modified at random positions within the molecule, or at predetermined positions within the molecule and may include one, two, three, or more attached chemical moieties.

[0255] The polymer may be of any molecular weight, and may be branched or unbranched. For polyethylene glycol, the preferred molecular weight is between about 1 kDa and about 100 kDa (the term "about" indicating that in preparations of polyethylene glycol, some molecules will weigh more, some less, than the stated molecular weight) for ease in handling and manufacturing. Other sizes may be used, depending on the desired therapeutic profile (e.g., the duration of sustained release desired, the effects, if any on biological activity, the

ease in handling, the degree or lack of antigenicity and other known effects of the polyethylene glycol to a therapeutic protein or analog). For example, the polyethylene glycol may have an average molecular weight of about 200, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10,000, 10,500, 11,000, 11,500, 12,000, 12,500, 13,000, 13,500, 14,000, 14,500, 15,000, 15,500, 16,000, 16,500, 17,000, 17,500, 18,000, 18,500, 19,000, 19,500, 20,000, 25,000, 30,000, 35,000, 40,000, 50,000, 55,000, 60,000, 65,000, 70,000, 75,000, 80,000, 85,000, 90,000, 95,000, or 100,000 kDa. Branched polyethylene glycols are described, for example, in U.S. Patent No. 5,643,575; Morpurgo et al., *Appl. Biochem. Biotechnol.*, 56:59-72 (1996); Vorobjev et al., *Nucleosides and Nucleotides*, 18:2745-2750 (1999); and Caliceti et al., *Bioconjug. Chem.*, 10:638-646 (1999), the disclosures of each of which are incorporated herein by reference.

[0256] There are a number of attachment methods available to those skilled in the art (See e.g., EP 0 401 384, herein incorporated by reference, disclosing a method of coupling PEG to G-CSF; and Malik et al., *Exp. Hematol.*, 20:1028-1035 (1992) (reporting pegylation of GM-CSF using tresyl chloride)). For example, polyethylene glycol may be covalently bound through amino acid residues via a reactive group, such as, a free amino or carboxyl group. Reactive groups are those to which an activated polyethylene glycol molecule may be bound. The amino acid residues having a free amino group may include lysine residues and the N-terminal amino acid residues; those having a free carboxyl group may include aspartic acid residues glutamic acid residues and the C-terminal amino acid residue. Sulfhydryl groups may also be used as a reactive group for attaching the polyethylene glycol molecules. Preferred for therapeutic purposes is attachment at an amino group, such as attachment at the N-terminus or lysine group.

[0257] As suggested above, polyethylene glycol may be attached to proteins via linkage to any of a number of amino acid residues. For example, polyethylene glycol can be linked to polypeptides via covalent bonds to lysine, histidine, aspartic acid, glutamic acid, or cysteine residues. One or more reaction chemistries may be employed to attach polyethylene glycol to specific amino acid residues (e.g., lysine, histidine, aspartic acid, glutamic acid, or cysteine) or to more than one type of amino acid residue (e.g., lysine, histidine, aspartic acid, glutamic acid, cysteine and combinations thereof).

[0258] Alternatively, antibodies or antigen binding fragments thereof may have increased *in vivo* half-lives via fusion with albumin (including but not limited to recombinant human serum albumin or fragments or variants thereof (See, e.g., U.S. Patent No. 5,876,969 , EP 0

413 622, and U.S. Patent No. 5,766,883, herein incorporated by reference in their entirety)), or other circulating blood proteins such as transferrin or ferritin. In a preferred embodiment, polypeptides and/or antibodies of the present invention (including fragments or variants thereof) are fused with the mature form of human serum albumin (i.e., amino acids 1-585 of human serum albumin as shown in FIGS. 1 and 2 of EP 0 322 094) which is herein incorporated by reference in its entirety. Polynucleotides encoding fusion proteins of the invention are also encompassed by the invention.

[0259] Regarding detectable moieties, further exemplary enzymes include, but are not limited to, horseradish peroxidase, acetylcholinesterase, alkaline phosphatase, *beta*-galactosidase, and luciferase. Further exemplary fluorescent materials include, but are not limited to, rhodamine, fluorescein, fluorescein isothiocyanate, umbelliferone, dichlorotriazinylamine, phycoerythrin, and dansyl chloride. Further exemplary chemiluminescent moieties include, but are not limited to, luminol. Further exemplary bioluminescent materials include, but are not limited to, luciferin and aequorin. Further exemplary radioactive materials include, but are not limited to, Iodine 125 (¹²⁵I), Carbon 14 (¹⁴C), Sulfur 35 (³⁵S), Tritium (³H) and Phosphorus 32 (³²P).

[0260] Methods are known in the art for conjugating an antibody or antigen binding fragment thereof to a detectable moiety and the like, such as for example those methods described by Hunter et al., *Nature*, 144:945 (1962); David et al., *Biochemistry*, 13:1014 (1974); Pain et al., *J. Immunol. Meth.*, 40:219 (1981); and Nygren, J., *Histochem. and Cytochem.*, 30:407 (1982).

[0261] Embodiments described herein further include variants and equivalents that are substantially homologous to the antibodies, antibody fragments, diabodies, SMIPs, camelbodies, nanobodies, IgNAR, polypeptides, variable regions, and CDRs set forth herein. These may contain, e.g., conservative substitution mutations, (i.e., the substitution of one or more amino acids by similar amino acids). For example, conservative substitution refers to the substitution of an amino acid with another within the same general class, e.g., one acidic amino acid with another acidic amino acid, one basic amino acid with another basic amino acid, or one neutral amino acid by another neutral amino acid. What is intended by a conservative amino acid substitution is well known in the art.

[0262] In another embodiment, the invention contemplates polypeptide sequences having at least 90% or greater sequence homology to any one or more of the polypeptide sequences of antigen binding fragments, variable regions and CDRs set forth herein. More preferably, the invention contemplates polypeptide sequences having at least 95% or greater sequence homology, even more preferably at least 98% or greater sequence homology, and still more

preferably at least 99% or greater sequence homology to any one or more of the polypeptide sequences of antigen binding fragments, variable regions, and CDRs set forth herein.

[0263] Methods for determining homology between nucleic acid and amino acid sequences are well known to those of ordinary skill in the art.

[0264] In another embodiment, the invention further contemplates the above-recited polypeptide homologs of the antigen binding fragments, variable regions and CDRs set forth herein further having anti-PACAP activity. Non-limiting examples of anti-PACAP activity are set forth herein, e.g., ability to inhibit PACAP binding to PAC1-R, VPAC1-R, and/or VPAC2-R, thereby resulting in the reduced production of cAMP.

[0265] In another embodiment, the invention further contemplates the generation and use of antibodies that bind any of the foregoing sequences, including, but not limited to, anti-idiotypic antibodies. In an exemplary embodiment, such an anti-idiotypic antibody could be administered to a subject who has received an anti-PACAP antibody to modulate, reduce, or neutralize, the effect of the anti-PACAP antibody. Such antibodies could also be useful for treatment of an autoimmune disease characterized by the presence of anti-PACAP antibodies. A further exemplary use of such antibodies, e.g., anti-idiotypic antibodies, is for detection of the anti-PACAP antibodies of the present invention, for example to monitor the levels of the anti-PACAP antibodies present in a subject's blood or other bodily fluids. For example, in one embodiment, the invention provides a method of using the anti-idiotypic antibody to monitor the *in vivo* levels of said anti-PACAP antibody or antigen binding fragment thereof in a subject or to neutralize said anti-PACAP antibody in a subject being administered said anti-PACAP antibody or antigen binding fragment thereof.

[0266] The present invention also contemplates anti-PACAP antibodies comprising any of the polypeptide or polynucleotide sequences described herein substituted for any of the other polynucleotide sequences described herein. For example, without limitation thereto, the present invention contemplates antibodies comprising the combination of any of the variable light chain and variable heavy chain sequences described herein, and further contemplates antibodies resulting from substitution of any of the CDR sequences described herein for any of the other CDR sequences described herein.

[0267] Exemplary Polynucleotides Encoding Anti-PACAP Antibody Polypeptides

[0268] The invention is further directed to polynucleotides encoding antibody polypeptides having binding specificity to PACAP.

[0269] Antibody Ab10

[0270] In one embodiment, the invention is further directed to the use of polynucleotides encoding antibody polypeptides having binding specificity to PACAP. In one embodiment of the invention, polynucleotides comprise, or alternatively consist of, the polynucleotide sequence of SEQ ID NO: 411 which encodes the heavy chain sequence of SEQ ID NO: 401 and which consists of the heavy chain variable region coding sequence of SEQ ID NO: 412 and the heavy chain constant region coding sequence of SEQ ID NO: 420.

[0271] In another embodiment of the invention, the polynucleotides comprise, or alternatively consist of, the following polynucleotide sequence encoding the variable heavy chain polypeptide sequence of SEQ ID NO: 402:

cagtcgggtggaggagtcggggggcgcctggtcacgcctgggacacccctgacactcacctgcacagtctctggaatcgacctcaat
agctactacatgacctgggtccgccaggctccagggaaggggctggaatggatcgattcattgatgctgggtgggacgcatactacg
cgagctggggcgaagggccgattcaccatctccaaaacctcgaccacgggtggatctgaaaatcaccagtccgacaaccgaggacacg
gccacctattctgtgccagagatcttgactgtggggccaggggcacccctggtcaccgtctcgagc (SEQ ID NO: 412).

[0272] In another embodiment of the invention, polynucleotides comprise, or alternatively consist of, the following polynucleotide sequence encoding the constant heavy chain polypeptide sequence of SEQ ID NO: 410:

gcctccaccaagggcccatcggtcttccccctggcacccctctccaagagcacctctggggggcacagcggccctgggctgctgg
caaggactacttccccgaaccgggtgacgggtgctgtggaactcaggcgcctgaccagcggcgtgcacaccttccggctgtctaca
gtctcaggactctactccctcagcagcgtgggtgaccgtgccccccagcagcttgggcacccagacctacatctgcaacgtgaatcac
aagcccagcaacaccaaggtggagcgcgagagtgagcccaaatctgtgacaaaactcacacatgccaccctgcccagcacctga
actctgggggggaccgtcagcttctcttcccccaaaaacccaaggacacctcatgatctcccggacctgaggtcatatgcgtg
gtgggtggacgtgagccacgaagacctgaggtcaagttcaactggtacgtggacggcgtggaggtgcataatgccaagacaaagcc
gcgggaggagcagtagccagcacgtaccgtgtggtcagcgtcctcaccgtcctgcaccaggactggctgaatggcaaggagtac
aagtcaaggtctccaacaaagccctcccagcccccatcgagaaaaaccatctccaaagccaaagggcagccccgagaaccacagg
tgtacacctgccccatcccgggaggagatgaccaagaaccaggtcagcctgacctgcctgggtcaaaggctctatcccagcgaca
tcgocgtggagtgggagagcaatgggcagccggagacaactacaagaccacgcctcccgtgctggactccgacggctctctctc
ctctacagcaagctcaccgtggacaagagcaggtggcagcaggggaacgtcttctcatgctccgtgatgcatgaggctctgcacaac
cactacacgcagaagagcctctccctgtctccgggtaaa (SEQ ID NO: 420).

[0273] In another embodiment of the invention, polynucleotides comprise, or alternatively consist of, the polynucleotide sequence of SEQ ID NO: 431 which encodes the light chain polypeptide sequence of SEQ ID NO: 421 and which consists of the light chain variable region coding sequence of SEQ ID NO: 432 and the light chain constant region coding sequence of SEQ ID NO: 440.

[0274] In another embodiment of the invention, polynucleotides comprise, or alternatively consist of, the following polynucleotide sequence encoding the variable light chain polypeptide sequence of SEQ ID NO: 422:

gcccgcgtgctgacccagactccatctcccgtgtctgcagctgtgggaggcacagtcaccatcaattgccagtcagtgagagtggtta
 cggtaactacttagcctgggttcagcagaaaccagggcagcctcccaagctcctgatctacgaagcatccaaactggaatctggggtc
 ccatogcgggttcagcggcagtgatctgggacacagttcactctccatcagcagcttgcagtgtagcagtgctgccacttactactgt
 gcagggcggatattagtgaaaggtgtgcttccggcggaggaccgaggtgggtggtcaaact (SEQ ID NO: 432).

[0275] In another embodiment of the invention, polynucleotides comprise, or alternatively consist of, the following polynucleotide sequence encoding the constant light chain polypeptide sequence of SEQ ID NO: 430:

aeggtagcggccccatctgtcttcactctcccgccatctgatgagcagttgaaatctggaactgcctctgtgtgtgcctgctgaataact
 ctatcccagagaggccaaagtacagtggaaggtggataacgccctccaatcgggtaactcccaggagagtgtagcagagcaggaca
 gcaaggacagcacctacagcctcagcagcaccctgacgctgagcaaagcagactacgagaaacacaaagtctacgcctgccaagt
 caccatcagggcctgagctcggccgtcacaagagctcaacaggggagagtg (SEQ ID NO: 440).

[0276] In a further embodiment of the invention, polynucleotides encoding antigen binding fragments having binding specificity to PACAP comprise, or alternatively consist of, one or more of the polynucleotide sequences of SEQ ID NO: 414; SEQ ID NO: 416; and SEQ ID NO: 418, which correspond to polynucleotides encoding the CDRs, or hypervariable regions, of the heavy chain sequence of SEQ ID NO: 401, or the variable heavy chain sequence of SEQ ID NO: 402, and/or one or more of the polynucleotide sequences of SEQ ID NO: 434; SEQ ID NO: 436 and SEQ ID NO: 438, which correspond to the CDRs, or hypervariable regions, of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422, or combinations of these polynucleotide sequences. In another embodiment of the invention, the polynucleotides encoding the antibodies and antigen binding fragments thereof comprise, or alternatively consist of, combinations of polynucleotides encoding one or more of the CDRs, the variable heavy chain and variable light chain sequences, and the heavy chain and light chain sequences set forth above, including all of them.

[0277] In a further embodiment of the invention, polynucleotides encoding antigen binding fragments having binding specificity to PACAP comprise, or alternatively consist of, one or more of the polynucleotide sequences of SEQ ID NO: 413; SEQ ID NO: 415; SEQ ID NO: 417; and SEQ ID NO: 419, which correspond to polynucleotides encoding the FRs, or constant regions, of the heavy chain sequence of SEQ ID NO: 401, or the variable heavy chain sequence of SEQ ID NO: 402, and/or one or more of the polynucleotide sequences of

SEQ ID NO: 433; SEQ ID NO: 435; SEQ ID NO: 437; and SEQ ID NO: 439, which correspond to the FRs, or constant regions, of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422, or combinations of these polynucleotide sequences. In another embodiment of the invention, the polynucleotides encoding the antibodies and antigen binding fragments thereof comprise, or alternatively consist of, combinations of one or more of the FRs, the variable heavy chain and variable light chain sequences, and the heavy chain and light chain sequences set forth above, including all of them.

[0278] The invention also contemplates the use of polynucleotide sequences including one or more of the polynucleotide sequences encoding antigen binding fragments described herein. In one embodiment of the invention, polynucleotides encoding antigen binding fragments having binding specificity to PACAP comprise, or alternatively consist of, one, two, three or more, including all of the following polynucleotides encoding antigen binding fragments: the polynucleotide SEQ ID NO: 411 encoding the heavy chain sequence of SEQ ID NO: 401; the polynucleotide SEQ ID NO: 412 encoding the variable heavy chain sequence of SEQ ID NO: 402; the polynucleotide SEQ ID NO: 431 encoding the light chain sequence of SEQ ID NO: 421; the polynucleotide SEQ ID NO: 432 encoding the variable light chain sequence of SEQ ID NO: 422; polynucleotides encoding the CDRs (SEQ ID NO: 414; SEQ ID NO: 416; and SEQ ID NO: 418) of the heavy chain sequence of SEQ ID NO: 401 or the variable heavy chain sequence of SEQ ID NO: 402; polynucleotides encoding the CDRs (SEQ ID NO: 434; SEQ ID NO: 436; and SEQ ID NO: 438) of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422; polynucleotides encoding the FRs (SEQ ID NO: 413; SEQ ID NO: 415; SEQ ID NO: 417; and SEQ ID NO: 419) of the heavy chain sequence of SEQ ID NO: 401, or the variable heavy chain sequence of SEQ ID NO: 402; and polynucleotides encoding the FRs (SEQ ID NO: 433; SEQ ID NO: 435; SEQ ID NO: 437; and SEQ ID NO: 439) of the light chain sequence of SEQ ID NO: 421, or the variable light chain sequence of SEQ ID NO: 422.

[0279] In a preferred embodiment of the invention, polynucleotides comprise, or alternatively consist of, polynucleotides encoding Fab fragments having binding specificity for PACAP. With respect to antibody Ab10, the polynucleotides encoding the full length Ab10 antibody comprise, or alternatively consist of, the polynucleotide SEQ ID NO: 411 encoding the heavy chain sequence of SEQ ID NO: 401, and the polynucleotide SEQ ID NO: 431 encoding the light chain sequence of SEQ ID NO: 421.

[0280] Another embodiment of the invention contemplates these polynucleotides incorporated into an expression vector for expression in mammalian cells such as CHO, NSO, HEK-293 cells, or in fungal, insect, or microbial systems such as yeast cells such as the yeast *Pichia*. Suitable *Pichia* species include, but are not limited to, *Pichia pastoris*. In one embodiment of the invention described herein, Fab fragments can be produced by enzymatic digestion (e.g., papain) of Ab10 following expression of the full-length polynucleotides in a suitable host. In another embodiment of the invention, anti-PACAP antibodies such as Ab10 or Fab fragments thereof can be produced via expression of Ab10 polynucleotides in mammalian cells such as CHO, NSO, or HEK 293 cells, fungal, insect, or microbial systems such as yeast cells (for example diploid yeast such as diploid *Pichia*) and other yeast strains. Suitable *Pichia* species include, but are not limited to, *Pichia pastoris*.

[0281] Host cells and vectors comprising said polynucleotides are also contemplated.

[0282] The invention further contemplates vectors comprising the polynucleotide sequences encoding the variable heavy and light chain polypeptide sequences, as well as the individual CDRs (hypervariable regions), as set forth herein, as well as host cells comprising said vector sequences. In embodiments of the invention, the host cells are mammalian cells, such as CHO cells. In embodiments of the invention, the host cells are yeast cells, such as yeast cells of the genus *Pichia*.

B-Cell Screening and Isolation

[0283] In one embodiment, the present invention contemplates the preparation and isolation of a clonal population of antigen-specific B-cells that may be used for isolating at least one PACAP antigen-specific cell, which can be used to produce a monoclonal antibody against PACAP, which is specific to a desired PACAP antigen, or a nucleic acid sequence corresponding to such an antibody. Methods of preparing and isolating said clonal population of antigen-specific B-cells are taught, for example, in U.S. Patent Publication No. US2007/0269868 to Carvalho-Jensen et al., the disclosure of which is herein incorporated by reference in its entirety. Methods of preparing and isolating said clonal population of antigen-specific B-cells are also taught herein in the examples. Methods of "enriching" a cell population by size or density are known in the art. See, e.g., U.S. Patent No. 5,627,052. These steps can be used in addition to enriching the cell population by antigen-specificity.

Methods of Humanizing Antibodies

[0284] In another embodiment, the present invention contemplates methods for humanizing antibody heavy and light chains. Methods for humanizing antibody heavy and light chains that may be applied to anti-PACAP antibodies are taught, for example, in U.S. Patent Publication No. US2009/0022659 to Olson et al., and in U.S. Patent No. 7,935,340 to Garcia-Martinez et al., the disclosures of each of which are herein incorporated by reference in their entirety.

Methods of Producing Antibodies and Fragments thereof

[0285] In another embodiment, the present invention contemplates methods for producing anti-PACAP antibodies and fragments thereof. Methods for producing anti-PACAP antibodies and fragments thereof secreted from polyploid, preferably diploid or tetraploid strains of mating competent yeast are taught, for example, in U.S. Patent Publication No. US2009/0022659 to Olson et al., and in U.S. Patent No. 7,935,340 to Garcia-Martinez et al., the disclosures of each of which are herein incorporated by reference in their entirety.

[0286] Other methods of producing antibodies are well known to those of ordinary skill in the art. For example, methods of producing chimeric antibodies are now well known in the art (*See*, for example, U.S. Patent No. 4,816,567 to Cabilly et al.; Morrison et al., *Proc. Natl. Acad. Sci. U.S.A.*, 81:8651-55 (1984); Neuberger et al., *Nature*, 314:268-270 (1985); Boulianne, G.L. et al., *Nature*, 312:643-46 (1984), the disclosures of each of which are herein incorporated by reference in their entirety).

[0287] Likewise, other methods of producing humanized antibodies are now well known in the art (*See*, for example, U.S. Patent Nos. 5,530,101, 5,585,089, 5,693,762, and 6,180,370 to Queen et al; U.S. Patent Nos. 5,225,539 and 6,548,640 to Winter; U.S. Patent Nos. 6,054,297, 6,407,213 and 6,639,055 to Carter et al; U.S. Patent No. 6,632,927 to Adair; Jones, P.T. et al., *Nature*, 321:522-525 (1986); Reichmann, L. et al., *Nature*, 332:323-327 (1988); Verhoeyen, M. et al., *Science*, 239:1534-36 (1988), the disclosures of each of which are herein incorporated by reference in their entirety).

[0288] Antibody polypeptides of the invention having PACAP binding specificity may also be produced by constructing, using conventional techniques well known to those of ordinary skill in the art, an expression vector containing a promoter (optionally as a component of a eukaryotic or prokaryotic operon) and a DNA sequence encoding an antibody heavy chain in which the DNA sequence encoding the CDRs required for antibody specificity is derived from a non-human cell source, preferably a rabbit B-cell source, while the DNA sequence encoding the remaining parts of the antibody chain is derived from a human cell source.

[0289] A second expression vector is produced using the same conventional means well known to those of ordinary skill in the art, said expression vector containing a promoter (optionally as a component of a eukaryotic or prokaryotic operon) and a DNA sequence encoding an antibody light chain in which the DNA sequence encoding the CDRs required for antibody specificity is derived from a non-human cell source, preferably a rabbit B-cell source, while the DNA sequence encoding the remaining parts of the antibody chain is derived from a human cell source.

[0290] The expression vectors are transfected into a host cell by convention techniques well known to those of ordinary skill in the art to produce a transfected host cell, said transfected host cell cultured by conventional techniques well known to those of ordinary skill in the art to produce said antibody polypeptides.

[0291] The host cell may be co-transfected with the two expression vectors described above, the first expression vector containing DNA encoding a promoter (optionally as a component of a eukaryotic or prokaryotic operon) and a light chain-derived polypeptide and the second vector containing DNA encoding a promoter (optionally as a component of a eukaryotic or prokaryotic operon) and a heavy chain-derived polypeptide. The two vectors contain different selectable markers, but preferably achieve substantially equal expression of the heavy and light chain polypeptides. Alternatively, a single vector may be used, the vector including DNA encoding both the heavy and light chain polypeptides. The coding sequences for the heavy and light chains may comprise cDNA, genomic DNA, or both.

[0292] The host cells used to express the antibody polypeptides may be either a bacterial cell such as *E. coli*, or a eukaryotic cell such as *P. pastoris*. In one embodiment of the invention, a mammalian cell of a well-defined type for this purpose, such as a myeloma cell, a CHO cell line, a NSO cell line, or a HEK293 cell line may be used.

[0293] The general methods by which the vectors may be constructed, transfection methods required to produce the host cell and culturing methods required to produce the antibody polypeptides from said host cells all include conventional techniques. Although preferably the cell line used to produce the antibody is a mammalian cell line, any other suitable cell line, such as a bacterial cell line such as an *E. coli*-derived bacterial strain, or a yeast cell line, may alternatively be used.

[0294] Similarly, once produced the antibody polypeptides may be purified according to standard procedures in the art, such as for example cross-flow filtration, ammonium sulphate precipitation, affinity column chromatography, hydrophobic interaction chromatography ("HIC"), and the like.

[0295] The antibody polypeptides described herein may also be used for the design and synthesis of either peptide or non-peptide mimetics that would be useful for the same therapeutic applications as the antibody polypeptides of the invention (*See, for example, Saragobi et al., Science, 253:792-795 (1991), the contents of which are herein incorporated by reference in its entirety*).

Screening Assays

[0296] The invention also includes screening assays designed to assist in the identification and/or selection of antibodies and antigen binding fragments thereof having binding specificity for PACAP or a PACAP receptor, such as PAC1-R, useful in the disclosed methods for treating, ameliorating, or preventing diseases and disorders associated with PACAP, such as photophobia or light aversion, in subjects exhibiting symptoms of a PACAP associated disease or disorder, particularly conditions associated with PACAP-associated photophobia or light aversion, which are identified herein. Exemplary screening methods are useful for identifying or selecting polypeptides having activities that ameliorate, inhibit, reduce, treat, prevent, relieve, or otherwise diminish the effects of photophobia and/or light aversion or conditions associated with photophobia.

[0297] In some embodiments, the antibody or fragment thereof disclosed herein is used as a diagnostic tool. The antibody can be used to assay the amount of PACAP present in a sample and/or subject, for instance a subject being treated for PACAP-associated photophobia or a subject having already been treated for PACAP-associated photophobia. In some embodiments, the diagnostic antibody is not a neutralizing antibody. In some embodiments, the diagnostic antibody binds to a different epitope than the neutralizing antibody binds to. In some embodiments, the two antibodies do not compete with one another.

[0298] In some embodiments, the anti-PACAP, or anti-PACAP receptor, antibodies or antigen binding fragments thereof are used or provided in an assay kit and/or for use in a method for the detection of PACAP in mammalian tissues, or cells in order to screen/diagnose for a disease or disorder associated with changes in levels of PACAP, or changes in light aversion or PACAP-associated photophobia. The kit comprises an antibody that binds PACAP and means for indicating the binding of the antibody with PACAP, if present, and optionally PACAP protein levels. Various means for indicating the presence of an antibody can be used. For example, fluorophores, other molecular probes, or enzymes can be linked to the antibody and the presence of the antibody can be observed in a variety of ways. The method for screening for such disorders can involve the use of the kit, or simply

the use of one of the disclosed antibodies, and the determination of whether the antibody binds to PACAP in a sample. As will be appreciated by one of skill in the art, high or elevated levels of PACAP will result in larger amounts of the antibody binding to PACAP in the sample. Thus, degree of antibody binding can be used to determine how much PACAP is in a sample. Subjects or samples with an amount of PACAP that is greater than a predetermined amount (e.g., an amount or range that a person without a PACAP-related disorder would have, such as a "normal" amount, or an amount typically present in a cohort of individuals who exhibit no PACAP-associated photophobia or light aversion) can be characterized as having a PACAP-mediated disorder, e.g., migraine, headache, pain, photophobia, light aversion, or other condition.

[0299] The present invention further provides for a kit for detecting binding of an anti-PACAP, or anti-PACAP receptor, antibody of the invention to PACAP, or PACAP receptor, respectively. In particular, the kit may be used to detect the presence of PACAP specifically reactive with an anti-PACAP antibody of the invention, or an immunoreactive fragment thereof. The kit may also include an antibody bound to a substrate, a secondary antibody reactive with the antigen, and a reagent for detecting a reaction of the secondary antibody with the antigen. Such a kit may be an ELISA kit and may comprise the substrate, primary, and secondary antibodies when appropriate, and any other necessary reagents, such as detectable moieties, enzyme substrates, and color reagents, for example, as described herein. The diagnostic kit may also be in the form of an immunoblot kit. The diagnostic kit may also be in the form of a chemiluminescent kit (see, for example, Meso Scale Discovery, Gaithersburg, MD). The diagnostic kit may also be a lanthanide-based detection kit (PerkinElmer, San Jose, CA).

[0300] A skilled clinician would understand that a biological sample includes, but is not limited to, sera, plasma, urine, saliva, mucous, pleural fluid, synovial fluid and spinal fluid.

Methods of Ameliorating or Reducing Symptoms of, or Treating, or Preventing, Diseases and Disorders Associated with PACAP

[0301] In another embodiment of the invention, anti-PACAP antibodies described herein, or antigen binding fragments thereof, are useful for ameliorating or reducing the symptoms of, or treating, or preventing, diseases and disorders associated with PACAP. Non-limiting examples of such symptoms or diseases may be photophobia, light aversion or avoidance, and sensitivity to light. Anti-PACAP antibodies described herein, or antigen binding fragments thereof, as well as combinations, can also be administered in a therapeutically

effective amount to patients in need of treatment of diseases and disorders associated with PACAP in the form of a pharmaceutical composition as described in greater detail below.

[1] In another embodiment of the invention, anti-PACAP antibodies described herein, or antigen binding fragments thereof, are useful (either alone or in combination with another agent) for ameliorating or reducing the symptoms of, or treating, or preventing a disease or condition associated with PACAP, such as photophobia, light aversion or avoidance and sensitivity to light.

[2] In another embodiment of the invention, anti-PACAP antibodies described herein, or antigen binding fragments thereof, with or without a second agent, are useful for ameliorating or reducing the symptoms of, or treating, or preventing, the following non-limiting listing of diseases and disorders: migraine (with or without aura), hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, general headaches, hot flush, photophobia, chronic paroxysmal hemicrania, secondary headaches due to an underlying structural problem in the head or neck, cranial neuralgia, sinus headaches (e.g., headache associated with sinusitis), allergy-induced headaches or migraines, pain, chronic pain, neuroinflammatory or inflammatory pain, post-operative incision pain, post-surgical pain, trauma-related pain, eye pain, tooth pain, complex regional pain syndrome, cancer pain (e.g., primary or metastatic bone cancer pain), fracture pain, osteoporotic fracture pain, pain resulting from burn, gout joint pain, pain associated with sickle cell crises, pain associated with temporomandibular disorders, cirrhosis, hepatitis, neurogenic pain, neuropathic pain, nociceptive pain, visceral pain, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, menstrual pain, ovarialgia, reflex sympathetic dystrophy, osteoarthritis or rheumatoid arthritis pain, lower back pain, diabetic neuropathy, sciatica, dyspepsia, irritable bowel syndrome, inflammatory bowel disease, Crohn's disease, ileitis, ulcerative colitis, renal colic, dysmenorrhea, cystitis, interstitial cystitis, menstrual period, labor, menopause, pancreatitis, schizophrenia, depression, post-traumatic stress disorder, anxiety disorders, diabetes, autoimmune diabetes, endothelial dysfunction, ischemia, Raynaud's syndrome, coronary heart disease ("CHD"), coronary artery disease ("CAD"), heart failure, peripheral arterial disease ("PAD"), pulmonary hypertension ("PH"), connective tissue disorders, stroke, Sjögren's syndrome, multiple sclerosis, bronchial hyperreactivity, asthma, bronchitis, bronchodilation, emphysema, chronic obstructive pulmonary disease ("COPD"), inflammatory dermatitis, adenocarcinoma in glandular tissue, blastoma in embryonic tissue of organs, carcinoma in epithelial tissue, leukemia in tissues that form blood cells, lymphoma in lymphatic tissue, myeloma in bone marrow, sarcoma in connective or supportive tissue,

adrenal cancer, AIDS-related lymphoma, anemia, bladder cancer, bone cancer, brain cancer, breast cancer, carcinoid tumors, cervical cancer, chemotherapy, colon cancer, cytopenia, endometrial cancer, esophageal cancer, gastric cancer, head cancer, neck cancer, hepatobiliary cancer, kidney cancer, leukemia, liver cancer, lung cancer, lymphoma, Hodgkin's disease, non-Hodgkin's, nervous system tumors, oral cancer, ovarian cancer, pancreatic cancer, prostate cancer, rectal cancer, skin cancer, stomach cancer, testicular cancer, thyroid cancer, urethral cancer, cancer of bone marrow, multiple myeloma, tumors that metastasize to the bone, tumors infiltrating the nerve and hollow viscus, tumors near neural structures. Further preferably the cancer pain comprises visceral pain, preferably visceral pain which arises from pancreatic cancer and/or metastases in the abdomen. Further preferably the cancer pain comprises somatic pain, preferably somatic pain due to one or more of metastasis in the bone, postsurgical pain, sarcomas cancer of the connective tissue, cancer of bone tissue, cancer of blood-forming cells of the bone marrow, multiple myeloma, leukemia, primary or secondary bone cancer, acne vulgaris, atopic dermatitis, urticaria, keloids, hypertrophic scars and rosacea, allergic dermatitis, psoriasis, pruritus, neurogenic cutaneous redness, erythema, weight loss, anorexia, sarcoidosis, shock, sepsis, opiate withdrawal syndrome, morphine tolerance, epilepsy, lower urinary tract ("LUT") disorders such as urinary tract infection, abnormal voiding, urinary urgency, nocturia, urinary incontinence, overactive bladder and for preventing or alleviating the pain associated with such LUT conditions. Preferably, the subject anti-PACAP antibodies and antigen binding fragments described herein are useful for ameliorating or reducing the symptoms of, treating, or preventing migraine, headache and a pain associated disease or condition.

[3] In particular, the subject anti-PACAP antibodies and antigen binding fragments can also be useful for ameliorating or reducing the symptoms of, treating, or preventing photophobia, occurring with a headache and/or migraine as well as occurring independent of a headache and/or a migraine.

[4] Migraineurs typically develop worsening pain and migraine symptoms when exposed to light, a phenomenon known as photophobia. Photophobia is also common in ocular disorders, such as iritis and uveitis, and intracranial disorders, such as meningitis. In the classic visual pathway, light activates rods and cones in the retina, which activate retinal ganglion cells that project via the optic nerve, to the lateral geniculate nucleus, superior colliculus, and then the visual cortex. This pathway includes image-forming and non-image-forming data. A new pathway (non-image-forming information) allows maintenance of normal circadian rhythms via the suprachiasmatic nucleus and is regulated by intrinsically

photosensitive retinal ganglion cells (ipRGCs). These ipRGCs are independent of the rods and cones and contain melanopsin, a photopigment.

[5] Nosedá, R. et al., *Nat. Neurosci.*, 13:239–245 (2010) studied blind individuals who had migraine and correlated these findings with rat models involving tracing of ipRGC projections to areas in perception of pain from the dura. Of the blind patients with migraine, 6 had no light perception due to severe optic nerve damage or bilateral enucleation. These subjects experienced abnormal sleep patterns and poor pupillary light responses. Their migraines did not worsen with light exposure. In contrast, 14 blind subjects who were able to detect light despite minimal perception of images had normal sleep patterns and a normal pupillary light reflex. Despite widespread rod and cone degeneration, these patients had worsening migraine symptoms with light exposure during migraine attacks, suggesting that ipRGCs, and not rods and cones, are important in photophobia.

[6] These retinal projections of non-image-forming brain areas project to the contralateral dorsocaudal region of the posterior thalamus, as demonstrated by anterograde tracing in the rat. ipRGC input to this area modulates dura-sensitive pain neurons, which also project to this region. Thalamic neurons, dually sensitive to dural pain and light input, project widely to multiple cortical regions, including the primary somatosensory cortex, the primary and secondary motor cortices, the parietal association cortex, and the primary and secondary visual cortices. These cortical projections may help explain other common migraine symptoms, in addition to photophobia, such as motor weakness or incoordination, visual disturbances, and poor concentration.

[7] Photophobia also accompanies other less frequent but likewise disabling conditions, such as cluster headache and other trigeminal autonomic cephalalgias and blepharospasm. The mechanisms underlying photophobia involve the trigeminal system. Photophobia in blind patients suggests contributions from a nonvisual pathway. In addition, trigeminal autonomic cephalalgias, a less common group of primary headache disorders, are characterized by unilateral trigeminal-mediated pain frequently associated with ipsilateral photophobia.

[8] Common causes of photophobia include migraine headaches, cataracts, or severe ophthalmologic diseases such as uveitis or corneal abrasion. A more extensive list of disorders associated with photophobia includes eye related causes such as achromatopsia, aniridia, anticholinergic drugs may cause photophobia by paralyzing the iris sphincter muscle, aphakia (absence of the lens of the eye), buphthalmos (abnormally narrow angle between the cornea and iris), cataracts, cone dystrophy, congenital abnormalities of the eye, viral conjunctivitis ("pink eye"), corneal abrasion, corneal dystrophy, corneal ulcer,

disruption of the corneal epithelium, such as that caused by a corneal foreign body or keratitis, ectopia lentis, endophthalmitis, eye trauma caused by disease, injury, or infection such as chalazion, episcleritis, glaucoma, keratoconus, or optic nerve hypoplasia, hydrophthalmos, or congenital glaucoma iritis, optic neuritis, pigment dispersion syndrome, pupillary dilation (naturally or chemically induced), retinal detachment, scarring of the cornea or sclera and uveitis.

[9] In addition, photophobia has nervous-system-related or neurological causes including: autism spectrum disorders, Chiari malformation, dyslexia, encephalitis including myalgic encephalomyelitis aka chronic fatigue syndrome, meningitis, subarachnoid hemorrhage, tumor of the posterior cranial fossa, as well as other causes such as ankylosing spondylitis, albinism, ariboflavinosis, benzodiazepines (long term use of or withdrawal from benzodiazepines), chemotherapy, chikungunya, cystinosis, Ehlers-Danlos syndrome, hangover, influenza, infectious mononucleosis, magnesium deficiency, mercury poisoning, migraine, rabies, and tyrosinemia type II, also known as "Richner-Hanhart syndrome".

[10] Additionally, it is known that photophobia is elevated in depression, bipolar disorder and agoraphobia.

[11] The subject anti-PACAP antibodies and antigen binding fragments described herein can be effective for treating or preventing photophobia in any of these conditions, preferably, in a subject with post-traumatic stress disorder ("PTSD") or in a subject with traumatic brain injury.

[12] Headaches may be classified by cause, as discussed below.

[13] **Primary headaches.** A primary headache is caused by problems with or overactivity of pain-sensitive structures in the head. A primary headache is generally not considered to be a symptom of an underlying disease. Instead, chemical activity in the brain, the nerves or blood vessels of the head outside the skull, or muscles of the head and neck, or some combination of these factors, may play a role in primary headaches. Some people may carry genes that make them more likely to develop such headaches. Exemplary common primary headaches include, but are not limited to, cluster headache; tension headache (or tension-type headache); and trigeminal autonomic cephalalgia ("TAC"), including paroxysmal hemicrania. There are other headache patterns that may be considered types of primary headache, e.g., chronic daily headaches, cough headaches, exercise headaches, and sex headaches. These headaches are less common and have distinct features, such as an unusual duration or pain associated with a certain activity. Although these headaches are generally considered primary, each of them could be a symptom of an underlying disease. Additionally, some

primary headaches can be triggered by lifestyle factors, including: alcohol; certain foods (e.g., processed meats that contain nitrates); changes in sleep or lack of sleep; poor posture; skipped meals; and stress.

[14] **Secondary headaches.** A secondary headache is a symptom of a disease that can activate the pain-sensitive nerves of the head. Any number of conditions, which can vary greatly in severity, may cause secondary headaches. Exemplary sources of secondary headaches include, but are not limited to, acute sinusitis; arterial tears (carotid or vertebral dissections); venous thrombosis in the brain; brain aneurysm; brain arteriovenous malformation; carbon monoxide poisoning; Chiari malformation; concussion; dehydration; dental problems; ear infection (middle ear); encephalitis; giant cell arteritis; glaucoma; hangovers; influenza (flu); intracranial hematoma; medications to treat other disorders; meningitis; monosodium glutamate ("MSG"); overuse of pain medication; panic attacks; post-concussion syndrome; pressure from tight-fitting headgear, e.g., helmet or goggles; pseudotumor cerebri; toxoplasmosis; and trigeminal neuralgia. Specific types of secondary headaches include, but are not limited to, external compression headaches (a result of pressure-causing headgear); ice cream headaches (commonly called "brain freeze"); rebound headaches (caused by overuse of pain medication); sinus headaches (caused by inflammation and congestion in sinus cavities); spinal headaches (caused by low levels of cerebrospinal fluid, possibly the result of trauma, spinal tap or spinal anesthesia); and thunderclap headaches (a group of disorders that involves sudden, severe headaches).

[15] Exemplary, non-limiting pain associated diseases and disorders that can be treated and/or prevented by the administration of the anti-PACAP antibodies of the present invention include, pain resulting from any condition associated with neurogenic, neuropathic, inflammatory, or nociceptive pain. Preferably, the pain-associated disorder will be associated with increased PACAP at the pain site.

[16] In certain embodiments, the pain associated disorder to be treated is cancer pain arising from malignancy or from cancer selected from one or more of: adenocarcinoma in glandular tissue, blastoma in embryonic tissue of organs, carcinoma in epithelial tissue, leukemia in tissues that form blood cells, lymphoma in lymphatic tissue, myeloma in bone marrow, sarcoma in connective or supportive tissue, adrenal cancer, AIDS-related lymphoma, anemia, bladder cancer, bone cancer, brain cancer, breast cancer, carcinoid tumors, cervical cancer, chemotherapy, colon cancer, cytopenia, endometrial cancer, esophageal cancer, gastric cancer, head cancer, neck cancer, hepatobiliary cancer, kidney cancer, leukemia, liver cancer, lung cancer, lymphoma, Hodgkin's disease, non-Hodgkin's, nervous system tumors,

oral cancer, ovarian cancer, pancreatic cancer, prostate cancer, rectal cancer, skin cancer, stomach cancer, testicular cancer, thyroid cancer, urethral cancer, cancer of bone marrow, multiple myeloma, tumors that metastasize to the bone, tumors infiltrating the nerve and hollow viscus, tumors near neural structures. Further preferably the cancer pain comprises visceral pain, preferably visceral pain which arises from pancreatic cancer and/or metastases in the abdomen. Further preferably the cancer pain comprises somatic pain, preferably somatic pain due to one or more of metastasis in the bone, postsurgical pain, sarcomas cancer of the connective tissue, cancer of bone tissue, cancer of blood-forming cells of the bone marrow, multiple myeloma, leukemia, primary or secondary bone cancer.

[17] In other embodiments, the pain associated condition to be treated is associated with neuropathic pain and included, by way of example, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, and reflex sympathetic dystrophy are preferably treated.

[18] Further exemplary pain associated diseases or conditions, include but are not limited to, general pain, chronic pain, inflammatory pain, post-operative incision pain, post-surgical pain, trauma-related pain, lower back pain, eye pain, tooth pain, complex regional pain syndrome, cancer pain (e.g., primary or metastatic bone cancer pain), fracture pain, osteoporotic fracture pain, pain resulting from burn, gout joint pain, pain associated with sickle cell crises, pain associated with temporomandibular disorders, cirrhosis, hepatitis, neurogenic pain, neuropathic pain, nociceptive pain, visceral pain, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, menstrual pain, ovarialgia, reflex sympathetic dystrophy, osteoarthritis or rheumatoid arthritis pain, lower back pain, diabetic neuropathy, sciatica, dyspepsia, irritable bowel syndrome, inflammatory bowel disease, Crohn's disease, ileitis, ulcerative colitis, renal colic, dysmenorrhea, cystitis, interstitial cystitis, menstrual period, labor, menopause, pancreatitis, schizophrenia, depression, post-traumatic stress disorder, anxiety disorders, diabetes, autoimmune diabetes, endothelial dysfunction, ischemia, Raynaud's syndrome, coronary heart disease ("CHD"), coronary artery disease ("CAD"), heart failure, peripheral arterial disease ("PAD"), pulmonary hypertension ("PH"), connective tissue disorders, stroke, Sjögren's syndrome, multiple sclerosis, overactive bladder, bronchial hyperreactivity, asthma, bronchitis, bronchodilation, emphysema, chronic obstructive pulmonary disease ("COPD"), inflammatory dermatitis, acne vulgaris, atopic dermatitis, urticaria, keloids, hypertrophic scars and rosacea, allergic dermatitis, psoriasis, pruritus, neurogenic cutaneous redness, erythema, sarcoidosis, shock, sepsis, and opiate withdrawal syndrome.

[19] Thus, the present invention includes methods of treating, preventing, and/or ameliorating any disease or disorder associated with PACAP activity or PACAP upregulation (including any of the above mentioned exemplary pain associated diseases, disorders and conditions) through use of the antibodies and antigen binding fragments of the invention.

[20] Also, the subject PACAP antibodies and antigen binding fragments may be used alone or in conjunction with other active agents, e.g., opioids and non-opioid analgesics such as NSAIDs to elicit analgesia or to potentiate the efficacy of another analgesic.

[21] The subject antibodies potentially may be combined with any opioid analgesic or NSAID or other analgesic, potentially another antibody or another biologic such as, e.g., an anti-NGF or anti-CGRP or anti-CGRP-R antibody or antibody fragment or NGF, CGRP or CGRP-R polypeptide fragment or conjugate, in order to increase or enhance pain management. This may allow for such analgesic compounds to be administered for longer duration or at reduced dosages thereby potentially alleviating adverse side effects associated therewith.

[22] Of particular interest is the co-administration of the subject anti-PACAP antibodies and antibody fragments with an anti-CGRP antibody (e.g., ALD403) or an anti-CGRP-R antibody or antibody fragment and, moreover, the use of the subject anti-PACAP antibodies and antibody fragments to treat subjects that previously received an anti-CGRP or anti-CGRP-R antibody or antibody fragment. For example, the previously treated subject (who previously received at least one anti-CGRP or anti-CGRP-R antibody or antibody fragment administration) may be a migraineur who did not adequately respond to anti-CGRP or anti-CGRP-R antibody treatment ("poor responder") and/or has elicited an immune response to the anti-CGRP or anti-CGRP-R antibody or antibody fragment.

[23] Likewise, the co-administration of the subject anti-PACAP antibodies and antigen binding fragments with BOTOX® (Botulinum toxin) is also of particular interest, e.g., in treating a migraineur. In some instances, the migraineur may not have adequately responded to previous treatments ("poor responder") and/or has elicited an immune response to the previous treatment.

[24] In some embodiments, aspirin and/or acetaminophen may be taken in conjunction with the subject anti-PACAP antibody or antigen binding fragment. Aspirin is another type of non-steroidal anti-inflammatory compound.

[0302] The subject to which the pharmaceutical formulation is administered can be, e.g., any human or non-human animal that is in need of such treatment, prevention and/or amelioration, or who would otherwise benefit from the inhibition or attenuation of PACAP-

mediated activity. For example, the subject can be an individual that is diagnosed with, or who is deemed to be at risk of being afflicted by any of the aforementioned diseases or disorders. The present invention further includes the use of any of the pharmaceutical formulations disclosed herein in the manufacture of a medicament for the treatment, prevention and/or amelioration of any disease or disorder associated with PACAP activity (including any of the above mentioned exemplary diseases, disorders and conditions).

Administration

[0303] In one embodiment of the invention, the anti-PACAP antibodies described herein, or PACAP binding fragments thereof, as well as combinations of said antibodies or antigen binding fragments thereof, are administered to a subject at a concentration of between 0.1 mg/ml and about any one of 0.5, 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, or 200 mg/ml, +/-10% error.

[0304] In another embodiment of the invention, the anti-PACAP antibodies and fragments thereof described herein are administered to a subject at a dose of between about 0.01 and 100.0 or 200.0 mg/kg of body weight of the recipient subject. In certain embodiments, depending on the type and severity of the PACAP-related disease, about 1 µg/kg to 50 mg/kg (e.g., 0.1-20 mg/kg) of antibody is an initial candidate dosage for administration to the patient, whether, for example, by one or more separate administrations, or by continuous infusion. In another embodiment, about 1 µg/kg to 15 mg/kg (e.g., 0.1 mg/kg-10 mg/kg) of antibody is an initial candidate dosage for administration to the patient. A typical daily dosage might range from about 1 µg/kg to 100 mg/kg or more, depending on several factors, e.g., the particular mammal being treated, the clinical condition of the individual patient, the cause of the disorder, the site of delivery of the agent, the method of administration, the scheduling of administration, and other factors known to medical practitioners. However, other dosage regimens may be useful.

[0305] For example, in addition to the relative dosages (mg/kg) discussed herein, the subject anti-PACAP antibodies and antigen binding fragments thereof can be administered to a subject at an absolute dose (mg). Accordingly, in one embodiment of the invention, the anti-PACAP antibodies and antigen binding fragments thereof described herein are administered to a subject at a dose of between about 1 microgram and about 1000 milligrams regardless of the route of administration.

[0306] In a preferred embodiment of the invention, the anti-PACAP antibodies described herein, or anti-PACAP antigen binding fragments thereof, as well as combinations of said

antibodies or antigen binding fragments thereof, are administered to a recipient subject with a frequency of once every twenty-six weeks or less, such as once every sixteen weeks or less, once every eight weeks or less, once every four weeks or less, once every two weeks or less, once every week or less, or once daily or less.

[0307] According to preferred embodiments, the antibody containing medicament or pharmaceutical composition is peripherally administered to a subject via a route selected from one or more of: orally, sublingually, buccally, topically, rectally, via inhalation, transdermally, subcutaneously, intravenously, intra-arterially, or intramuscularly, via intracardiac administration, intraosseously, intradermally, intraperitoneally, transmucosally, vaginally, intravitreally, epicutaneously, intra-articularly, peri-articularly, or locally.

[0308] Fab fragments may be administered every two weeks or less, every week or less, once daily or less, multiple times per day, and/or every few hours. In one embodiment of the invention, a patient receives Fab fragments of 0.1 mg/kg to 40 mg/kg per day given in divided doses of 1 to 6 times a day, or in a continuous perfusion form, effective to obtain desired results.

[0309] It is to be understood that the concentration of the antibody or Fab administered to a given patient may be greater or lower than the exemplary administration concentrations set forth above.

[0310] A person of skill in the art would be able to determine an effective dosage and frequency of administration through routine experimentation, for example guided by the disclosure herein and the teachings in, *Goodman & Gilman's The Pharmacological Basis of Therapeutics*, Brunton, L.L. et al. editors, 11th edition, New York, New York: McGraw-Hill (2006); Howland, R. D. et al., *Pharmacology, Volume 864, Lippincott's illustrated reviews.*, Philadelphia, PA: Lippincott Williams & Wilkins (2006); and Golan, D. E., *Principles of pharmacology: the pathophysiologic basis of drug therapy*, Philadelphia, PA: Lippincott Williams & Wilkins (2007).

[0311] In another embodiment of the invention, the anti-PACAP antibodies described herein, or PACAP binding fragments thereof, as well as combinations of said antibodies or antigen binding fragments thereof, are administered to a subject in a pharmaceutical formulation. In a preferred embodiment, the subject is a human.

[0312] A "pharmaceutical composition" or "medicament" refers to a chemical or biological composition suitable for administration to a subject, preferably a mammal, more preferably a human. Such compositions may be specifically formulated for administration *via* one or more of a number of routes, including but not limited to buccal, epicutaneous, epidural, inhalation,

intraarterial, intracardial, intracerebroventricular, intradermal, intramuscular, intranasal, intraocular, intraperitoneal, intraspinal, intrathecal, intravenous, oral, parenteral, rectally *via* an enema or suppository, subcutaneous, subdermal, sublingual, transdermal, and transmucosal. In addition, administration can occur by means of injection, powder, liquid, gel, drops, or other means of administration.

[0313] In one embodiment of the invention, the anti-PACAP antibodies described herein, or PACAP binding fragments thereof, as well as combinations of said antibodies or antigen binding fragments thereof, may be optionally administered in combination with one or more active agents. Such active agents include analgesic, anti-histamine, antipyretic, anti-inflammatory, antibiotic, antiviral, and anti-cytokine agents. Active agents include agonists, antagonists, and modulators of TNF- α , IL-2, IL-4, IL-6, IL-10, IL-12, IL-13, IL-18, IFN- α , IFN- γ , BAFF, CXCL13, IP-10, VEGF, EPO, EGF, HRG, Hepatocyte Growth Factor ("HGF"), Heparin, NGF, CGRP including antibodies reactive against any of the foregoing, and antibodies reactive against any of their receptors. Active agents also include but are not limited to 2-arylpropionic acids, aceclofenac, acemetacin, acetylsalicylic acid (aspirin), alclofenac, alminoprofen, amoxicillin, ampyrone, arylalkanoic acids, azapropazone, benorylate/benorilate, benoxaprofen, bromfenac, carprofen, celecoxib, choline magnesium salicylate, clofezone, COX-2 inhibitors, dexibuprofen, dexketoprofen, diclofenac, diflunisal, droxicam, etenzamide, etodolac, etoricoxib, fentanyl, fenamic acids, fenbufen, fenoprofen, flufenamic acid, flunoxaprofen, flurbiprofen, ibuprofen, ibuprofen, ibuprofen, indomethacin, indoprofen, ketoprofen, ketorolac, lornoxicam, loxoprofen, lumiracoxib, magnesium salicylate, meclofenamic acid, mefenamic acid, meloxicam, metamizole, methyl salicylate, mofebutazone, nabumetone, naproxen, N-arylanthranilic acids, NGF, oxametacin, oxaprozin, oxicams, oxyphenbutazone, oxytocin, parecoxib, phenazone, phenylbutazone, phenylbutazone, piroxicam, piroxicam, piroxicam, profens, proglumetacin, pyrazolidine derivatives, rofecoxib, salicyl salicylate, salicylamide, salicylates, substance P, sulfonpyrazone, sulindac, suprofen, tenoxicam, tiaprofenic acid, tolfenamic acid, tolmetin, and valdecoxib. For instance, the selected anti-PACAP antibodies, or PACAP-binding fragments thereof, as well as combinations of these antibodies or antigen binding fragments, can be optionally administered in combination with oxytocin, for instance administered in a nasal formulation, for intranasal delivery.

[0314] An anti-histamine can be any compound that opposes the action of histamine or its release from cells (e.g., mast cells). Anti-histamines include but are not limited to acrivastine, astemizole, azatadine, azelastine, betastastine, brompheniramine, buclizine, cetirizine,

cetirizine analogues, chlorpheniramine, clemastine, CS 560, cyproheptadine, desloratadine, dexchlorpheniramine, ebastine, epinastine, fexofenadine, HSR 609, hydroxyzine, levocabastine, loratadine, methscopolamine, mizolastine, norastemizole, phenindamine, promethazine, pyrilamine, terfenadine, and tranilast.

[0315] Antibiotics include but are not limited to amikacin, aminoglycosides, amoxicillin, ampicillin, ansamycins, arsphenamine, azithromycin, azlocillin, aztreonam, bacitracin, carbacephem, carbapenems, carbenicillin, cefaclor, cefadroxil, cefalexin, cefalothin, cefalotin, cefamandole, cefazolin, cefdinir, cefditoren, cefepime, cefixime, cefoperazone, cefotaxime, cefoxitin, cefpodoxime, cefprozil, ceftazidime, ceftibuten, ceftizoxime, ceftobiprole, ceftriaxone, cefuroxime, cephalosporins, chloramphenicol, cilastatin, ciprofloxacin, clarithromycin, clindamycin, cloxacillin, colistin, co-trimoxazole, dalfopristin, demeclocycline, dicloxacillin, dirithromycin, doripenem, doxycycline, enoxacin, ertapenem, erythromycin, ethambutol, flucloxacillin, fosfomycin, furazolidone, fusidic acid, gatifloxacin, geldanamycin, gentamicin, glycopeptides, herbimycin, imipenem, isoniazid, kanamycin, levofloxacin, lincomycin, linezolid, lomefloxacin, loracarbef, macrolides, mafenide, meropenem, methicillin, metronidazole, mezlocillin, minocycline, monobactams, moxifloxacin, mupirocin, nafcillin, neomycin, netilmicin, nitrofurantoin, norfloxacin, ofloxacin, oxacillin, oxytetracycline, paromomycin, penicillin, penicillins, piperacillin, platensimycin, polymyxin B, polypeptides, prontosil, pyrazinamide, quinolones, quinupristin, rifampicin, rifampin, roxithromycin, spectinomycin, streptomycin, sulfacetamide, sulfamethizole, sulfanilamide, sulfasalazine, sulfisoxazole, sulfonamides, teicoplanin, telithromycin, tetracycline, tetracyclines, ticarcillin, tinidazole, tobramycin, trimethoprim, trimethoprim-sulfamethoxazole, troleandomycin, trovafloxacin, and vancomycin.

[0316] Active agents also include aldosterone, beclomethasone, betamethasone, corticosteroids, cortisol, cortisone acetate, deoxycorticosterone acetate, dexamethasone, fludrocortisone acetate, glucocorticoids, hydrocortisone, methylprednisolone, prednisolone, prednisone, steroids, and triamcinolone. Any suitable combination of these active agents is also contemplated.

[0317] A "pharmaceutical excipient" or a "pharmaceutically acceptable excipient" is a carrier, usually a liquid, in which an active therapeutic agent is formulated. In one embodiment of the invention, the active therapeutic agent is a humanized antibody described herein, or one or more fragments thereof. The excipient generally does not provide any pharmacological activity to the formulation, though it may provide chemical and/or biological stability, and release characteristics. Exemplary formulations can be found, for

example, in *Remington's Pharmaceutical Sciences*, Gennaro, A. editor, 19th edition, Philadelphia, PA: Williams and Wilkins (1995), which is incorporated by reference.

[0318] As used herein "pharmaceutically acceptable carrier" or "excipient" includes any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic, and absorption delaying agents that are physiologically compatible. In one embodiment, the carrier is suitable for parenteral administration. Alternatively, the carrier can be suitable for intravenous, intraperitoneal, intramuscular, or sublingual administration. Pharmaceutically acceptable carriers include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions. The use of such media and agents for pharmaceutically active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the active compound, use thereof in the pharmaceutical compositions of the invention is contemplated. Supplementary active compounds can also be incorporated into the compositions.

[0319] Pharmaceutical compositions typically must be sterile and stable under the conditions of manufacture and storage. The invention contemplates that the pharmaceutical composition is present in lyophilized form. The composition can be formulated as a solution, microemulsion, liposome, or other ordered structure suitable to high drug concentration. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyethylene glycol), and suitable mixtures thereof. The invention further contemplates the inclusion of a stabilizer in the pharmaceutical composition. The proper fluidity can be maintained, for example, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants.

[0320] In many cases, it will be preferable to include isotonic agents, for example, sugars, polyalcohols such as mannitol and sorbitol, or sodium chloride in the composition. Absorption of the injectable compositions can be prolonged by including an agent that delays absorption, for example, monostearate salts and gelatin. Moreover, the alkaline polypeptide can be formulated in a time-release formulation, for example in a composition that includes a slow release polymer. The active compounds can be prepared with carriers that will protect the compound 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, polylactic acid, polylactic and polyglycolic copolymers ("PLG"). Many methods for the preparation of such formulations are known to those skilled in the art.

[0321] For each of the recited embodiments, the compounds can be administered by a variety of dosage forms. Any biologically acceptable dosage form known to persons of ordinary skill in the art, and combinations thereof, are contemplated. Examples of such dosage forms include, without limitation, reconstitutable powders, elixirs, liquids, solutions, suspensions, emulsions, powders, granules, particles, microparticles, dispersible granules, cachets, inhalants, aerosol inhalants, patches, particle inhalants, implants, depot implants, injectables (including subcutaneous, intramuscular, intravenous, and intradermal), infusions, and combinations thereof.

[0322] The above description of various illustrated embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. The teachings provided herein of the invention can be applied to other purposes, other than the examples described above.

[0323] These and other changes can be made to the invention in light of the above detailed description. In general, in the following claims, the terms used should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Accordingly, the invention is not limited by the disclosure, but instead the scope of the invention is to be determined entirely by the following claims.

[0324] The invention may be practiced in ways other than those particularly described in the foregoing description and examples. Numerous modifications and variations of the invention are possible in light of the above teachings and, therefore, are within the scope of the appended claims.

[0325] Certain teachings related to methods for obtaining a clonal population of antigen-specific B-cells were disclosed in U.S. Patent Publication No. US2013/0316353, the disclosure of which is herein incorporated by reference in its entirety.

[0326] Certain teachings related to humanization of rabbit-derived monoclonal antibodies and preferred sequence modifications to maintain antigen-binding affinity were disclosed in International Publication No. WO 2008/144757, entitled *Novel Rabbit Antibody Humanization Methods and Humanized Rabbit Antibodies*, filed May 21, 2008, the disclosure of which is herein incorporated by reference in its entirety.

[0327] Certain teachings related to producing antibodies or fragments thereof using mating competent yeast and corresponding methods were disclosed in U.S. Patent Publication No. US2006/0270045, the disclosure of which is herein incorporated by reference in its entirety.

[0328] Certain teachings related to producing antibodies or fragments thereof in *Pichia* and preferred methods for obtaining and purifying antibodies are also disclosed in U.S. Patent Publication Nos. 2014/0288272; 2014/0287952; 2013/0055888; and 2012/0277408, the disclosures of each of which are herein incorporated by reference in their entirety.

[0329] Certain teachings related to producing antibodies or fragments thereof in CHO cells and exemplary methods for obtaining and purifying antibodies are also disclosed in U.S. Patent and Publication Nos. 7,932,087; 2009/0285795; 9,090,672; and 2010/0221781; the disclosures of each of which are herein incorporated by reference in their entirety.

[0330] Certain anti-PACAP antibody polynucleotides and polypeptides are disclosed in the sequence listing accompanying this patent application filing, and the disclosure of said sequence listing is herein incorporated by reference in its entirety.

[0331] The entire disclosure of each document cited (including patents, patent applications, journal articles, abstracts, manuals, books, or other disclosures) in the Background of the Invention, Detailed Description, and Examples is herein incorporated by reference in their entireties.

[0332] The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the subject invention, and are not intended to limit the scope of what is regarded as the invention. Efforts have been made to ensure accuracy with respect to the numbers used (*e.g.* amounts, temperature, concentrations, *etc.*), but some experimental errors and deviations should be allowed for. Unless otherwise indicated, parts are parts by weight, molecular weight is average molecular weight, temperature is in degrees centigrade; and pressure is at or near atmospheric.

[0333]

EXAMPLES

Example 1: Preparation of Antibodies that Selectively Bind PACAP

[0334] By using an antibody selection protocol substantially as described herein, a panel of antibodies specific to PACAP38 and PACAP27, and a panel of antibodies specific to PACAP38 only, were produced.

Immunization Strategy

[0335] Rabbits were immunized with PACAP38 (American Peptide, Vista, CA) (SEQ ID NO: 1241). Peptides were prepared for immunization as follows. A 0.15 ml volume of 10

mg/ml keyhole limpet hemocyanin ("KLH") dissolved in Dulbecco's phosphate buffered saline ("DPBS") supplemented to 1M NaCl was combined with 1.0 ml of 1 mg/ml peptide (dissolved in deionized water). Then 1.0 ml of 40 mM carbodiimide was added prior to a 12-hour incubation at room temperature with gentle mixing. Excess carbodiimide and unconjugated peptide were removed by dialysis to DPBS prior to sterile filtration. Next unconjugated peptide equal to the initial mass of KLH was added prior to preparation for injection into rabbits. Alternatively, equal masses of sterile KLH and peptide were mixed without carbodiimide chemistry.

[0336] Immunizations were performed by diluting 200 µg of antigen to 0.5 ml with DPBS and mixing with an equal volume of complete Freund's adjuvant for subcutaneous 1 ml injection at Day 1.

[0337] Boost injections of 100 µg were performed with incomplete Freund's adjuvant at Days 21 and 42.

Antibody Selection Functional Titer Assessment

[0338] To identify antibodies that neutralize PACAP38 (SEQ ID NO: 1241) induced signaling via PAC1-R, polyclonal antibody solutions were first purified via Protein A and dialyzed into a neutral buffer. Briefly, antibody solutions were incubated with PACAP38 (SEQ ID NO: 1241) at 4x the final concentration (100 pM) for 1 hr. While the antibody/antigen complexes were incubated, PAC1-R expressing PC-12 cells (Japanese Collection of Research Bioresources Cell Bank) were washed and re-suspended at 2×10^6 cells per ml in cell culture media. Cells (10 µl) and antigen/antibody complex (40 µl) were transferred to a homogenous time resolved fluorescence ("HTRF") plate and shaken at room temperature for 30 min. Following the incubation, 20 µl of (1:20 diluted) Eu^{3+} cryptate-labeled mAb anti-cAMP and 20 µl of (1:20 diluted) d2-labeled cAMP in lysis buffer were added, and the plate was incubated for 1 hr while shaking. Following incubation, plates were read (excitation 330 nm, emission 620/665 nm), and a ratio of 620:665 signal was determined.

Tissue Harvesting

[0339] Once acceptable titers were established, the rabbit(s) were sacrificed. Spleen, lymph nodes, and whole blood were harvested and processed as follows:

[0340] Spleen and lymph nodes were processed into a single cell suspension by disassociating the tissue and pushing through sterile wire mesh at 70 µm (Thermo Fisher

Scientific, Waltham, MA) with a plunger of a 20 cc syringe. Cells were collected in phosphate buffered saline ("PBS"). Cells were then washed twice by centrifugation. After the last wash, cell density was determined by trypan blue. Cells were centrifuged at 1500 RPM for 10 minutes; the supernatant was then discarded. Cells were resuspended in the appropriate volume of 10% dimethyl sulfoxide ("DMSO", Sigma-Aldrich Co., St. Louis, MO) in fetal bovine serum ("FBS" HYCLONE™, GE Healthcare Life Sciences, Marlborough, MA) and dispensed at 1 ml/vial. Vials were stored at -70°C in a slow freezing chamber for 24 hours and stored in liquid nitrogen.

[0341] Peripheral blood mononuclear cells ("PBMCs") were isolated by mixing whole blood with equal parts of PBS. 35 ml of the whole blood mixture was carefully layered onto 8 ml of LYMPHOLYTE® Rabbit (Cedarlane Laboratories, Burlington, Ontario) into a 45 ml conical tube (Corning, Corning, NY) and centrifuged for 30 minutes at 2500 RPM at room temperature without brakes. After centrifugation, the PBMC layers were carefully removed using a glass Pasteur pipette (VWR International, Radnor, PA), combined, and placed into a clean 50 ml vial. Cells were washed twice with PBS by centrifugation at 1500 RPM for 10 minutes at room temperature, and cell density was determined by trypan blue staining. After the last wash, cells were resuspended in an appropriate volume of 10% DMSO/FBS medium and frozen as described above.

B-Cell Selection, Enrichment, and Culture Conditions

[0342] On the day of setting up B-cell culture, PBMC, splenocyte, or lymph node vials were thawed for use. Vials were removed from liquid nitrogen tank and placed in a 37°C water bath until thawed. Contents of vials were transferred into 15 ml conical centrifuge tube (Corning, Inc., Corning, NY) and 10 ml of modified RPMI was slowly added to the tube. Cells were centrifuged for 5 minutes at 2000 RPM, and the supernatant was discarded. Cells were resuspended in 10 ml of fresh media. Cell density and viability was determined by trypan blue.

[0343] For positive selection of anti-PACAP38 producing B-cells, biotinylated PACAP38 (SEQ ID NO: 1241) was pre-loaded onto the streptavidin beads as follows. 75 µl of streptavidin beads (Miltenyi Biotec, Auburn, CA) were mixed with N-terminally biotinylated PACAP38 (10 µg/ml final concentration) and 300 µl of PBS supplemented with 0.5% bovine serum albumin ("BSA") and 2 mM EDTA ("PBF"). This mixture was incubated at 4°C for 30 minutes, and unbound biotinylated PACAP38 (AnaSpec, Fremont, CA) was removed using a MACS® separation column (Miltenyi Biotec, Auburn, CA) with a 1 ml

rinse to remove unbound material. The bound material was plunged out by detachment from the magnet and used to resuspend cells from above in 100 μ l per 1×10^7 cells. The mixture was then incubated at 4°C for 30 minutes and washed once with 10 ml of PBF. After washing, the cells were resuspended in 500 μ l of PBF and set aside. A MACS® MS column (Miltenyi Biotec, Auburn, CA) was pre-rinsed with 500 μ l of PBF on a magnetic stand (Miltenyi Biotec, Auburn, CA). Cell suspension was applied to the column through a pre-filter, and unbound fraction was collected. The column was washed with 2.5 ml of PBF buffer. The column was removed from the magnet stand and placed onto a clean, sterile 1.5 ml EPPENDORF™ tube. 1 ml of PBF buffer was added to the top of the column, and positive selected cells were collected. The yield and viability of positive cell fraction was determined by trypan blue staining. Positive selection yielded an average of 1% of the starting cell concentration.

[0344] A pilot cell screen was established to provide information on seeding levels for the culture. Plates were seeded at 5, 10, 25, 50, 100, or 200 enriched B-cells/well. In addition, each well contained 25-50K cells/well of irradiated EL-4.B5 cells (5,000 Rads) and an appropriate level of activated rabbit T-cell supernatant (See U.S. Patent Application Publication No. 20070269868) (ranging from 1-5% depending on preparation) in high glucose modified RPMI medium at a final volume of 250 μ l/well. Cultures were incubated for 5 to 7 days at 37°C in 4% CO₂.

B-Cell Culture Screening by Antigen-Recognition (ELISA)

[0345] To identify wells producing anti-PACAP38 antibodies, B-cell supernatants were tested by antigen-recognition (ELISA). Briefly, NEUTRAVIDIN™-coated plates (Thermo Fisher Scientific, Waltham, MA), were coated with either N-term or C-term biotinylated PACAP38 (AnaSpec Inc., Fremont, CA) (50 μ l per well; 1 μ g/ml) diluted in ELISA buffer (0.5% fish skin gelatin in PBS pH 7.4) either for approximately 1 hour at room temperature or alternatively overnight at 4°C. The plates were then further blocked with ELISA buffer for one hour at room temperature and washed using PBS with 0.05% Tween 20 ("wash buffer"). B-cell supernatant samples (50 μ l) were transferred onto the wells and incubated for one hour at room temperature. After this incubation, the plate was washed with wash buffer. For development, an anti-rabbit specific Fc-Horse Radish Peroxidase ("Fc-HRP") (1:5000 dilution in ELISA buffer) was added onto the wells and incubated for 45 minutes at room temperature. After a 3X wash step with wash solution, the plate was developed using

3,3',5,5'-Tetramethylbenzidine ("TMB") substrate for two minutes at room temperature, and the reaction was quenched using 0.5M HCl. The well absorbance was read at 450 nm.

[0346] To identify wells producing anti-PACAP38 antibodies that do not recognize VIP (SEQ ID NO: 1243), supernatant from wells positive for PACAP38 binding by ELISA were tested by ELISA for binding to VIP. Briefly, biotinylated VIP (AnaSpec Inc., Fremont, CA) was bound onto NEUTRAVIDIN™ coated plates (50 µg per well, 1 µg/µl each peptide). B-cell supernatant samples (50 µl) were tested without prior dilution. Recognition in this assay may indicate cross reactivity with a closely related peptide, VIP.

Identification of Functional Activity in B-cell Supernatants using one or more assays

[0347] To identify wells producing anti-PACAP38 antibodies that block signaling of PACAP38 via PAC1-R, supernatant from positive wells for PACAP38 binding by ELISA were tested in a cAMP HTRF assay (Cisbio US, Bedford, MA). Supernatants (78 µl) were pre-incubated with 2 µl 5 nM PACAP38 (American Peptide Company, Sunnyvale, CA) for 1 hour at 37°C. During the incubation, PC-12 cells were prepared as described for titer assessment. Cells (10 µl) and antigen/antibody complex (40 µl) were transferred to an HTRF plate and shaken at room temperature for 30 minutes. Following the incubation, 20 µl of (1:20 diluted) Eu³⁺ cryptate-labeled mAb anti-cAMP and 20 µl of (1:20 diluted) d2-labeled cAMP in lysis buffer were added, and the plate was incubated for 1 hour while shaking. Following incubation plates were read (excitation 330 nm, emission 620/665 nm), and a ratio of 620:665 signal was determined.

Isolation of Antigen-Specific B-cells

[0348] Antigen-specific B-cells were isolated (for general methods see co-owned publication no. WO 2014/146074, which is hereby incorporated by reference in its entirety). Plates containing wells of interest were removed from -70°C, and the cells from each well were recovered using five washes of 200 µl of medium (10% RPMI complete, 55 µM β-mercaptoethanol ("BME")) per well. The recovered cells were pelleted by centrifugation and the supernatant was carefully removed. Cells from each well were then re-suspended in 100 µl of medium and transferred to a 96 well plate. Cells were incubated for 90 minutes at 37°C. Following incubation, cells were pelleted by centrifugation, stained with a fluorescein isothiocyanate-labeled ("FITC-labeled") anti-rabbit IgG (final concentration 6.25 µg/ml) (Creative Diagnostics, Shirley, NY), and washed with up to 2 ml fluorescence-activated cell

sorting buffer ("FACS buffer") (Dulbecco's PBS w/ 2%FBS) and re-suspended in 250 µl of FACS buffer.

[0349] Control wells from the same culture sets that were similar in composition to pooled wells of interest were thawed and stained alongside target wells. These samples were initially run on FACS (BD INFLUX™, Becton, Dickinson and Company, Franklin Lakes, NJ), and gates were established for IgG, viability, and physical parameters (Forward scatter ("FSC")/side scatter ("SSC")) that differentiate B-cells from the murine EL4 cells. Once gates were established, the sample of interest was run, and IgG positive, viable cells that were of a consistent physical (FSC/SSC) population were sorted individually into wells of a 96 well plate pre-loaded with RT-PCR master mix. Upwards of 8 cells per well were sorted. Sorted plates were removed from the sorter and transferred directly to thermocyclers for PCR.

Amplification and Sequence Determination of Antibody Sequences From FACS-sorted B-Cells

[0350] Antibody sequences were recovered using a combined RT-PCR based method from a single cell sorted B-cell. Primers containing restriction enzymes were designed to anneal in conserved and constant regions of the target immunoglobulin genes (heavy and light), such as rabbit immunoglobulin sequences, and a two-step nested PCR recovery was used to amplify the antibody sequence. Amplicons from each well were sequenced and analyzed. Representative antibodies from the resulting sequence clusters were selected for recombinant protein expression. The original heavy and light variable regions amplified from rabbit cells were cloned into human heavy and light chain constant region expression vectors via restriction enzyme digestion and ligation, and via Gibson method. Vectors containing subcloned DNA fragments were amplified and purified. The sequences of the subcloned heavy and light chains were verified prior to expression.

Recombinant Production of Monoclonal Antibody of Desired Antigen Specificity and/or Functional Properties

[0351] To determine antigen specificity and functional properties of recovered antibodies from specific B-cells, the heavy and light chain plasmids were co-transfected to generate rabbit/human chimeric antibodies for testing. Briefly, heavy and light chimeric plasmids were transiently transfected into HEK-293 cells. Transfections were allowed to incubate for 5-7 days, and upon harvest, cells were pelleted by centrifugation. Supernatants were submitted

for purification via Protein A. Resulting purified chimeric antibodies were then evaluated in a variety of assays to confirm specificity and potency.

[0352] Using the above-described methods, numerous functional (antagonistic) antibodies that bind PACAP38 and PACAP27, or that bind PACAP38 only, but which do not, or do not appreciably, bind to VIP were identified. Polypeptide and exemplary coding sequences of exemplary antagonistic anti-PACAP antibodies are contained in the included biological sequence listing.

[0353] The full-length antibodies Ab10 and Ab20 used in these examples were expressed as the heavy chain polypeptides having the sequences of SEQ ID NO: 401 and 441, respectively, and the light chain polypeptides of SEQ ID NO: 421 and 461, respectively. The heavy chain polypeptides of antibodies Ab10 and Ab20 were expressed from the polynucleotides of SEQ ID NO: 411 and 451, respectively. The light chain polypeptides of antibodies Ab10 and Ab20 were expressed from the polynucleotides of SEQ ID NO: 431 and 471, respectively. Additional features of said antibodies are identified by SEQ ID NOS in FIGs. 1-12.

Antigen Binding Specificity of Antibodies by Competitive HTRF Binding Assay

[0354] The binding and functional properties of exemplary anti-PACAP38 and anti-PACAP27 antibodies produced according to the invention are further described below.

[0355] To identify antibodies that preferentially bind PACAP38 (SEQ ID NO: 1241) and PACAP27 (SEQ ID NO: 1242), but do not bind VIP (SEQ ID NO: 1243), or to identify antibodies that specifically bind PACAP38, but do not bind appreciably PACAP27, or do not appreciably bind VIP, etc., a competition HTRF binding assay was performed.

[0356] In parallel, 10 μ l of an antibody dilution series (highest final concentration of 100 nM) were incubated with 10 μ l of N-terminal or C-terminal biotinylated PACAP38 (35 nM final) alone, or in combination with either PACAP27 (350 nM final) or VIP (350 nM final), i.e., 10x PACAP27 or 10x VIP, respectively, in a HTRF plate. 20 μ l of Eu³⁺ cryptate labeled anti-hu Fc donor and 20 μ l of d2-labeled streptavidin acceptor were added to each well and incubated for 1 hour at room temperature. Fluorescence was measured at 620 and 665 nm with a delay of 300 μ sec.

[0357] Binding data were obtained based on experiments assaying the binding of Ab10, Ab20, Ab21, Ab1.H, Ab22, and Ab23 to PACAP38 and to PACAP27. These binding curve data showed that VIP is unable to effectively compete with binding of PACAP38. The lack of effect of VIP on binding to PACAP38 indicated its inability to compete with binding of

PACAP38. These results demonstrated that Ab10, Ab20, Ab21, and Ab1.H bind to PACAP38 and PACAP27, but do not bind (or do not appreciably bind) VIP. These results also demonstrated that Ab22 and Ab23 bind to PACAP38, but do not bind (or do not appreciably bind) PACAP27 or VIP.

[0358] EC₅₀ values, i.e. the concentration of an antibody that yields a response halfway between the baseline and the maximum value within a specified time period, were computed for each antibody based upon their binding curves and are shown in Table 1 below. The results demonstrated that Ab10, Ab20, Ab21, Ab22, and Ab23 bound to and recognized human PACAP38 with high affinity. A humanized form of antibody Ab1 was produced and is identified by an appended ".H", i.e., Ab1.H also bound PACAP38 with high affinity.

TABLE 1

Binding (EC₅₀) of PACAP38 by anti-PACAP antibodies

ANTIBODY	PACAP38-binding EC50 (nM)
Ab10	0.36
Ab20	0.38
Ab21	0.84
Ab1.H	0.46
Ab22	0.57
Ab23	0.56

Ability of anti-PACAP Antibodies to Neutralize PACAP38-induced and PACAP27-induced cAMP Production

[0359] The ability of anti-PACAP antibodies to neutralize PACAP38-induced and PACAP27-induced PAC1-R signaling was tested in a cell-based assay.

[0360] For Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 to identify antibodies that neutralized PACAP38-induced and PACAP27-induced signaling via PAC1-R, antibody solutions were incubated with either PACAP38 or with PACAP27 at 4x the final concentration (100 pM) for 1 hour. While the antibody/antigen complexes were incubated, PAC1-R expressing PC-12 cells (Japanese Collection of Research Bioresources Cell Bank) were washed and re-suspended at 2×10^6 cells per ml in cell culture media. Cells (10 μ l) and antigen/antibody complex (40 μ l) were transferred to an HTRF plate and shaken at room

temperature for 30 minutes. Following the incubation, 20 μ l of (1:20 diluted) Eu³⁺ cryptate-labeled mAb anti-cAMP and 20 μ l of (1:20 diluted) d2-labeled cAMP in lysis buffer were added, and the plate was incubated for 1 hour while shaking. Following incubation, plates were read (excitation 330 nm, emission 620/665 nm), and a ratio of 620:665 signal was determined. The final concentration of PACAP38 and PACAP27 in each well was 0.1 nM.

[0361] Inhibition curves were obtained for Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23. The inhibition results were quantified for each antibody to yield an IC₅₀ value, which are summarized in Table 2 below. These results demonstrated that anti-PACAP antibodies Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 inhibited PACAP38-induced cAMP increase in cells expressing PAC1-R. Additionally, these results demonstrated that anti-PACAP antibodies Ab10, Ab20, Ab21, Ab1.H, Ab10.H, and Ab21.H, but not Ab22 or Ab23, inhibited PACAP27-induced cAMP increase in cells expressing PAC1-R.

TABLE 2

Inhibition (IC₅₀) of PACAP38-induced and PACAP27-induced cAMP increase in cells expressing PAC1-R by anti-PACAP antibodies

ANTIBODY	Inhibition of 0.1 nM PACAP38-induced PAC1-R mediated cAMP increase IC ₅₀ (pM)	Inhibition of 0.1 nM PACAP27-induced PAC1-R mediated cAMP increase IC ₅₀ (pM)
Ab10	180.3	227.0
Ab20	368.2	187.8
Ab21	239.1	140.2
Ab1.H	259.6	57.7
Ab10.H	163.4	84.0
Ab21.H	246.0	203.6
Ab22	101.4	n/a *
Ab23	114.9	n/a *

* n/a: not active because these Abs are PACAP38 specific

Example 2: Binding Affinities of anti-PACAP Antibodies

[0362] Binding affinities of monoclonal antibodies for human PACAP were estimated using SPR on the PROTEON™ XPR36 (Bio-Rad, Hercules, CA). Antibody was immobilized to the surface of general amine coupling (“GLC” or “GLM”) Chips (Bio-Rad, Hercules, CA). A dilution series of human PACAP38 (SEQ ID NO: 1241) prepared in 1 x PBST Buffer (4.3 mM Na Phosphate, 1.4 mM K Phosphate, 135 mM NaCl, 2.7 mM KCl 0.05% Polysorbate-20) purchased from Teknova (Cat# P1192, Teknova, Hollister, CA) and supplemented with 0.25 M arginine (from J.T. BAKER®), 0.2mg/ml BSA (Jackson Immuno Research Labs, West Grove, PA), and 0.005% sodium azide (VWR International, Radnor, PA) with the pH adjusted to 7 was used to query the antibodies. Antigen (ranging from 1.23 nM to 100 nM) was typically run sequentially with association times of 2-4 minutes and dissociation times of 3-120 minutes grouped with the PROTEON™ Manager Software (v3.1.0.6 (Bio-Rad, Hercules, CA)) and fitted using a 1:1 Langmuir binding model. Surfaces were regenerated between analyte queries using 0.85% Phosphoric Acid. A single K_D was calculated for each antibody with association times limited near the rate of diffusion (1.0×10^6) and dissociation times limited to 1.5×10^5 where no discernible dissociation was observed.

[0363] The same procedure was used to determine binding affinities of antibodies for human VIP (SEQ ID NO: 1243) and PACAP27 (SEQ ID NO: 1242) though peptide concentrations ranged from 1.23 nM to 1000 nM with association times of 200 seconds and dissociation times of 3-120 minutes.

[0364] The measured antibody affinities for PACAP38 are listed in Table 3.

TABLE 3

Antibody affinity constants for PACAP38

Antibody	k_a (1/Ms)	k_d (1/s)	K_D (M)
Ab10	2.6E+05	2.0E-05	7.5E-11
Ab20	1.2E+05	2.4E-05	2.1E-10
Ab21	3.7E+05	1.0E-05	2.7E-11
Ab22	3.7E+05	1.0E-05	2.7E-11
Ab23	5.1E+05	3.6E-05	7.1E-11
Ab1.H	4.7E+05	1.0E-05	2.1E-11
Ab10.H	3.4E+05	1.0E-05	2.9E-11
Ab21.H	4.8E+05	1.0E-05	2.1E-11

[0365] Examples of antibody affinity constants for VIP are listed in Table 4.

TABLE 4

Antibody affinity constants for VIP

Antibody	k_a (1/Ms)	k_d (1/s)	K_D (M)
Ab10	3.7E+04	1.0E-02	2.8E-07
Ab20	4.5E+05	4.8E-01	1.1E-06
Ab21	1.7E+03	5.4E-04	3.1E-07
Ab22	2.7E+05	1.8E-01	6.9E-07
Ab23	4.3E+05	3.2E-01	7.3E-07
Ab1.H	3.8E+04	1.8E-01	4.8E-06
Ab10.H	3.8E+05	3.9E-02	1.0E-07
Ab21.H	1.4E+05	5.9E-02	4.4E-07

[0366] Examples of antibody affinity constants for PACAP27 are listed in Table 5.

TABLE 5

Antibody affinity constants for PACAP27

Antibody	k_a (1/Ms)	k_d (1/s)	K_D (M)
Ab10	1.0E+06	1.0E-05	1.0E-11
Ab20	3.2E+05	2.2E-05	7.0E-11
Ab21	7.9E+05	1.0E-05	1.3E-11
Ab22	1.0E+00	1.0E-01	1.0E-01
Ab23	8.9E+05	3.1E-02	3.5E-08
Ab1.H	7.6E+05	1.0E-05	1.3E-11
Ab10.H	5.3E+05	1.8E-05	3.3E-11
Ab21.H	6.3E+05	1.0E-05	1.6E-11

[0367] The binding affinity results of Tables 3 and 5 present data demonstrating that Ab23 weakly bound to PACAP27 as compared to its binding affinity for PACAP38. Tables 3 and 5 additionally present data demonstrating that Ab22 did not specifically recognize PACAP27, but that Ab22 specifically bound to PACAP38.

Example 3: Inhibition of PACAP38-Induced Signaling via VPAC1-R

[0368] To identify antibodies that neutralize PACAP38-induced signaling via human VPAC1-R, CHO-K1 cells expressing human VPAC1-R were used in a cAMP HTRF cell-based assay. Antibody dilutions were incubated with PACAP38 at 4x the final concentration (5 nM) for 1 hour. While the antibody/antigen complexes were incubated for 1 hour, VPAC1-R expressing CHO-K1 cells (generated at Alder Biopharmaceuticals, by stable transfection of CHO-K1 cells (ATCC, catalog # CCL-61) with human VPAC1-R cDNA; selected clone 1 was used for *in vitro* cell based assays) were detached with 0.25% trypsin for 4 minutes. The cells were washed and re-suspended at 1×10^6 cells per ml culture media. 20 μ l of Ab/antigen mixture was mixed with 20 μ l of cells in HTRF plates and incubated with shaking for 30 minutes. 20 μ l of Eu^{3+} cryptate labeled anti-cAMP mAb (1:20 diluted) and 20 μ l of (1:20 diluted) d2-labeled cAMP in lysis buffer were added to each well and incubated for 1 hour with shaking. The final concentration of PACAP38 in each well was 5 nM. Following incubation, plates were read (excitation 330 nm, emission 620/665 nm), and a ratio of 620:665 signal was determined.

[0369] Inhibition curves were obtained for Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23. The computed IC_{50} values for each antibody, which are shown below in Table 6, demonstrated that Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 inhibited PACAP38-induced cAMP increase in cells expressing human VPAC1-R.

TABLE 6

Inhibition (IC_{50}) of PACAP38-induced cAMP increase in cells expressing human VPAC1-R by anti-PACAP antibodies

ANTIBODY	Inhibition of 5 nM PACAP38-induced human VPAC1-R mediated cAMP increase IC_{50} (pM)
Ab10	649.1
Ab20	3889.0
Ab21	2846.0
Ab1.H	1021.1

Ab10.H	1336.0
Ab21.H	2105.0
Ab22	1300.0
Ab23	2667.0

Example 4: Inhibition of PACAP38-Induced Signaling via VPAC2-R

[0370] To identify antibodies that neutralize PACAP38-induced signaling via human VPAC2-R, CHO-K1 cells expressing human VPAC2-R were used in a cAMP HTRF cell based assay. Antibody dilutions were incubated with PACAP38 at 4x the final concentration (1 nM) for 1 hr. While the antibody/antigen complexes were incubated for 1 hour, VPAC2-R expressing CHO-K1 cells (generated at Alder Biopharmaceuticals, by stable transfection of CHO-K1 cells (ATCC, catalog # CCL-61) with human VPAC2-R cDNA; selected clone 8 was used for *in vitro* cell based assays) were detached with 0.25% trypsin for 4 minutes. The cells were washed and re-suspended at 1×10^6 cells per ml culture media. 20 μ l of Ab/antigen mixture was mixed with 20 μ l of cells in HTRF plates and incubated with shaking for 30 minutes. 20 μ l of Eu^{3+} cryptate labeled anti-cAMP mAb (1:20 diluted) and 20 μ l of (1:20 diluted) d2-labeled cAMP in lysis buffer were added to each well and incubated for 1 hour with shaking. The final concentration of PACAP38 in the wells was 1 nM. Following incubation, plates were read (excitation 330 nm, emission 620/665 nm) and, a ratio of 620:665 signal was determined.

[0371] Inhibition curves were obtained using this method for Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 respectively). The computed IC_{50} values for each antibody, which are shown below in Table 7, demonstrated that Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 inhibited PACAP38-induced cAMP increase in cells expressing human VPAC2-R.

TABLE 7

Inhibition (IC_{50}) of PACAP38-induced cAMP increase in cells expressing human VPAC2-R by anti-PACAP antibodies

ANTIBODY	Inhibition of 1 nM PACAP38-induced human VPAC2-R mediated cAMP increase IC_{50} (pM)
Ab10	188.5
Ab20	14570.0
Ab21	5215.0
Ab1.H	983.0
Ab10.H	988.0
Ab21.H	1507.0
Ab22	515.0
Ab23	1789.0

Example 5: Inhibition of PACAP38 Binding to PAC1-R-Expressing Cells

[0372] To identify antibodies that block PACAP38 binding to PAC1-R-expressing cells, adherent PC-12 cells (ATCC, Manassas, VA) expressing PAC1-R were used in a Europium-based PAC1-R-expressing cells binding assay. Antibody solutions were incubated with N-terminal biotinylated PACAP38 at 10x the final concentration (100 nM or 30 nM) for 1 hr, then added to PC-12 cells that were plated 24 hrs prior in black clear bottom 96 well plates (COSTAR™, Corning Incorporated, Corning, NY) and further incubated for 1 hr at room temperature. After three washes, the cells were incubated with 20 μ l Europium-labeled streptavidin (PerkinElmer, Waltham, MA) for 1 hr at room temperature. Cells were washed three times, then 20 μ l DELFIA® Enhancement solution (PerkinElmer, Waltham, MA) was added to each well and incubated for 15 minutes with gentle shaking. Plates were read (Time Resolved Fluorescence ("TRF")) on SPECTRAMAX® (Molecular Devices, Sunnyvale, CA) plate reader.

[0373] Inhibition curves were obtained using this method for Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 wherein the PAC1-R expressing cells were PC-12 cells. The computed IC_{50} values for each antibody, which are shown below in Table 8,

demonstrated that Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 inhibited PACAP38 binding to PAC1-R expressing PC-12 cells.

TABLE 8

Inhibition (IC_{50}) of PACAP38 binding to PAC1-R-expressing PC-12 cells by anti-PACAP antibodies

ANTIBODY	Inhibition of 100 nM biotinylated PACAP38 binding to PAC1-R-expressing PC-12 cells IC_{50} (nM)
Ab10	17.8
Ab20	32.7

ANTIBODY	Inhibition of 30 nM Biotinylated PACAP38 binding to PAC1-R-expressing PC-12 cells IC_{50} (nM)
Ab21	20.3
Ab1.H	56.3
Ab10.H	14.5
Ab21.H	12.7
Ab22	13.8
Ab23	14.9

Example 6: PACAP38-mediated binding of anti-PACAP Antibodies to the Cell Surface of PAC1-R-Expressing Cells

[0374] To identify anti-PACAP antibodies that bind, via PACAP38, to the cell surface of PAC1-R expressing cells, adherent PC-12 cells (Japanese Collection of Research

Bioresources Cell Bank) expressing PAC1-R were used in a cell surface binding-based assay. To perform the binding experiment, PAC1-R expressing PC-12 cells were first seeded into Corning 96 well white solid bottom plates (Corning, Corning, NY). Cells were initially seeded at 1×10^5 cells/well in a solution of complete RPMI ("cRPMI": RPMI medium supplemented with 10% sterile heat-inactivated FBS and 1% sterile antibiotic/antimycotic) + 10% FBS, and the plates were allowed to incubate overnight at 37°C. On the day of the binding assay, antibodies at an initial concentration of 15 µg/ml were diluted at a 1:3 ratio in DELFIA® binding buffer (50 mM Tris, 150 mM NaCl, 0.1% azide, 2% horse serum) (Perkin-Elmer, Waltham, MA) to a total volume of 60 µL in a separate 96 well round bottom plate. PACAP38 was prepared for the binding assay by diluting it in DELFIA® binding buffer to a concentration of 200 nM, and then 60 µl of the diluted PACAP38 was added to each of the antibody-containing wells to form antibody:antigen complexes. Following addition of PACAP38, the antibody:antigen complexes were incubated at room temperature on a shaker for 1 hour. Separately, the PC-12 cells were prepared for addition of antibody:antigen complexes by washing the cells two times with DELFIA® wash buffer (50 mM Tris, 150 mM NaCl, 0.1 % Azide) (Perkin-Elmer, Waltham, MA). After washing the cells two times and following the 1 hour room temperature incubation of the antibody:antigen complexes, 50 µl of the antibody:antigen complex was added to each well containing cells. The mixtures of cells and antibody:antigen complexes were then incubated for 30 minutes at room temperature. Following this 30 minute incubation, each mixture was washed two times with DELFIA® wash buffer (Perkin-Elmer, Waltham, MA).

[0375] DELFIA® Europium labeled anti-human IgG detection reagent (Cat # 1244-330, Perkin-Elmer, Waltham, MA) was diluted to a concentration of 300 ng/ml in DELFIA® Binding Buffer. Following dilution, 50 µl of the anti-human IgG detection reagent was added to each well containing cells, and a 30 minute incubation at room temperature followed this addition of IgG detection reagent. After completion of the 30 minute room temperature incubation, the cells were then washed two times with DELFIA® wash buffer. Next, 50 µl of DELFIA® Enhancement Solution (Cat # 1244-105, Perkin-Elmer, Waltham, MA) was added to each well containing cells for a final 15 minute room temperature incubation with shaking. The plates were then read (TRF, excitation 330nm, emission 620nm) on a SPECTRAMAX® (Molecular Devices, Sunnyvale, CA) plate reader.

[0376] FIGS. 19A-H are representative of the binding curves obtained by this method (results are shown for Ab10, Ab20, Ab21, Ab1.H, Ab10.H, Ab21.H, Ab22, and Ab23 respectively) wherein the PAC1-R expressing cells were PC-12 cells. Ab1.H demonstrated

binding to the surface of PAC1-R expressing cells in the presence of PACAP38, while Ab20, Ab21, Ab10.H, Ab21.H, Ab22, and Ab23 did not appear to appreciably bind to the surface of PAC1-R expressing cells using this assay. The binding of Ab1.H to the cell surface of PAC1-R cells was only observed in the presence of PACAP38. Without intent to be bound by theory, it is hypothesized that the binding of the antibodies to the cell surface was mediated by binding of PACAP38 to GAGs that were present on the cell surface, since binding of PACAP38 by GAGs has been previously demonstrated as a PAC1-R receptor independent mechanism of PACAP38 binding and internalization by PC-12 cells (see Doan et al., 2012; Juhász et al., 2014; and Neree et al., 2015).

Example 7: Inhibition of PACAP38-induced Dermal Vasodilation in Rabbits by Anti-PACAP Antibody Ab1.H

[0377] Intradermal injection of PACAP38 has been shown to elicit a localized vasodilation in rabbits and humans (Warren et al., *J. Cardio. Pharmacol.*, 29(1): 83-87, 1992; Seelinger et al., *Am. J. Path.*, 177(5):2563-2575, 2010). An *in vivo* efficacy study was conducted to determine the activity of Ab1.H to inhibit a localized dermal vasodilation induced by an intradermal injection of PACAP38 in male New Zealand White rabbits.

[0378] Groups of 4 rabbits were dosed with either 90 mg/kg of Ab1.H or with negative control vehicle (25 mM histidine, 250 mM sorbitol, pH 6.0). Injections were performed by IV (ear vein) bolus administration on day 0. Prior to each rabbit PACAP38 challenge, the scapular region of each animal was clipped free of hair and wiped with 20% (v/v) alcohol in water. On day 2, the animals were pre-anesthetized with ketamine hydrochloride and maintained under deep anesthesia with isoflurane gas. Four sites (Region of Interest ("ROI")) for injection were identified on the back of each animal using a SHARPIE® permanent marker. Dermal vasodilation and blood perfusion were monitored using the PeriCam PSI NR system for Laser Speckle Contrast Analysis ("LASCA") imaging (Perimed, Järfälla, Sweden), before (baseline) and for 35 minutes after intradermal PACAP38 challenge. Intradermal PACAP38 challenge was performed as follows: each animal received single intradermal administrations (100 µl/site) of vehicle (one site or ROI) and PACAP38 at 30 pmoles/site (3 sites or 3 ROIs). The blood perfusion rates for each ROI were reported by the PeriCam PSI NR system in Perfusion units ("PU") and analyzed using PIMSoft (Ver. 1.5, Perimed, Järfälla, Sweden).

[0379] For each treatment group, the relative %PU change following Ab1.H or negative control administration compared to baseline was calculated for each ROI (%PU change for

each PACAP38 challenge site - %PU change for the vehicle site). The relative %PU change in the Ab1.H group was compared to the relative %PU change in the Negative control group by performing a two-tailed unpaired t-test statistical evaluation using GraphPad Prism (version 5.0d, GraphPad Software, La Jolla, CA) software.

[0380] FIG. 13 demonstrates that Ab1.H inhibited PACAP38-induced dermal vasodilation in rabbits, indicating effectiveness of the antibody at neutralizing PACAP38 activity *in vivo*.

Example 8: Inhibition of PACAP38-induced Dermal Vasodilation in Rabbits by Anti-PACAP Antibody Ab10

[0381] Intradermal injection of PACAP38 has been shown to elicit a localized vasodilation in rabbits and humans (Warren et al., 1992; and Seelinger et al., 2010). An *in vivo* efficacy study was conducted to determine the activity of Ab10 to inhibit a localized dermal vasodilation induced by an intradermal injection of PACAP38 in male New Zealand White rabbits.

[0382] Groups of 4 rabbits were dosed with either 72 mg/kg of Ab10 or with isotype antibody control. Injections were by (ear vein) bolus intravenous administration on day 0. Prior to each rabbit PACAP38 challenge, the scapular region of each animal was clipped free of hair and wiped with 20% (v/v) alcohol in water. On day 2, the animals were pre-anesthetized with ketamine hydrochloride and maintained under deep anesthesia with isoflurane gas. Four sites (ROIs) for injection were identified on the back of each animal using a SHARPIE® permanent marker. Dermal vasodilation and blood perfusion were monitored using the PeriCam PSI NR system for LASCA imaging (Perimed, Järfälla, Sweden), before (baseline) and for 35 minutes after intradermal PACAP38 challenge. Intradermal PACAP38 challenge was performed as follows: each animal received single intradermal administrations (100 µl/site) of vehicle (one site or ROI) and PACAP38 at 30 pmoles/site (3 sites or 3 ROIs). The blood perfusion rates for each ROI were reported by the PeriCam PSI NR system in PU and analyzed using PIMSoft (Ver. 1.5 (Perimed, Järfälla, Sweden)).

[0383] For each treatment group, the relative %PU change following Ab10 or Isotype Ab control administration compared to baseline was calculated for each ROI (%PU change for each PACAP38 challenge site - %PU change for the vehicle site). The relative %PU change in the Ab10 group was compared to the relative %PU change in the Isotype Ab control group by performing a two-tailed unpaired t-test statistical evaluation using GraphPad Prism (version 5.0d, GraphPad Software, La Jolla, CA) software.

[0384] FIG. 14 demonstrates that Ab10 inhibited PACAP38-induced dermal vasodilation in rabbits, indicating effectiveness of the antibody at neutralizing PACAP38 activity *in vivo*.

Example 9: Epitope Binning of Anti-PACAP Antibodies, Ab1 and Ab10

[0385] Ab1 was biotinylated at a 10:1 molar ratio with biotin (Thermo Fisher Scientific, Waltham, MA) per manufacturer guidelines. A 5 step biolayer interferometry experiment was performed as follows: In step 1, streptavidin biosensors (Pall ForteBio LLC, Menlo Park, CA) were equilibrated for 50 seconds in 1x kinetics buffer (a 1:10 dilution in DBS of Pall ForteBio LLC, Menlo Park, CA, cat# 18-5032). In step 2, a 2 μ g/ml dilution of biotinylated antibody Ab1 in 1x kinetics buffer was immobilized for 500 seconds onto Streptavidin biosensors. In step 3, the antibody-functionalized biosensors were incubated in a solution of 2 μ M unlabeled PACAP peptide (American Peptide Company, Sunnyvale, CA, catalog # 34-0-20) in 1x kinetics buffer for 200 seconds. In step 4, the sensors were placed into 67 nM solutions of either unlabeled antibody Ab10 (FIG. 15A) or unlabeled antibody Ab1 as control (FIG. 15B) in 1x kinetics buffer for a 1000 second association step. Stability of binding was monitored during step 5 for a 1000 second dissociation in 1x kinetics buffer. In FIG. 15A, the "sandwich-style" capture of Ab10 via Ab1-captured PACAP indicates simultaneous and non-competitive binding of these two antibodies to PACAP. The control experiment in FIG. 15B shows minimal "sandwich-style" capture of Ab1 via Ab1-captured PACAP. The experiment was conducted on a ForteBio OCTET® QK instrument (Pall ForteBio LLC, Menlo Park, CA) at 30°C and 1000 RPM.

Example 10: Inhibition of PACAP27 Binding to human PAC1-R by anti-PACAP Antibodies

[0386] To identify antibodies that block PACAP27 binding to PAC1-R, antibodies at an initial concentration of 30 nM were diluted in incubation buffer (50 mM HEPES pH 7.4, 1 mM CaCl₂, 5 mM MgCl₂, 0.2% BSA) and serial 1:3 dilutions were performed. Antibody dilutions (30 nM, 10 nM, 3 nM, 1 nM, 0.3 nM, 0.1 nM, 0.03 nM, 0.01 nM, 0.003 nM and 0.001 nM) were then mixed and pre-incubated at 25°C for 30 minutes with 0.1 nM of ¹²⁵I-labelled PACAP27 in incubation buffer. The antibody: ¹²⁵I-labelled PACAP27 mixture was then added to 0.5 μ g aliquots of cell membranes derived from Chem-1 cells expressing human recombinant PAC1-R long isoform in incubation buffer. The mixture was then incubated for 1 hour at 25°C. Following incubation, the samples were filtered and washed. Afterward, the filters were counted to quantitate ¹²⁵I-labelled PACAP27. As an experimental control, non-specific binding to the cell membranes was estimated using 0.1 μ M of labeled PACAP27.

The results indicated that Ab1.H, Ab10.H, and Ab21.H were capable of blocking PACAP27 binding to PAC1-R, thereby demonstrating inhibition of ligand-receptor binding by the tested antibodies presented in Table 9.

Table 9

Inhibition (IC₅₀) of 0.1 nM ¹²⁵I-PACAP27 binding to PAC1-R by anti-PACAP antibodies

ANTIBODY	IC ₅₀ (nM)
Ab1.H	0.70
Ab10.H	0.22
Ab21.H	0.39

Example 11: Effect of anti-PACAP Antibody on Light Aversion

[0387] To examine the effect of anti-PACAP antibodies on photophobia, a mouse model was employed in which mice were administered PACAP to trigger photophobia. Photophobia was detected using a light aversion assay using a light-dark box as described in Kaiser et al., *J. Neurosci.*, 32(44):15439-15449, 2012. Mice were then administered anti-PACAP antibodies Ab1.H or Ab10.H or an unrelated control antibody and their aversion to light quantitated. Results are reflected in FIGS. 16-18.

Light Aversion Assay

[0388] As described in Kaiser et al., the testing chambers were a plexiglas open field (27 cm wide × 27 cm deep × 20.3 cm high) containing three sets of 16 beam infrared arrays (two sets of perpendicular beams cross at a height of 1.0 cm to detect mouse location and locomotion, and the third beam crosses the width of the chamber at a height of 7.3 cm to detect vertical activity). The field was divided in two equal sized zones by a dark insert, which is a five-sided, black-colored plexiglas box with a top, but no floor. The use of infrared light beams allowed tracking in both zones. An opening (5.2 cm × 6.8 cm) in the dark insert allowed free movement between zones. While the dark insert blocked direct light, some light could still enter through the opening. Each testing chamber was located inside a sound-attenuating cubicle (56 cm wide × 38 cm deep × 36 cm high) with a fan for ventilation (Med Associates,

Inc.®, St. Albans, VT). A computer using Activity Monitor v6.02 (Med Associated Inc.) was used for recording data from the six chambers.

[0389] For each chamber, a LED panel was attached to the ceiling of the sound-attenuating cubicle. The LED panel contains 36 collimated 1 watt LEDs (5500k Daylight White) (LEDwholesalers.com, Burlingame, CA). To control light intensity, each LED panel was connected to a dimmable LED driver (LINEARdrive®; eldoLED America Inc., San Jose, CA) leading to a potential range of light intensity from 3.0×10^2 to 2.7×10^4 lx. Levels were further attenuated to 5.5×10^1 lx using wax paper placed on a clear plexiglass tray below the LEDs. Light intensity was measured with Traceable Dual-Display Light Meter (Control Company, Friendswood, TX) placed on the floor of the testing chamber. At 2.7×10^4 lx, LED lights generated some heat in the sound attenuating chamber with the dark zone at ~ 25 °C and light zone at ~ 27 °C.

[0390] On the day of the experiment, mice were transported from animal housing and allowed to acclimate to the testing room (~ 22 °C) for at least 30 to 60 minutes with standard overhead fluorescent lighting (~ 200 lx inside the housing cage). Room lights remained on, unless noted otherwise. In addition, all sound-generating equipment were turned on during acclimation and remained on until testing was complete. There was minimal human presence in the room during acclimation. Behavioral testing was performed between 0800 CST and 1400 CST. Any abnormal physical conditions (e.g. missing eye) were noted.

[0391] Ten week old male and female CD1 mice were used in the study (strain #022, Charles River, Wilmington, MA, US). Mice were allowed to recover from shipping for one to two weeks prior to testing.

Acclimation

[0392] All mice were acclimated in the testing room at least 30 to 60 minutes prior to being placed in the light/dark chamber. The light intensity in the chamber was initially set to 2.7×10^3 lx. The mice were tested for thirty minutes in the chamber every day they were exposed to the light/dark chamber. Baseline time in light for each mouse was obtained by exposing the mice to the light/dark chamber twice, with a period of rest of three days between baseline measurements (FIGS. 16 and 18, "Baseline1" and "Baseline2," or "Baseline", respectively).

Treatment

[0393] The mice were administered 30 mg/kg of either anti-PACAP antibody or control IgG antibody (negative control antibody having the same framework as the tested antibodies and

that recognizes digoxigenin) by i.p. injection. The mice were then returned to their home cage to rest for one day (24 hours) prior to testing. The mice were then administered 0.6 mg/kg PACAP or vehicle by i.p. injection and rested for 30 minutes. The mice were then placed in the light/dark chamber for 30 minutes (FIG. 16 and FIG. 18, "Treatment"). After each mouse was exposed to the light/dark chamber, the light/dark chamber and components were cleaned with germicidal wipes and dried. About 5 to 7 minutes after a mouse was placed in the light/dark chamber, the next mouse to be tested was injected with PACAP or vehicle, as described above. This interval was approximately the amount of time required to clean the light/dark chamber between experiments.

Motility Measurements

[0394] Motility was measured at 5 minute intervals over the 30 minute testing period as described in Kaiser et al., *J. Neurosci.*, 2012. Briefly, the number of vertical movements, such as rearing, ambulatory distance (cm, the total distance traveled during ambulatory movement status), transitions, and resting (percentage of time spent breaking no new beams), were measured by light beam. All motility parameters were normalized to the time spent in each zone to account for different amount of time spent in that zone; thus, the raw value for each parameter was divided by the time spent in that zone during the 5 min interval. Time spent in each chamber was analyzed using GraphPad Prism software (GraphPad Software, San Diego, CA), and reported as mean \pm standard error of the mean ("SEM"). Comparison was calculated by two-way repeated measure ANOVA, with Bonferroni's multiple-comparison test for post-hoc analysis.

[0395] Mice were excluded based on three criteria: (1) after the first two exposures to the box the baseline time in light was analyzed and any mouse that spent +/- one standard deviation of mean time in light at baseline was removed from the experiment and not given drug treatment, (2) mice were excluded from analysis if they were identified as statistical outliers (box plot, 10-90%), and (3) mice were excluded if they moved less than 10% of the time (combined light and dark).

[0396] In two experiments comparing the response of mice administered either antibody Ab1.H or Ab10.H to control IgG, the results indicate that mice administered either PACAP antibody Ab1.H or Ab10.H spent more time in light as compared to IgG control mice. FIG. 16 shows that mice behaved normally and similarly in both baseline measurements. On the other hand, the data provided in FIG. 16 show that mice treated with control IgG antibody and then PACAP spent statistically less time in light (squares) than mice administered anti-

PACAP antibody Ab1.H and then PACAP (circles). (See, FIG. 16, "Treatment"). The data provided in FIG. 18 also show that mice behaved normally and similarly in baseline measurements. On the other hand, the data provided in FIG. 18 show that mice treated with control IgG antibody and then PACAP spent statistically less time in light (triangles) than mice administered anti-PACAP antibody Ab10.H and then PACAP (inverted triangles). (See, FIG. 18, "Treatment"). Time between each measurement was three days. The mean \pm SEM is provided for each 5-minute interval. Mice administered vehicle only behaved as normal controls. Data provided in FIG. 17 shows that administration of either anti-PACAP antibody Ab1.H, or control IgG, and vehicle ("Veh + PAC Ab" and "Veh + Con Ab," respectively) did not markedly alter mouse behavior. FIG. 17 also shows that the average time of the mouse in light decreased when PACAP and control IgG were administered ("PACAP + Con Ab"), whereas mice administered anti-PACAP antibody Ab1.H and PACAP exhibited normal, non-light-sensitive behavior ("PACAP + PAC Ab").

Example 12: Epitope Mapping of Anti-PACAP Antibodies

[0397] In order to determine the epitopes contained within PACAP to which the anti-PACAP antibodies and antigen binding fragments thereof of the invention bind, alanine scanning experiments were used. To perform these experiments, PACAP peptides were synthesized with a single point mutation in each position replacing the native amino acid with an Alanine ("Ala"), and the consequences of a single point mutation as it relates to binding affinity of PACAP and an antibody were measured. Since an alanine residue already occupies positions 18, 24, and 25 of wild-type PACAP, according to convention, these Ala residues were replaced with Valine ("Val") to determine the possible effects of the removal of the alanine at these positions on the binding of the subject anti-PACAP antibodies to PACAP. Per the usual convention these Ala mutants were labeled according to the position in PACAP 1-38 followed by the letter code for the substituted amino acid, e.g., 10A indicates PACAP 1-38 substituted with alanine at amino acid position 10. Binding of monoclonal antibodies for human PACAP and each mutant peptide was detected using SPR on the PROTEON™ XRP36 (Bio-Rad Laboratories, Hercules, CA). Samples and sample controls were immobilized onto a PROTEON™ GLC sensor chip (Bio-Rad Laboratories, Hercules, CA) at a single density using standard amine coupling. The running buffer used for immobilization was DPBS/modified (HYCLONE™, GE Healthcare Life Sciences, Marlborough, MA) and immobilization was conducted at 25°C. The PROTEON™ GLC sensor chip (Bio-Rad Laboratories, Hercules, CA) was initialized and pre-conditioned per the manufacturer's

protocol (bi-directional injections of 0.5% SDS, 50 mM NaOH, 100 mM HCl). The immobilization process was performed step-wise to ensure a unique antibody on the spots of the PROTEON™ Chip (Bio-Rad Laboratories, Hercules, CA). The surface of the chip was activated with a 1:1 mixture of 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide/N-hydroxysuccinimide (“EDAC/NHS”) and flow rate of 30 μ L/min x 5 minutes. Antibody samples were previously dialyzed or exchanged to 10 mM HEPES 150 mM NaCl pH 7.2, and the antibody concentration was quantified using a NANODROP™2000 spectrophotometer (Thermo Fisher Scientific, Waltham, MA). The immobilization targeted 2000-3000 response units (“RU”). Antibody samples (5 μ g/ml) in 10 mM sodium acetate, pH 5.5, were flowed at 30 μ L/min x 4 minutes. Deactivation was achieved at a flow rate of 30 μ L/min for 5 minutes using 0.3 M ethanolamine concomitantly with the next activation.

[0398] Following immobilization, the running buffer was changed to 1x PBST (4.3 mM sodium phosphate, 1.4 mM potassium phosphate, 135 mM NaCl, 2.7 mM KCl, 0.05% TWEEN®) with 0.2 M arginine HCl (to reduce non-specific binding), BSA (0.2 mg/ml, as a carrier) and PROCLIN300® (0.005% as a preservative, Sigma Aldrich, St. Louis, MO) and the chip surface was allowed to re-equilibrate with an injection of new running buffer. Stock solutions of human PACAP peptide (1-38) and alanine/valine mutant peptides (Molecular Weight(s): 4.5 kD) at a concentration of 1 mg/ml were added to the running buffer to final concentrations of 0.45 μ g/ml (100 nM). These mixtures were then used to query individual spots on the chip surface with flow rates of 100 μ L/min x 2 minutes and allowed to dissociate for 600 seconds. Chip surfaces were regenerated between analytes by the addition of 0.85% phosphoric acid. Each of antibodies Ab10, Ab20, Ab21, Ab22, and Ab23 were examined under the same conditions as herein described.

[0399] Sensorgrams representing affinity data of mutant peptide binding to a panel of antibodies were assessed using multiple parameters. A visual inspection was first performed for each sensorgram to assess apparent maximal response (“R_{max}”) relative to the wild-type PACAP peptide (1-38). Second, a visual inspection of the dissociation phase was performed with an emphasis on the curve shape relative to the wild-type PACAP peptide. Off-rates (dissociation rates) were calculated for wild-type PACAP peptide and the binding of each mutant peptide to the panel of antibodies. Finally, as a control experiment to confirm the integrity of each peptide variant (wild-type or mutant), the binding affinity of each member of the peptide library was individually determined for each member of a panel of antibodies that were known to bind wild-type PACAP, to ensure that each Ala mutant PACAP peptide exhibited binding affinity that was similar to the binding affinity of wild-type PACAP

peptide. Collective assessment of all described parameters identified PACAP amino acid residues important for PACAP/antibody binding.

[0400] Binding and dissociation data were obtained for binding of antibodies Ab10, Ab20, Ab21, Ab22, and Ab23 to wild-type PACAP and PACAP mutants.

[0401] The PACAP residue positions contributing most to antibody binding were interpreted to jointly comprise the epitopes bound by each antibody. Based on data obtained in these alanine scanning studies, the epitopes bound by each antibody were concluded to comprise the following residues:

- (i) Ab10: residues 19, 22, 23, and 27 of human PACAP.
- (ii) Ab20: residues 19, 22, 23, 24, and 27 of human PACAP.
- (iii) Ab21: residues 19, 22, 23, and 27 of human PACAP.
- (iv) Ab22: residues 22, 23, 27, 28, and 31 of human PACAP.
- (v) Ab23: residues 12, 20, 23, 24, 26, 27, and 28 of human PACAP.

[0402] It was further noted based on the alanine scanning experimental results that the affinity of each of antibodies Ab10, Ab20, Ab21, Ab22, and Ab23 for PACAP involves or depends on residues 19, 22, 23, and/or 27 of human PACAP.

[0403] Additionally, it was observed that the affinity of each of antibodies Ab22 and Ab23 to PACAP involves or requires specific amino acid residues that are present in human wild-type PACAP38, but which are not present in human wild-type PACAP27, e.g., residues 28 and 31 of PACAP38.

[0404] With respect to the foregoing alanine scanning results humanized variants of the subject anti-PACAP antibodies should interact with the identical or substantially identical residues of human PACAP as humanization should not appreciably impact the specificity of the binding of the humanized anti-PACAP antibody to human PACAP compared to the parent (unhumanized) antibody. Particularly, Ab10.H should interact with the same residues on human PACAP as Ab10, and Ab21.H should interact with the same residues on human PACAP as Ab21.

[0405] Antibodies which bind to the same or overlapping epitopes on human PACAP as the subject antibodies may be produced and identified using method described herein. It is reasonable to anticipate that antibodies which bind to the same or overlapping epitope as any of the antibodies identified herein will likely possess similar biological activity absent a meaningful difference in binding kinetics. Particularly, such antibodies should antagonize one or more of the biological effects elicited by PACAP analogously to the exemplified anti-PACAP antibodies which bind these epitopes. Additionally, antibodies that bind to these

same or overlapping epitopes, or a subset of residues thereof, are anticipated to mimic the binding characteristics of the subject antibodies. For example such antibodies are expected to selectively bind to PACAP and not bind or bind with much less affinity (weaker) to VIP or other peptides within this family of neuropeptides.

[0406] Having fully described and enabled the invention, the invention is further described by the claims that follow.

CLAIMS

What is claimed is:

1. A method of screening for an antibody or antigen binding fragment suitable for use in treating or preventing Pituitary Adenylate Cyclase-Activating Peptide (PACAP)-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, in a subject in need thereof, which comprises:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering PACAP to the at least one first test subject and the at least one second test subject;
- (iii) further administering to the at least one first test subject one or more anti-PACAP antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, or an antigen binding fragment of any of the foregoing;
- (iv) comparing the response of the at least one first test subject and at least one second test subject to light; and
- (v) based on this comparison, identifying one or more antibodies or antigen binding fragments thereof that yield a decreased light aversion or decreased photophobia in the at least one first test subject as compared with the at least one second test subject, thereby identifying an antibody or antigen binding fragment suitable for use in treating or preventing PACAP-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion in a subject in need thereof.

2. A method of screening for an antibody or antigen binding fragment thereof suitable for use in treating or preventing Pituitary Adenylate Cyclase-Activating Peptide (PACAP)-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, in a subject in need thereof, which comprises:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering to the at least one first test subject one or more anti-PACAP antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, preferably at least one

anti-PACAP antibody and/or at least one anti-PAC1-R antibody, or an antigen binding fragment of any of the foregoing;

(iii) administering PACAP to the at least one first test subject and the at least one second test subject;

(iv) comparing the response of the at least one first test subject and at least one second test subject to light; and

(v) based on this comparison, identifying antibodies or antigen binding fragments that yield decreased photophobia or decreased light aversion in the at least one first test subject as compared with the at least one second test subject, identifying an antibody or antigen binding fragment suitable for use in treating or preventing PACAP-associated photophobia or light aversion, or identifying an antibody or antigen binding fragment suitable for precluding the onset of PACAP-associated photophobia or light aversion, in a subject in need thereof.

3. The method of claim 1 or 2, wherein administering the one or more antibody or antigen binding fragments comprises administering one or more anti-PACAP antibodies or antigen binding fragments thereof, or administering one or more anti-PAC1-R antibodies or antigen binding fragments thereof.

4. The method of any one of the foregoing claims, wherein the efficacy of the one or more antibodies or antigen binding fragments for inhibiting PACAP-associated photophobia or light aversion, or precluding the onset of PACAP-associated photophobia or light aversion, is confirmed in a human subject.

5. The method of any of the foregoing claims, wherein the at least one first test subject and/or the at least one second test subject is a mammal.

6. The method of claim 5, wherein the at least one first test subject and/or at least one second test subject is (i) a mouse, monkey, rabbit, human, rat, guinea pig, dog, hamster, wherein optionally the monkey is a macaque, marmoset, tamarin, spider monkey, owl monkey, vervet monkey, squirrel monkey, or baboon; or (ii) wherein the at least one first test subject or at least one second test subject is a mouse, optionally a CD1 mouse.

7. The method of any of the foregoing claims, wherein the identified antibody or antigen binding fragment thereof specifically binds PACAP.

8. The method of any one of the foregoing claims, which further comprises adapting the identified antibody or antigen binding fragment for use in treating a subject who suffers from one or more of migraine, hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, secondary headaches due to an underlying structural

problem in the head or neck, cranial neuralgia, sinus headaches, allergy-induced headaches, headache, or other migraine condition.

9. The method of claim 8, wherein the subject has an ocular disorder associated with photophobia selected from one or more of achromatopsia, aniridia, photophobia caused by an anticholinergic drug, aphakia (absence of the lens of the eye), buphthalmos (abnormally narrow angle between the cornea and iris), cataracts, cone dystrophy, congenital abnormalities of the eye, viral conjunctivitis ("pink eye"), corneal abrasion, corneal dystrophy, corneal ulcer, disruption of the corneal epithelium, ectopia lentis, endophthalmitis, eye trauma caused by disease, injury, or infection such as chalazion, episcleritis, glaucoma, keratoconus, or optic nerve hypoplasia, hydrophthalmos, or congenital glaucoma Iritis, optic neuritis, pigment dispersion syndrome, pupillary dilation (naturally or chemically induced), retinal detachment, scarring of the cornea or sclera, and uveitis.

10. The method of claim 8, wherein the subject has a nervous-system-related or neurological condition associated with photophobia selected from one or more of autism spectrum disorders, chiari malformation, dyslexia, encephalitis including myalgic encephalomyelitis (chronic fatigue syndrome), meningitis, subarachnoid hemorrhage, tumor of the posterior cranial fossa, ankylosing spondylitis, albinism, ariboflavinosis, benzodiazepines (long term use of or withdrawal from benzodiazepines), chemotherapy, chikungunya infection, cystinosis, Ehlers-Danlos syndrome, hangover, influenza infection, infectious mononucleosis, magnesium deficiency, mercury poisoning, migraine, rabies, and tyrosinemia type II (Richner-Hanhart syndrome).

11. The method of claim 8, wherein the subject has a photophobia associated disorder selected from one or more of migraine (with or without aura), iritis, uveitis, meningitis, depression, bipolar disorder, cluster headache or another trigeminal autonomic cephalalgia or blepharospasm, depression, post-traumatic stress syndrome (PTSD) traumatic brain injury, and agoraphobia.

12. The method of any one of the foregoing claims, wherein the at least one first subject and/or at least one second subject suffers from migraine headaches.

13. The method of any of the foregoing claims, wherein the one or more antibodies or antigen binding fragments thereof are for use in combination with another active agent for treating migraine, or is for use as a monotherapy.

14. The method of any one of claims 1-13, wherein the anti-PACAP antibody or fragment thereof comprises: (a) an immunoglobulin variable heavy chain having the CDR1

sequence of SEQ ID NO: 404; a CDR2 sequence of SEQ ID NO: 406; and a CDR3 sequence of SEQ ID NO: 408; and/or an immunoglobulin variable light chain having the CDR1 sequence of SEQ ID NO: 424; a CDR2 sequence of SEQ ID NO: 426; and a CDR3 sequence of SEQ ID NO: 428; or

(b) an immunoglobulin variable heavy chain having the CDR1 sequence of SEQ ID NO: 444; a CDR2 sequence of SEQ ID NO: 446; and a CDR3 sequence of SEQ ID NO: 448; and/or an immunoglobulin variable light chain having the CDR1 sequence of SEQ ID NO: 464; a CDR2 sequence of SEQ ID NO: 466; and a CDR3 sequence of SEQ ID NO: 468.

15. The method of any one of the foregoing claims, wherein the anti-PACAP antibody or fragment thereof comprises: a light chain and/or a heavy chain, which has a framework (FR) region and one or more Complementary Determining Region(s) (CDR), and wherein one or more of the FR or CDR residues in the light chain and/or heavy chain is substituted with another amino acid residue.

16. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is a humanized antibody or fragment thereof.

17. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is a chimeric antibody or fragment thereof.

18. The method of any one of the foregoing claims, wherein the antibody or fragment thereof comprises a single chain antibody or fragment thereof.

19. The method of claim 17, wherein the chimeric antibody or fragment thereof comprises a human Fc, such as a human Fc is derived from IgG1, IgG2, IgG3, or IgG4.

20. The method of claim 14, wherein the anti-PACAP antibody or fragment thereof comprises a polypeptide sequence having at least 90% or greater homology to two of the polypeptide sequences recited therein.

21. The method of claim 14, wherein the anti-PACAP antibody or fragment thereof comprises a polypeptide sequence having at least 95% or greater homology to any one of the polypeptide sequences recited therein.

22. The method of any one of the foregoing claims, wherein the anti-PACAP antibody or fragment thereof binds to PACAP with a binding affinity (K_D) of less than or equal to 5×10^{-5} M, 10^{-5} M, 5×10^{-6} M, 10^{-6} M, 5×10^{-7} M, 10^{-7} M, 5×10^{-8} M, 10^{-8} M, 5×10^{-9} M, 10^{-9} M, 5×10^{-10} M, 10^{-10} M, 5×10^{-11} M, 10^{-11} M, 5×10^{-12} M, 10^{-12} M, 5×10^{-13} M, or 10^{-13} M, as determined by ELISA, bio-layer interferometry ("BLI"), KINEXA, or surface plasmon resonance at 25°C or 37°C.

23. The method of claim 22, wherein the anti-PACAP antibody or fragment thereof binds to PACAP with a K_D that is less than about 100 nM, less than about 40 nM, less than about 1 nM, less than about 100 pM, less than about 50 pM, or less than about 25 pM.

24. The method of claim 22, wherein the anti-PACAP antibody or fragment thereof binds to PACAP with a K_D that is between about 10 pM and about 100 pM.

25. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is entirely non-glycosylated, or lacks N-glycosylation, or contains only mannose residues.

26. The method of any one of the foregoing claims, wherein the antibody or fragment thereof contains an Fc region that is modified to alter effector function, half-life, proteolysis, and/or glycosylation.

27. The method of any one of the foregoing claims, wherein the anti-PACAP antibody or fragment thereof specifically binds to circulating soluble PACAP molecules *in vivo*.

28. The method of any one of the foregoing claims, wherein the anti-PACAP antibody or fragment thereof specifically binds to PACAP27 and/or PACAP38.

29. The method of any one of the foregoing claims, wherein the affinity of said anti-PACAP antibody or fragment thereof for PACAP is at least 10-fold, 30-fold, 100-fold, 300-fold, 1000-fold, 3000-fold, 10000-fold, 30000-fold, 100000-fold, 300000-fold, 1000000-fold, 3000000-fold, 10000000-fold, 30000000-fold or more stronger than the affinity of said anti-PACAP antibody and antigen binding fragment to VIP.

30. The method of any one of the foregoing claims, wherein the anti-PACAP antibody or fragment thereof (a) inhibits or neutralizes at least one biological effect elicited by PACAP; (b) neutralizes or inhibits PACAP activation of at least one of PAC1-R, VPAC1-R and/or VPAC2-R; (c) neutralizes or inhibits PACAP activation of each of PAC1-R, VPAC1-R and VPAC2-R; (d) neutralizes or inhibits PACAP activation of PAC1-R; (e) is capable of inhibiting PACAP binding to at least one of PAC1-R, VPAC1-R and/or VPAC2-R; (f) is capable of inhibiting PACAP binding to each of PAC1-R, VPAC1-R and/or VPAC2-R; (g) is capable of inhibiting PACAP binding to PAC1-R; and/or (h) inhibits PACAP-induced cAMP production.

31. The method of any one of the foregoing claims, wherein the anti-PACAP antibody or fragment thereof inhibits the association of PACAP with one or more PACAP receptors including PAC-1R, VPAC1-R, and/or VPAC2-R.

32. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is administered intramuscularly, subcutaneously, intravenously, rectally, by infusion, orally, transdermally, or by inhalation.

33. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is administered intravenously.

34. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is administered with an additional therapeutic agent or regimen selected from anti-histamines, anti-inflammatory agents, and antibiotics.

35. The method of any one of the foregoing claims, wherein the antibody or fragment thereof is directly or indirectly attached to a detectable label or therapeutic agent.

36. The method of any one of the foregoing claims, wherein the antibody or fragment thereof further comprises an effector moiety.

37. The method of claim 36, wherein the effector moiety is a detectable moiety or a functional moiety.

38. The method of claim 35, wherein the detectable label is a fluorescent dye, an enzyme, a substrate, a bioluminescent material, a radioactive material, or a chemiluminescent material.

39. The method of claim 37, wherein the functional moiety is streptavidin, avidin, biotin, a cytotoxin, a cytotoxic agent, or a radioactive material.

40. A method of assessing the potential *in vivo* efficacy of a candidate anti-Pituitary Adenylate Cyclase-Activating Peptide (PACAP) antibody, an anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibody, and antigen binding fragment thereof for treating PACAP-associated photophobia or light aversion, comprising determining whether the antibody or fragment thereof inhibits or diminishes light aversion behavior in a rodent administered PACAP, as compared to a rodent administered PACAP in the presence of one or more of the candidate anti-PACAP, anti-PAC1-R antibody or fragment thereof.

41. The method of claim 40, wherein this assay is used to assess whether the antibody or fragment thereof may be effective for treatment of a neurological condition characterized by increased PACAP levels.

42. The method of claim 40, wherein this assay is used to assess whether the antibody or fragment thereof may be effective for treatment of migraine, menstrual migraine, or chronic migraine.

43. The method of claim 40, wherein this assay is used to assess whether the antibody or fragment thereof may be effective for treatment of migraines (with or without aura), weight loss, cancer or tumors, angiogenesis associated with cancer or tumor growth, angiogenesis associated with cancer or tumor survival, hemiplegic migraines, cluster headaches, migrainous neuralgia, chronic headaches, tension headaches, general headaches, headache-free migraine, abdominal migraine, hot flashes, chronic paroxysmal hemicrania, secondary headaches caused by an underlying structural problem in the head or neck, cranial neuralgia, sinus headaches, allergy-induced headaches or allergy-induced migraines, pain, inflammatory pain, post-operative incision pain, complex regional pain syndrome, cancer pain, primary or metastatic bone cancer pain, fracture pain, osteoporotic fracture pain, pain resulting from burn, osteoporosis, gout joint pain, pain associated with sickle cell crises, nociceptive pain, hepatocellular carcinoma, breast cancer, liver cirrhosis, neurogenic pain, neuropathic pain, trigeminal neuralgia, post-herpetic neuralgia, phantom limb pain, fibromyalgia, menstrual pain, ovariatalgia, reflex sympathetic dystrophy, neurogenic pain, osteoarthritis or rheumatoid arthritis pain, lower back pain, diabetic neuropathy, sciatica, visceral pain associated with gastro-esophageal reflux, dyspepsia, irritable bowel syndrome, inflammatory bowel disease, Crohn's disease, ileitis, ulcerative colitis, renal colic, dysmenorrhea, cystitis, menstrual period, labor, menopause, prostatitis, or pancreatitis.

44. The method of any of the foregoing claims, which further comprises administering an additional active agent selected from a beta-blocker, flunarizine, valproic acid, topiramate, amitriptyline, venlafaxine, gabapentin, naproxen, butterbur root, vitamin B2, and/or magnesium.

45. The method of any of the foregoing claims, which further comprises administering analgesics, anti-histamines, antipyretics, anti-inflammatories, antibiotics, antivirals, and/or anti-cytokine agents.

46. The method of claim 44, wherein the additional active agent is selected from agonists, antagonists, and modulators of TNF- α , IL-2, IL-4, IL-6, IL-10, IL-12, IL-13, IL-18, IFN- α , IFN- γ , BAFF, CXCL13, IP-10, VEGF, EPO, EGF, HRG, Hepatocyte growth Factor (HGF), hepcidin, antibodies reactive against any of the foregoing, and antibodies reactive against any of their receptors.

47. The method of any of the foregoing claims, which further comprises administering an active agent selected from one or more of the following: 2-arylpropionic acids, aceclofenac, acemetacin, acetylsalicylic acid, alclofenac, alminoprofen, amoxicillin, ampyrone, arylalkanoic

acids, azapropazone, benorylate/benorilate, benoxaprofen, bromfenac, carprofen, celecoxib, choline magnesium salicylate, clofezone, COX-2 inhibitors, dexibuprofen, dexketoprofen, diclofenac, diflunisal, droxicam, ethenzamide, etodolac, etoricoxib, faislamine, fenamic acids, fenbufen, fenoprofen, flufenamic acid, flunoxaprofen, flurbiprofen, ibuprofen, ibuproxam, indomethacin, indoprofen, kebuzone, ketoprofen, ketorolac, lornoxicam, loxoprofen, lumiracoxib, magnesium salicylate, meclofenamic acid, mefenamic acid, meloxicam, metamizole, methyl salicylate, mofebutazone, nabumetone, naproxen, N-arylanthranilic acids, Nerve Growth Factor (NGF), oxametacin, oxaprozin, oxicams, oxyphenbutazone, oxytocin, parecoxib, phenazone, phenylbutazone, phenylbutazone, piroxicam, pirprofen, profens, proglumetacin, pyrazolidine derivatives, rofecoxib, salicyl salicylate, salicylamide, salicylates, substance P, sulfinpyrazone, sulindac, suprofen, tenoxicam, tiaprofenic acid, tolfenamic acid, tolmetin, and valdecoxib.

48. The method of any of the foregoing claims, which further comprises administering an anti-histamine active agent selected from one or more of the following: acrivastine, astemizole, azatadine, azelastine, betastastine, brompheniramine, buclizine, cetirizine, cetirizine analogues, chlorpheniramine, clemastine, CS 560, cyproheptadine, desloratadine, dexchlorpheniramine, ebastine, epinastine, fexofenadine, HSR 609, hydroxyzine, levocabastine, loratidine, methscopolamine, mizolastine, norastemizole, phenindamine, promethazine, pyrilamine, terfenadine, and tranilast.

49. The method of any of the foregoing claims, which further comprises administering an antibiotic active agent selected from one or more of the following: amikacin, aminoglycosides, amoxicillin, ampicillin, ansamycins, arspenamine, azithromycin, azlocillin, aztreonam, bacitracin, carbacephem, carbapenems, carbenicillin, cefaclor, cefadroxil, cefalexin, cefalothin, cefalotin, cefamandole, cefazolin, cefdinir, cefditoren, cefepime, cefixime, cefoperazone, cefotaxime, cefoxitin, cefpodoxime, cefprozil, ceftazidime, ceftibuten, ceftizoxime, ceftobiprole, ceftriaxone, cefuroxime, cephalosporins, chloramphenicol, cilastatin, ciprofloxacin, clarithromycin, clindamycin, cloxacillin, colistin, co-trimoxazole, dalfopristin, demeclocycline, dicloxacillin, dirithromycin, doripenem, doxycycline, enoxacin, ertapenem, erythromycin, ethambutol, flucloxacillin, fosfomicin, furazolidone, fusidic acid, gatifloxacin, geldanamycin, gentamicin, glycopeptides, herbimycin, imipenem, isoniazid, kanamycin, levofloxacin, lincomycin, linezolid, lomefloxacin, loracarbef, macrolides, mafenide, meropenem, methicillin, metronidazole, mezlocillin, minocycline, monobactams, moxifloxacin, mupirocin, nafcillin, neomycin, netilmicin, nitrofurantoin, norfloxacin,

ofloxacin, oxacillin, oxytetracycline, paromomycin, penicillin, penicillins, piperacillin, platensimycin, polymyxin B, polypeptides, prontosil, pyrazinamide, quinolones, quinupristin, rifampicin, rifampin, roxithromycin, spectinomycin, streptomycin, sulfacetamide, sulfamethizole, sulfanilamide, sulfasalazine, sulfisoxazole, sulfonamides, teicoplanin, telithromycin, tetracycline, tetracyclines, ticarcillin, tinidazole, tobramycin, trimethoprim, trimethoprim-sulfamethoxazole, troleandomycin, trovafloxacin, and vancomycin.

50. The method of any of the foregoing claims that further comprises administering an active agent selected from: aldosterone, beclomethasone, betamethasone, corticosteroids, cortisol, cortisone acetate, deoxycorticosterone acetate, dexamethasone, fludrocortisone acetate, glucocorticoids, hydrocortisone, methylprednisolone, prednisolone, prednisone, steroids, and triamcinolone, and combinations thereof.

51. The method of any of the foregoing claims, which further comprises administering an active agent selected from: ibuprofen, naproxen, sumatriptan, paracetamol/acetaminophen, caffeine, a triptan, a corticosteroid, an anti-mimetic, and combinations thereof.

52. A method of screening for antibodies or antigen binding fragments that decrease or inhibit light-induced pain signaling through intrinsically photosensitive retinal ganglion cells ("ipRGCs"), which comprises:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering PACAP to the first test subject and the second test subject;
- (iii) administering to the first test subject one or more of anti-Pituitary Adenylate Cyclase-Activating Peptide (PACAP) antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, preferably an anti-PACAP antibody or anti-PAC1-R antibody, or an antigen binding fragment of any of the foregoing;
- (iv) comparing the response of the at least one first test subject and at least one second test subject to light; and
- (v) based on this comparison, identifying one or more antibodies or antigen binding fragments thereof that decrease or inhibit light-induced pain signaling through intrinsically photosensitive retinal ganglion cells ("ipRGCs").

53. A method of screening for a test substance that treats or prevents photophobia or light aversion in a subject in need thereof by decreasing or inhibiting light-induced pain

signaling through intrinsically photosensitive retinal ganglion cells ("ipRGCs"), which comprises:

- (i) providing at least one first test subject and at least one second test subject;
- (ii) administering PACAP to the first test subject and the second test subject;
- (iii) administering to the first test subject one or more of anti-Pituitary Adenylate Cyclase-Activating Peptide (PACAP) antibodies, anti-Pituitary Adenylate Cyclase Activating Polypeptide type 1 Receptor (PAC1-R) antibodies, anti-vasoactive intestinal peptide receptor type 1 (VPAC1-R) antibodies, or anti-vasoactive intestinal peptide receptor type 2 (VPAC2-R) antibodies, preferably an anti-PACAP antibody or anti-PAC1-R antibody, or an antigen binding fragment of any of the foregoing;
- (iv) comparing the response of the at least one first test subject and at least one second test subject to light; and
- (v) based on this comparison, identifying one or more antibodies or antigen binding fragments thereof that are useful for treating or preventing light-induced pain signaling through ipRGCs.

Figure 1A
 Antibody Variable Heavy Chain Protein Features
 Sequence
 Name FR1 CDR1 FR2 CDR2
 Ab10 QSVEESSGRLVTPGTPLLTCTVSGIDLN SYMYT WVRQAPGKLEWIG FIDAGGJAYYASWAKG
 Ab20 QSVEESSGRLVTPGTPLLTCTVSGIDLN SYYMS WVRQAPGKLEWIG FIDTDGSAYYATWAKG

Figure 1B
 Antibody Variable Heavy Chain Protein Features
 Sequence
 Name FR3 CDR3 FR4
 Ab10 RFTISKSTSTVDLKITSPPTTEDTATYFCAR DLDL WGGQLVTVSS (SEQ ID NO: 402)
 Ab20 RFTISKSTSTVDLKITSPPTTEDTATYFCAR DLDL WGPGLVTVSS (SEQ ID NO: 442)

Figure 2A
 Antibody Variable Light Chain Protein Features
 Sequence
 Name FR1 CDR1 FR2 CDR2
 Ab10 AAVLTQTSPVSAVGGTVTINC QSSESVYGNLYA WFQQRPGQPPKLLIY EASKLES
 Ab20 AAVLTQTSPVSAVGGTVSISC QSSESVYSNYLA WFQQRPGQPPKLLIY EASKLAS

Figure 2B
 Antibody Variable Light Chain Protein Features
 Sequence
 Name FR3 CDR3 FR4
 Ab10 GVPSRFRSSGSGTQFTLLTISDLQCCDDAATYYC AGGDISSEGYA FGGGTEVVVKR (SEQ ID NO: 422)
 Ab20 GVPSRFRKSGSGTQFTLLTISDVQCDDAATYYC AGGYSSEGYA FGGGTEVVVKR (SEQ ID NO: 462)

Figure 3A
 Antibody Variable Heavy Chain DNA Features
 Sequence
 Name FR1
 Ab10 cagtcggtgagagagatcccggtgctcgcctcaccgcctgggacacacccctgacacctcacctggcacacagtcctctgaaa
 Ab20 cagtcggtgagagagatcccggtgctcgcctcaccgcctgggacacacccctgacacctcacctggcacacagtcctctgaaa

Ab20 gccgccgtgctgaccagactccatctcccgtgctcagctgrrggaggccacagtcagcatcagttgc

Figure 4B

Antibody Variable Light Chain DNA Features

Sequence

Name

CDR1

FR2

Ab10 cagtcagtgagagtggtttaccgtaactacttagcc tggtttcagccagaaaccaggcagccctcccagctcctga
 Ab20 cagtcacagtgagagtggtttataagtaactacttagcc tggtttcagccagaaaccaggcagccctcctaagttccttga

Figure 4C

Antibody Variable Light Chain DNA Features

Sequence

Name

FR2 CDR2

FR3

Ab10 tctac gaagcatccaactggaatct ggggtcccatcgcggttcagcgcagtgatctgggacacagttcaccc
 Ab20 tctac gaagcatccaactggaatct ggggtcccatcgcggttcagcgcagtgatctgggacacagttcaccc

Figure 4D

Antibody Variable Light Chain DNA Features

Sequence

Name

FR3

CDR3

Ab10 tcaccatcagcagacttgcaqtgtgacgatgctgaccacttactactgt gcaggcggtgatattagtgaaagtggtg
 Ab20 tcaccatcagcagacttgcaqtgtgacgatgctgaccacttactactgt gcaggcggtgatattagtgaaagtggtg

Figure 4E

Antibody Variable Light Chain DNA Features

Sequence

Name

3 FR4

Ab10 ct ttccggcggaggaccgaggtgtgtcacaacgt (SEQ ID NO: 432)
 Ab20 ct ttccggcggaggaccgaggtgtgtcacaacgt (SEQ ID NO: 472)

Figure 5
Antibody Heavy Chain Protein Features

Sequence Name	Variable region coordinates	SEQ ID NO:	CDR1 coordinates	SEQ ID NO:	CDR2 coordinates	SEQ ID NO:	CDR3 coordinates	SEQ ID NO:
Ab10	1-109	402	30-34	404	49-64	406	95-98	408
Ab20	1-109	442	30-34	444	49-64	446	95-98	448

Figure 6
Antibody Heavy Chain Protein Features

Sequence Name	FR1 coordinates	SEQ ID NO:	FR2 coordinates	SEQ ID NO:	FR3 coordinates	SEQ ID NO:	FR4 coordinates	SEQ ID NO:	Constant region coordinates	SEQ ID NO:
Ab10	1-29	403	35-48	405	65-94	407	99-109	409	110-439	410
Ab20	1-29	443	35-48	445	65-94	447	99-109	449	110-439	450

Figure 7
Antibody Light Chain Protein Features

Sequence Name	Variable region coordinates	SEQ ID NO:	CDR1 coordinates	SEQ ID NO:	CDR2 coordinates	SEQ ID NO:	CDR3 coordinates	SEQ ID NO:
Ab10	1-110	422	24-35	424	51-57	426	90-99	428
Ab20	1-110	462	24-35	464	51-57	466	90-99	468

Figure 8
Antibody Light Chain Protein Features

Sequence Name	FR1 coordinates	SEQ ID NO:	FR2 coordinates	SEQ ID NO:	FR3 coordinates	SEQ ID NO:	FR4 coordinates	SEQ ID NO:	Constant region coordinates	SEQ ID NO:
Ab10	1-23	423	36-50	425	58-89	427	100-110	429	111-216	430
Ab20	1-23	463	36-50	465	58-89	467	100-110	469	111-216	470

Figure 9
Antibody Heavy Chain DNA Features

Sequence Name	Variable region coordinates	SEQ ID NO:	CDR1 coordinates	SEQ ID NO:	CDR2 coordinates	SEQ ID NO:	CDR3 coordinates	SEQ ID NO:
Ab10	1-327	412	88-102	414	145-152	416	283-294	418
Ab20	1-327	452	88-102	454	145-152	456	283-294	458

Figure 10
Antibody Heavy Chain DNA Features

Sequence Name	FR1 coordinates	SEQ ID NO:	FR2 coordinates	SEQ ID NO:	FR3 coordinates	SEQ ID NO:	FR4 coordinates	SEQ ID NO:	Constant region coordinates	SEQ ID NO:
Ab10	1-87	413	103-144	415	193-262	417	295-327	419	328-1317	420
Ab20	1-87	453	103-144	455	193-262	457	295-327	459	328-1317	460

Figure 11
Antibody Light Chain DNA Features

Sequence Name	Variable region coordinates	SEQ ID NO:	CDR1 coordinates	SEQ ID NO:	CDR2 coordinates	SEQ ID NO:	CDR3 coordinates	SEQ ID NO:
Ab10	1-330	432	70-105	434	151-171	436	268-297	438
Ab20	1-330	472	70-105	474	151-171	476	268-297	478

Figure 12
Antibody Light Chain DNA Features

Sequence Name	FR1 coordinates	SEQ ID NO:	FR2 coordinates	SEQ ID NO:	FR3 coordinates	SEQ ID NO:	FR4 coordinates	SEQ ID NO:	Constant region coordinates	SEQ ID NO:
Ab10	1-69	433	106-150	435	172-267	437	298-330	439	331-648	440
Ab20	1-69	473	106-150	475	172-267	477	298-330	479	331-648	480

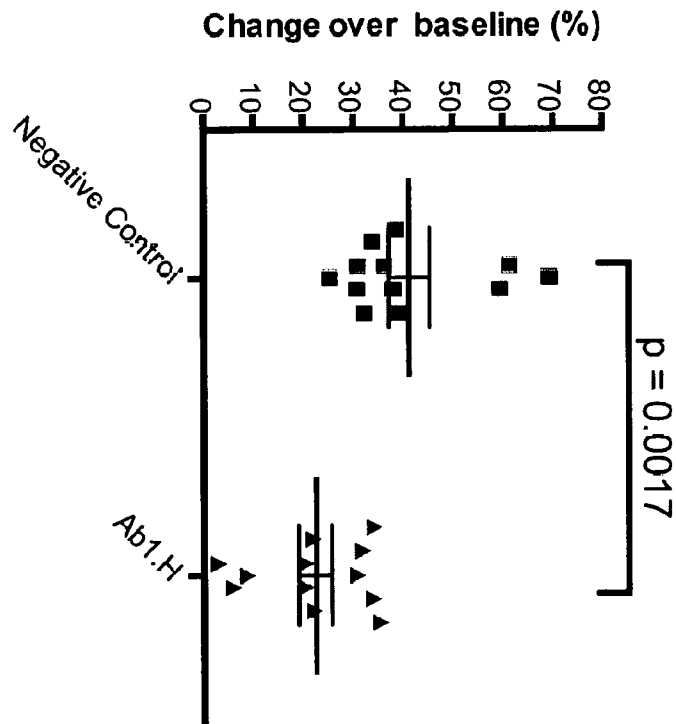


FIG. 13

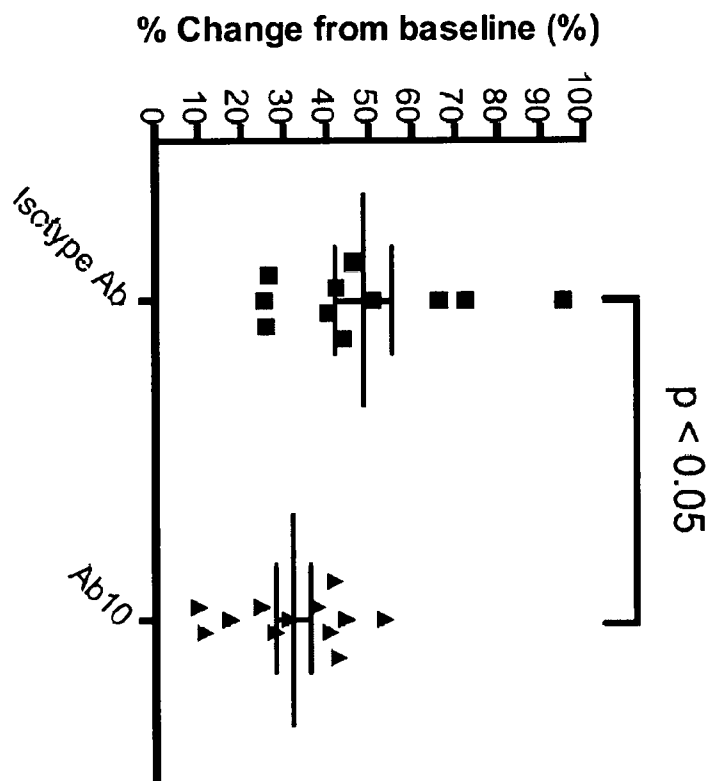


FIG. 14

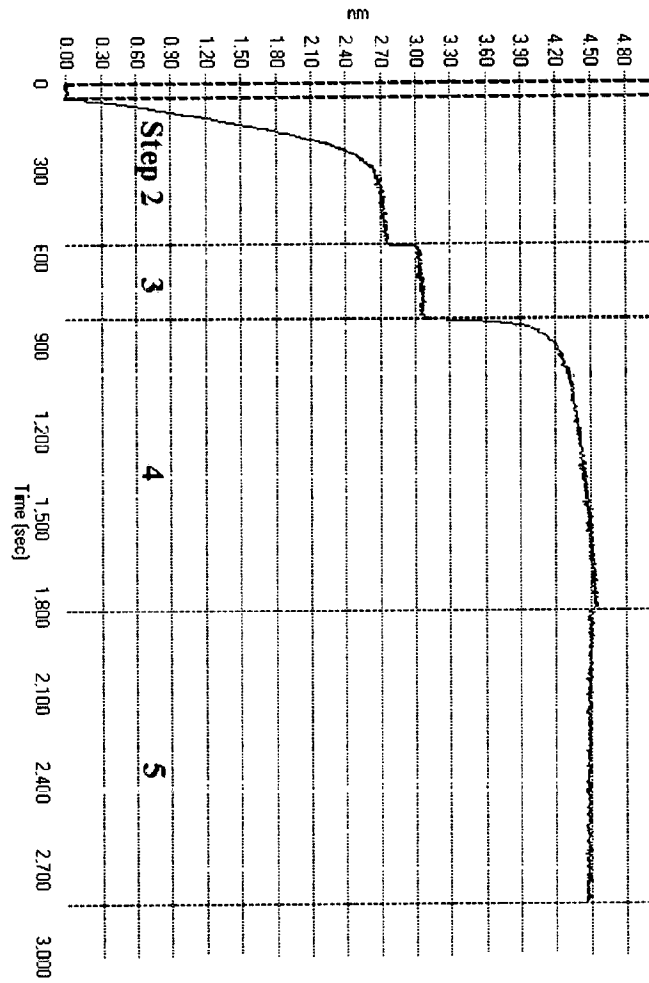


FIG. 15A

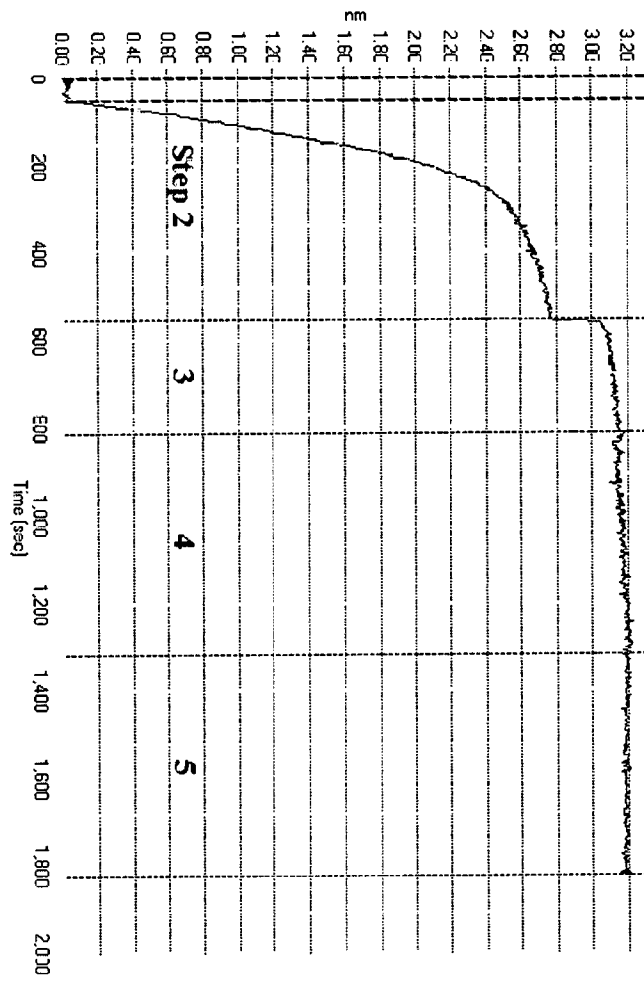


FIG. 15B

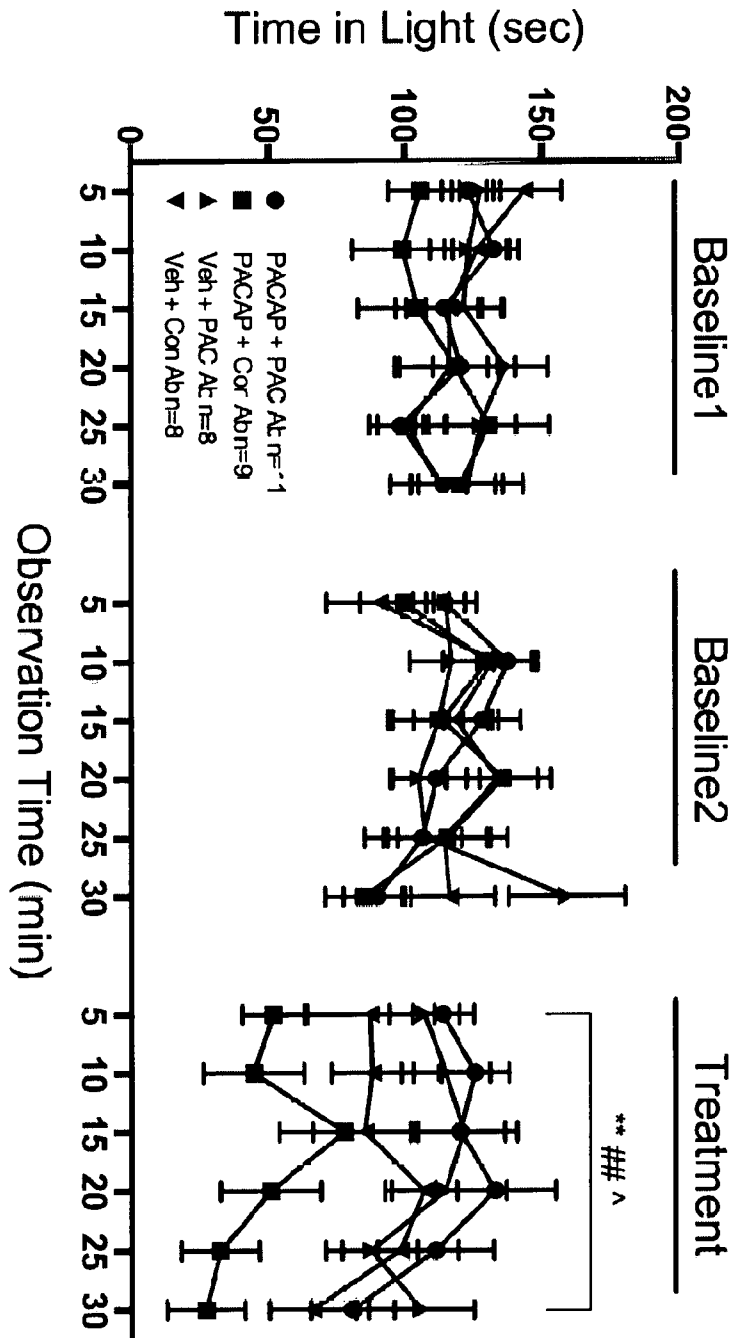


FIG. 16

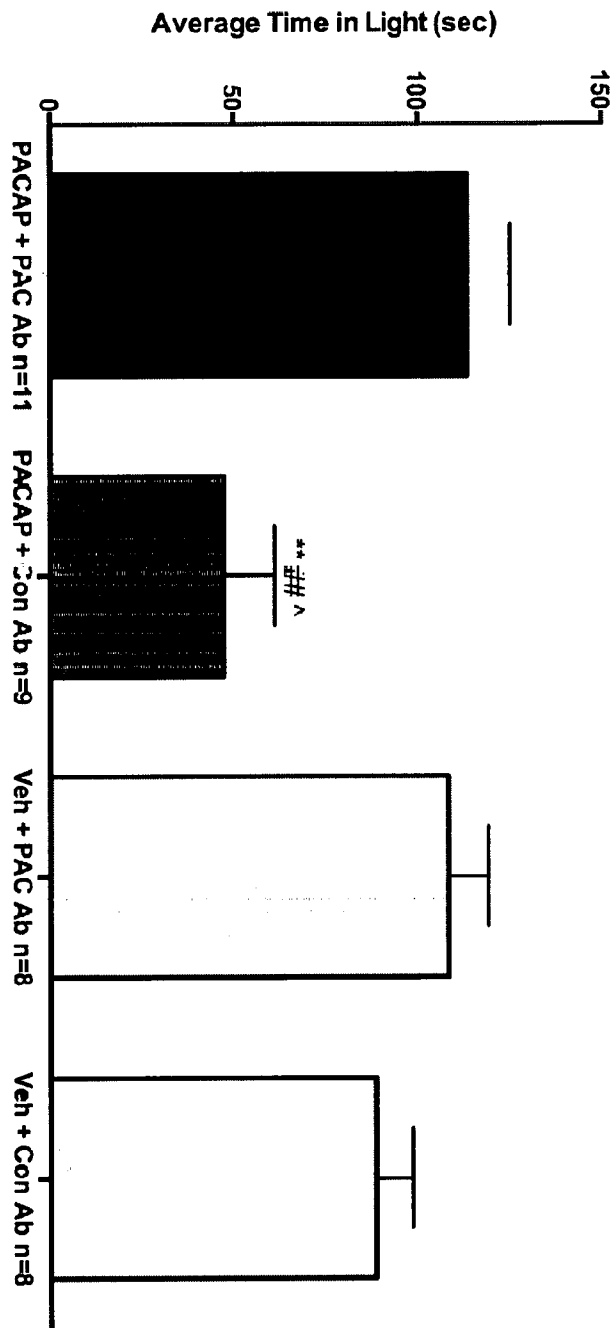


FIG. 17

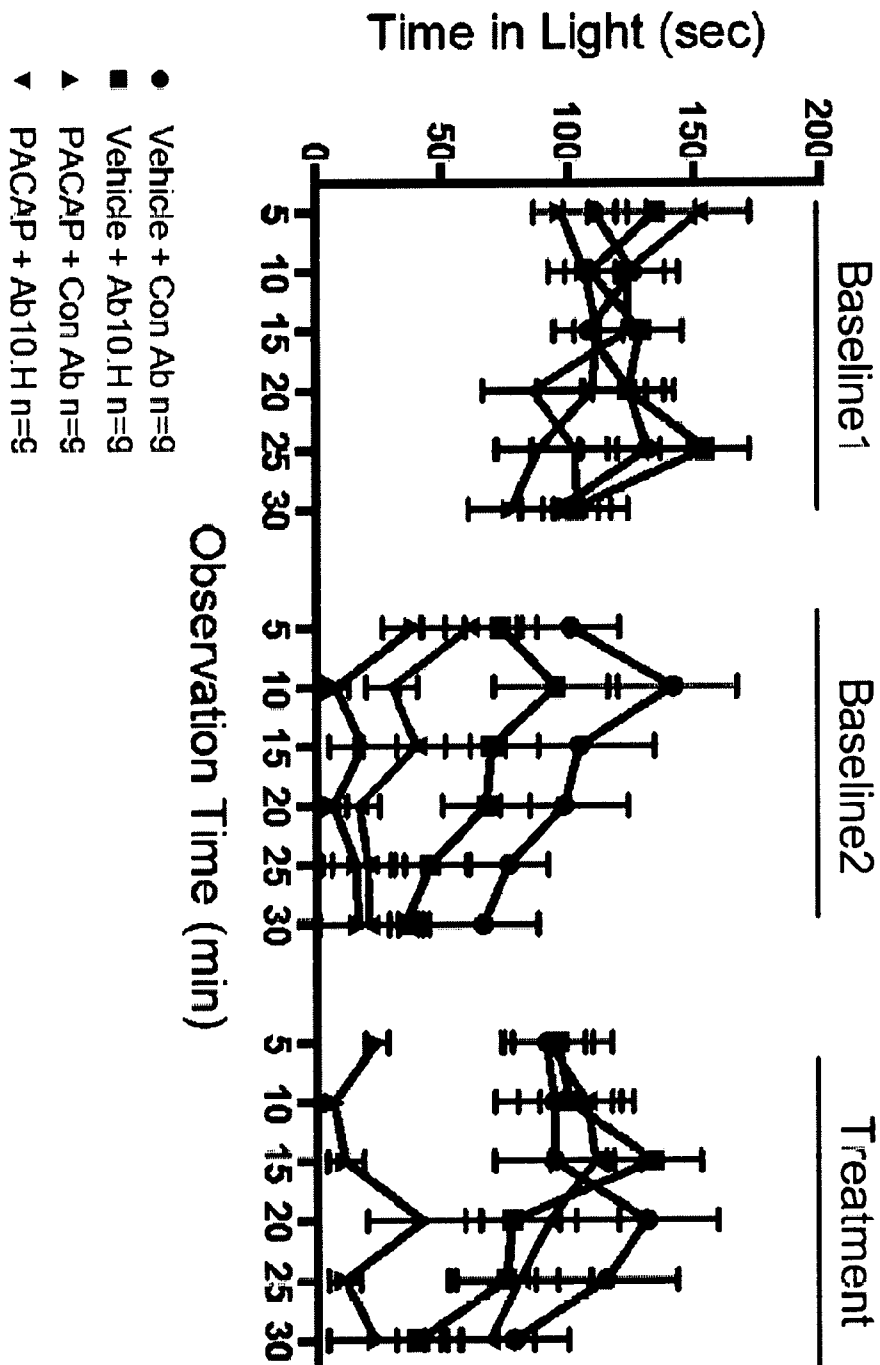


FIG. 18

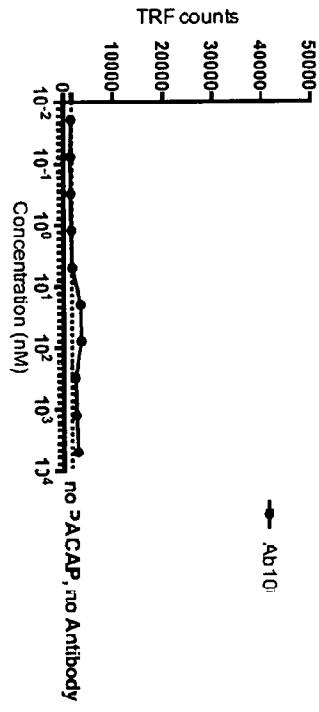


FIG. 19A

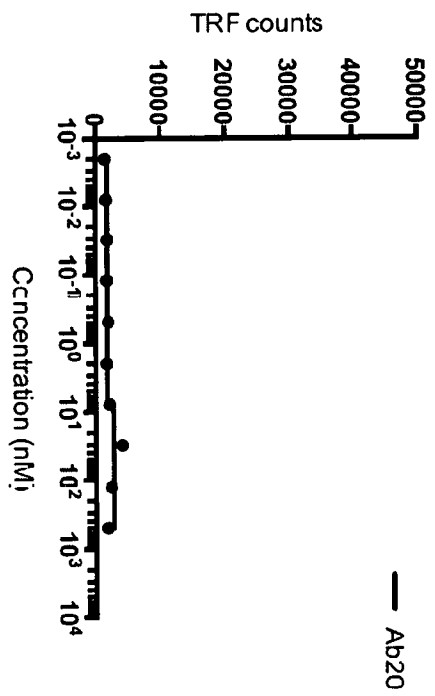


FIG. 19B

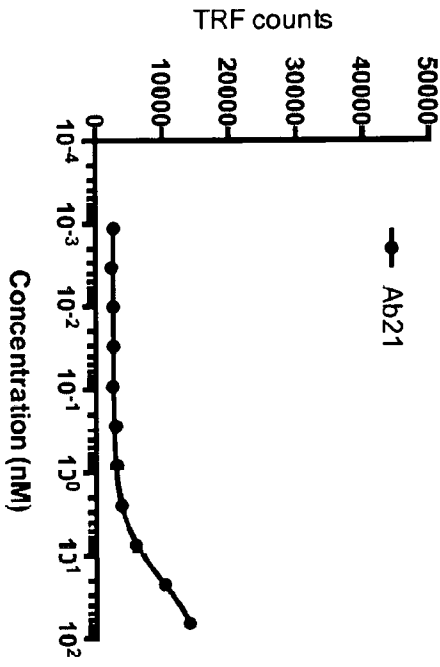


FIG. 19C

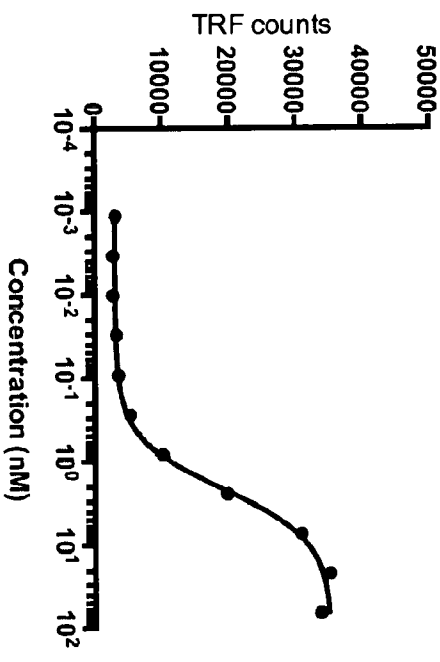


FIG. 19D

FIG. 19E

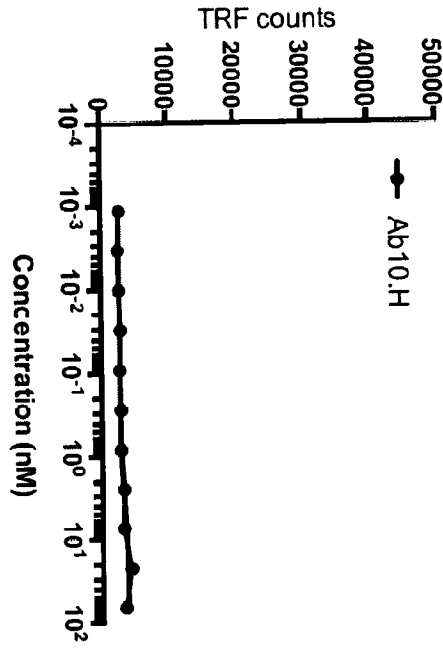


FIG. 19G

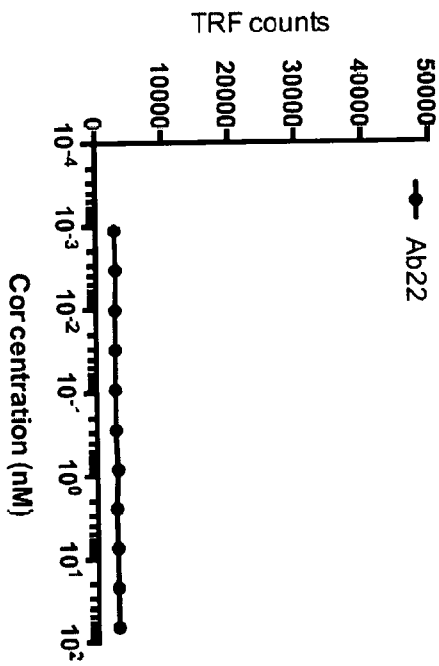


FIG. 19F

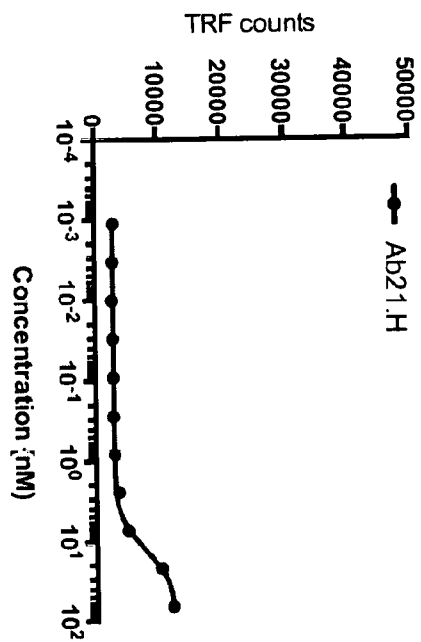
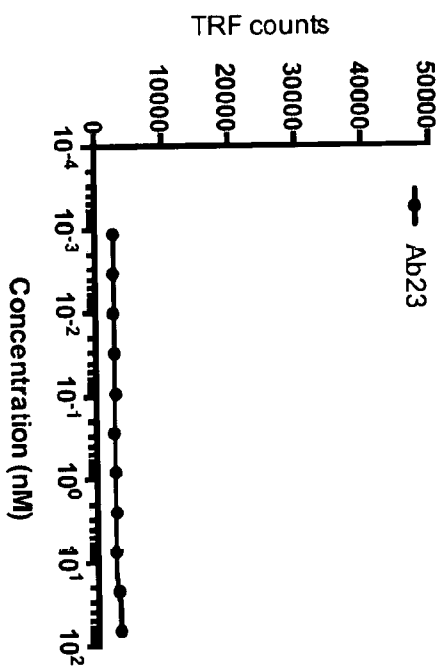


FIG. 19H



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US16/27981

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - A61P 25/06; A61K 39/395 (2016.01) CPC - A61K 38/2278, 39/395; C07K 16/18 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) IPC(8): A61P 25/04, 25/06, 31/16, 31/04; A61K 31/165, 31/404; 39/395 (2016.01) CPC: A61K 31/165, 31/404, 38/2278, 39/395, 2039/505; C07K 16/18 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) PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); EBSCO Discovery; PubMed; Google; Google Scholar; Google Patents; KEYWORDS: screen, antibody, Pituitary Adenylate Cyclase-Activating Peptide, treat, light aversion, photophobia		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/0294802 A1 (RUSSO, AF et al.) November 22, 2012; abstract; paragraphs [0005], [0020], [0024], [0326], [0575], [0577], [0582], [0585]-[0588]	1-2, 3/1-2, 40-43, 52, 53
Y	WO 2009/033489 A2 (GLOSTRUP HOSPITAL) March 19, 2009; abstract; page 3, lines 20-26; page 10, lines 12-13, 21-22; page 22, lines 16-19; page 48, lines 30-31; page 51, line 19	1-2, 3/1-2, 40-43, 52, 53
Y	(NOSEDA, R et al.) A Neural Mechanism For Exacerbation Of Headache By Light. Nature Neuroscience, 10 January 2010, Vol. 13, pp 239-245; page 243, column 1, paragraph 1. DOI:10.1038/nn.2475	52-53
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> 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 20 July 2016 (20.07.2016)		Date of mailing of the international search report 16 AUG 2016
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300		Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US16/27981

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing:
- a. forming part of the international application as filed:
 in the form of an Annex C/ST.25 text file.
 on paper or in the form of an image file.
- b. furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
- c. furnished subsequent to the international filing date for the purposes of international search only:
 in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).
 on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
2. In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
3. Additional comments:

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US16/27981

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.: 4-39, 44-51
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:

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 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.:

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.