

Neuropeptide Y receptors in GtoPdb v.2023.1

Annette G. Beck-Sickinger¹, William F. Colmers², Helen M. Cox³, Henri N. Doods⁴, Herbert Herzog⁵, Dan Larhammar⁶, Martin C. Michel⁷, Remi Quirion⁸, Thue Schwartz⁹ and Thomas Westfall¹⁰

1. Universität Leipzig, Germany
2. University of Alberta, Canada
3. Kings College London, UK
4. Dr Karl Thomae GmbH, Germany
5. St. Vincent Hospital, Australia
6. Uppsala University, Sweden
7. Johannes Gutenberg University, Germany
8. McGill University, Canada
9. University of Copenhagen, Denmark
10. St. Louis University, USA

Abstract

Neuropeptide Y (NPY) receptors (**nomenclature as agreed by the NC-IUPHAR Subcommittee on Neuropeptide Y Receptors [158]**) are activated by the endogenous peptides **neuropeptide Y**, neuropeptide Y-(3-36), **peptide YY**, PYY-(3-36) and **pancreatic polypeptide** (PP). The receptor originally identified as the Y3 receptor has been identified as the **CXCR4 chemokine receptor** (originally named LESTR, [139]). The y6 receptor is a functional gene product in mouse, absent in rat, but contains a frame-shift mutation in primates producing a truncated non-functional gene [84]. Three-dimensional structures have been determined for subtype active receptors Y₁, Y₂ and Y₄ [211, 114] and inactive antagonist bound Y₁ and Y₂ receptors [240, 210]. Many of the agonists exhibit differing degrees of selectivity dependent on the species examined. For example, the potency of PP is greater at the rat Y₄ receptor than at the human receptor [62]. In addition, many agonists lack selectivity for individual subtypes, but can exhibit comparable potency against pairs of NPY receptor subtypes, or have not been examined for activity at all subtypes. [¹²⁵I]-PYY or [¹²⁵I]-NPY can be used to label Y₁, Y₂, Y₅ and y₆ subtypes non-selectively, while [¹²⁵I][cPP(1-7), NPY(19-23), Ala³¹, Aib³², Gln³⁴]hPP may be used to label Y₅ receptors preferentially (note that cPP denotes chicken peptide sequence and hPP is the human sequence).

Contents

This is a citation summary for Neuropeptide Y receptors in the [Guide to Pharmacology](#) database (GtoPdb). It exists purely as an adjunct to the database to facilitate the recognition of citations to and from the database by citation analyzers. Readers will almost certainly want to visit the relevant sections of the database which are given here under database links.

[GtoPdb](#) is an expert-driven guide to pharmacological targets and the substances that act on them. GtoPdb is a reference work which is most usefully represented as an on-line database. As in any publication this work should be appropriately cited, and the papers it cites should also be recognized. This document provides a citation for the relevant parts of the database, and also provides a reference list for the research cited by those parts. For further details see [27].

Please note that the database version for the citations given in GtoPdb are to the most recent preceding version in which the family or its subfamilies and targets were substantially changed. The links below are to the current version. If you need to consult the cited version, rather than the most recent version, please contact the GtoPdb curators.

Database links

Neuropeptide Y receptors

<https://www.guidetopharmacology.org/GRAC/FamilyDisplayForward?familyId=46>

Introduction to Neuropeptide Y receptors

<https://www.guidetopharmacology.org/GRAC/FamilyIntroductionForward?familyId=46>

Receptors

Y₁ receptor

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=305>

Y₂ receptor

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=306>

Y₄ receptor

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=307>

Y₅ receptor

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=308>

Y₆ receptor

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=683>

References

1. Abounader R, Elhousseiny A, Cohen Z, Olivier A, Stanimirovic D, Quirion R and Hamel E. (1999) Expression of neuropeptide Y receptors mRNA and protein in human brain vessels and cerebromicrovascular cells in culture. *J Cereb Blood Flow Metab* **19**: 155-63 [PMID:10027771]
2. Abrahamsson C. (2000) Neuropeptide Y1- and Y2-receptor-mediated cardiovascular effects in the anesthetized guinea pig, rat, and rabbit. *J Cardiovasc Pharmacol* **36**: 451-8 [PMID:11026645]
3. Akanmu MA, Ukponmwan OE, Katayama Y and Honda K. (2006) Neuropeptide-Y Y2-receptor agonist, PYY3-36 promotes non-rapid eye movement sleep in rat. *Neurosci Res* **54**: 165-70 [PMID:16378653]
4. Allison SJ, Baldock P, Sainsbury A, Enriquez R, Lee NJ, Lin EJ, Klugmann M, Klugman M, During M and Eisman JA *et al.* (2006) Conditional deletion of hypothalamic Y2 receptors reverts gonadectomy-induced bone loss in adult mice. *J Biol Chem* **281**: 23436-44 [PMID:16785231]
5. Ammar DA, Eadie DM, Wong DJ, Ma YY, Kolakowski Jr LF, Yang-Feng TL and Thompson DA. (1996) Characterization of the human type 2 neuropeptide Y receptor gene (NPY2R) and localization to the chromosome 4q region containing the type 1 neuropeptide Y receptor gene. *Genomics* **38**: 392-8 [PMID:8975716]
6. Asakawa A, Inui A, Ueno N, Fujimiya M, Fujino MA and Kasuga M. (1999) Mouse pancreatic polypeptide modulates food intake, while not influencing anxiety in mice. *Peptides* **20**: 1445-8 [PMID:10698120]
7. Ashby D and Bloom SR. (2007) Recent progress in PYY research--an update report for 8th NPY meeting. *Peptides* **28**: 198-202 [PMID:17354277]
8. Balasubramaniam A, Mullins DE, Lin S, Zhai W, Tao Z, Dhawan VC, Guzzi M, Knittel JJ, Slack K and Herzog H *et al.* (2006) Neuropeptide Y (NPY) Y4 receptor selective agonists based on NPY(32-36): development of an anorectic Y4 receptor selective agonist with picomolar affinity. *J Med Chem* **49**: 2661-5 [PMID:16610810]
9. Baldock PA, Sainsbury A, Couzens M, Enriquez RF, Thomas GP, Gardiner EM and Herzog H. (2002) Hypothalamic Y2 receptors regulate bone formation. *J Clin Invest* **109**: 915-21 [PMID:11927618]
10. Ball HJ, Shine J and Herzog H. (1995) Multiple promoters regulate tissue-specific expression of the human NPY-Y1 receptor gene. *J Biol Chem* **270**: 27272-6 [PMID:7592987]
11. Baraban SC. (2002) Antiepileptic actions of neuropeptide Y in the mouse hippocampus require Y5 receptors. *Epilepsia* **43 Suppl 5**: 9-13 [PMID:12121287]
12. Bard JA, Walker MW, Branchek TA and Weinshank RL. (1995) Cloning and functional expression of a human Y4 subtype receptor for pancreatic polypeptide, neuropeptide Y, and peptide YY. *J Biol Chem*

- 270:** 26762-5 [PMID:7592911]
13. Barrios VE, Sun J, Douglass J and Toombs CF. (1999) Evidence of a specific pancreatic polypeptide receptor in rat arterial smooth muscle. *Peptides* **20**: 1107-13 [PMID:10499429]
 14. Batterham RL and Bloom SR. (2003) The gut hormone peptide YY regulates appetite. *Ann N Y Acad Sci* **994**: 162-168 [PMID:12851312]
 15. Batterham RL, Cowley MA, Small CJ, Herzog H, Cohen MA, Dakin CL, Wren AM, Brynes AE, Low MJ, Ghatei MA, Cone RD and Bloom SR. (2002) Gut hormone PYY(3-36) physiologically inhibits food intake. *Nature* **418**: 650-654 [PMID:12167864]
 16. Batterham RL, Le Roux CW, Cohen MA, Park AJ, Ellis SM, Patterson M, Frost GS, Ghatei MA and Bloom SR. (2003) Pancreatic polypeptide reduces appetite and food intake in humans. *J Clin Endocrinol Metab* **88**: 3989-92 [PMID:12915697]
 17. Beck B. (2006) Neuropeptide Y in normal eating and in genetic and dietary-induced obesity. *Philos Trans R Soc Lond, B, Biol Sci* **361**: 1159-85 [PMID:16874931]
 18. Bernet F, Maubert E, Bernard J, Montel V and Dupouy JP. (1994) In vitro steroidogenic effects of neuropeptide Y (NPY1-36), Y1 and Y2 receptor agonists (Leu31-Pro34 NPY, NPY18-36) and peptide YY (PYY) on rat adrenal capsule/zona glomerulosa. *Regul Pept* **52**: 187-93 [PMID:7800851]
 19. Bischoff A, Limmroth V and Michel MC. (1998) Indomethacin inhibits the natriuretic effects of neuropeptide Y in anesthetized rats. *J Pharmacol Exp Ther* **286**: 704-8 [PMID:9694924]
 20. Bischoff A and Michel MC. (1999) Emerging functions for neuropeptide Y5 receptors. *Trends Pharmacol Sci* **20**: 104-6 [PMID:10203865]
 21. Bischoff A and Michel MC. (1998) Renal effects of neuropeptide Y. *Pflugers Arch* **435**: 443-53 [PMID:9446690]
 22. Bischoff A, Püttmann K, Kötting A, Moser C, Buschauer A and Michel MC. (2001) Limited signal transduction repertoire of human Y(5) neuropeptide Y receptors expressed in HEC-1B cells. *Peptides* **22**: 387-94 [PMID:11287093]
 23. Blundell TL, Pitts JE, Tickle IJ, Wood SP and Wu CW. (1981) X-ray analysis (1.4-Å resolution) of avian pancreatic polypeptide: Small globular protein hormone. *Proc Natl Acad Sci USA* **78**: 4175-9 [PMID:16593056]
 24. Bonaventure P, Nepomuceno D, Mazur C, Lord B, Rudolph DA, Jablonowski JA, Carruthers NI and Lovenberg TW. (2004) Characterization of N-(1-Acetyl-2,3-dihydro-1H-indol-6-yl)-3-(3-cyano-phenyl)-N-[1-(2-cyclopentyl-ethyl)-piperidin-4yl]acrylamide (JNJ-5207787), a small molecule antagonist of the neuropeptide Y2 receptor. *J Pharmacol Exp Ther* **308**: 1130-7 [PMID:14617685]
 25. Borowsky B, Walker MW, Bard J, Weinshank RL, Laz TM, Vaysse P, Branchek TA and Gerald C. (1998) Molecular biology and pharmacology of multiple NPY Y5 receptor species homologs. *Regul Pept* **75-76**: 45-53 [PMID:9802393]
 26. Brumovsky P, Shi TS, Landry M, Villar MJ and Hökfelt T. (2007) Neuropeptide tyrosine and pain. *Trends Pharmacol Sci* **28**: 93-102 [PMID:17222466]
 27. Buneman P, Christie G, Davies JA, Dimitrellou R, Harding SD, Pawson AJ, Sharman JL and Wu Y. (2020) Why data citation isn't working, and what to do about it *Database* **2020** [PMID:32367113]
 28. Burcelin R, Brunner H, Seydoux J, Thorensa B and Pedrazzini T. (2001) Increased insulin concentrations and glucose storage in neuropeptide Y Y1 receptor-deficient mice. *Peptides* **22**: 421-427 [PMID:11287097]
 29. Burkhoff A, Linemeyer DL and Salon JA. (1998) Distribution of a novel hypothalamic neuropeptide Y receptor gene and its absence in rat. *Brain Res Mol Brain Res* **53**: 311-6 [PMID:9473707]
 30. Caberlotto L, Fuxe K, Rimland JM, Sedvall G and Hurd YL. (1998) Regional distribution of neuropeptide Y Y2 receptor messenger RNA in the human post mortem brain. *Neuroscience* **86**: 167-78 [PMID:9692752]
 31. Cabrele C, Wieland HA, Koglin N, Stidsen C and Beck-Sickingler AG. (2002) Ala31-Aib32: identification of the key motif for high affinity and selectivity of neuropeptide Y at the Y5-receptor. *Biochemistry* **41**: 8043-9 [PMID:12069595]
 32. Carvajal C, Dumont Y, Herzog H and Quirion R. (2006) Emotional behavior in aged neuropeptide Y (NPY) Y2 knockout mice. *J Mol Neurosci* **28**: 239-45 [PMID:16691011]
 33. Cavadas C, Céfal D, Rosmaninho-Salgado J, Vieira-Coelho MA, Moura E, Busso N, Pedrazzini T, Grand D, Rotman S and Waeber B *et al.*. (2006) Deletion of the neuropeptide Y (NPY) Y1 receptor gene reveals a regulatory role of NPY on catecholamine synthesis and secretion. *Proc Natl Acad Sci USA* **103**: 10497-10502 [PMID:16798884]

34. Cherbut C, Ferrier L, Rozé C, Anini Y, Blottière H, Lecannu G and Galmiche JP. (1998) Short-chain fatty acids modify colonic motility through nerves and polypeptide YY release in the rat. *Am J Physiol* **275**: G1415-22 [PMID:9843779]
35. Clark JT, Kalra PS, Crowley WR and Kalra SP. (1984) Neuropeptide Y and human pancreatic polypeptide stimulate feeding behavior in rats. *Endocrinology* **115**: 427-9 [PMID:6547387]
36. Colmers WF and Bleakman D. (1994) Effects of neuropeptide Y on the electrical properties of neurons. *Trends Neurosci* **17**: 373-9 [PMID:7529442]
37. Colmers WF, Klapstein GJ, Fournier A, St-Pierre S and Treherne KA. (1991) Presynaptic inhibition by neuropeptide Y in rat hippocampal slice in vitro is mediated by a Y2 receptor. *Br J Pharmacol* **102**: 41-4 [PMID:1646061]
38. Colmers WF, Lukowiak K and Pittman QJ. (1987) Presynaptic action of neuropeptide Y in area CA1 of the rat hippocampal slice. *J Physiol* **383**: 285-299 [PMID:2821236]
39. Coppes RP, Smit J, Geurtsen AM, Roffel AF, Dahlöf C, Doods HN and Zaagsma J. (1994) Heterogeneity of prejunctional neuropeptide Y receptors inhibiting noradrenaline overflow in the portal vein of freely moving rats. *Eur J Pharmacol* **261**: 311-6 [PMID:7813553]
40. Costoli T, Sgoifo A, Stilli D, Flugge G, Adriani W, Laviola G, Fuchs E, Pedrazzini T and Musso E. (2005) Behavioural, neural and cardiovascular adaptations in mice lacking the NPY Y1 receptor. *Neurosci Biobehav Rev* **29**: 113-23 [PMID:15652259]
41. Cox HM. (2007) Neuropeptide Y receptors; antisecretory control of intestinal epithelial function. *Auton Neurosci* **133**: 76-85 [PMID:17140858]
42. Cox HM. (2007) Peptide YY: a neuroendocrine neighbor of note. *Peptides* **28**: 345-51 [PMID:17194503]
43. Cox HM, Pollock EL, Tough IR and Herzog H. (2001) Multiple Y receptors mediate pancreatic polypeptide responses in mouse colon mucosa. *Peptides* **22**: 445-52 [PMID:11287100]
44. Cox HM and Tough IR. (1995) Functional characterization of receptors with affinity for PYY, NPY, [Leu31,Pro34]NPY and PP in a human colonic epithelial cell line. *Br J Pharmacol* **116**: 2673-8 [PMID:8590988]
45. Cox HM and Tough IR. (2002) Neuropeptide Y, Y1, Y2 and Y4 receptors mediate Y agonist responses in isolated human colon mucosa. *Br J Pharmacol* **135**: 1505-12 [PMID:11906964]
46. Criscione L, Rigollier P, Batzl-Hartmann C, Rüeger H, Stricker-Krongrad A, Wyss P, Brunner L, Whitebread S, Yamaguchi Y and Gerald C *et al.* (1998) Food intake in free-feeding and energy-deprived lean rats is mediated by the neuropeptide Y5 receptor. *J Clin Invest* **102**: 2136-45 [PMID:9854049]
47. Daly RN, Roberts MI, Ruffolo Jr RR and Hieble JP. (1988) The role of neuropeptide Y in vascular sympathetic neurotransmission may be enhanced in hypertension. *J Hypertens Suppl* **6**: S535-8 [PMID:2853757]
48. Daniels AJ, Grizzle MK, Wiard RP, Matthews JE and Heyer D. (2002) Food intake inhibition and reduction in body weight gain in lean and obese rodents treated with GW438014A, a potent and selective NPY-Y5 receptor antagonist. *Regul Pept* **106**: 47-54 [PMID:12047910]
49. Daniels AJ, Matthews JE, Slepatis RJ, Jansen M, Viveros OH, Tadepalli A, Harrington W, Heyer D, Landavazo A, Leban JJ and Spaltenstein A. (1995) High-affinity neuropeptide Y receptor antagonists. *Proc Natl Acad Sci USA* **92**: 9067-9071 [PMID:7568074]
50. Darby K, Eyre HJ, Lapsys N, Copeland NG, Gilbert DJ, Couzens M, Antonova O, Sutherland GR, Jenkins NA and Herzog H. (1997) Assignment of the Y4 receptor gene (PPYR1) to human chromosome 10q11.2 and mouse chromosome 14. *Genomics* **46**: 513-515 [PMID:9441761]
51. Doods H, Gaida W, Wieland HA, Dollinger H, Schnorrenberg G, Esser F, Engel W, Eberlein W and Rudolf K. (1999) BIIE0246: a selective and high affinity neuropeptide Y Y(2) receptor antagonist. *Eur J Pharmacol* **384**: R3-5 [PMID:10611450]
52. Doods HN, Wieland HA, Engel W, Eberlein W, Willim KD, Entzeroth M, Wiene W and Rudolf K. (1996) BIBP 3226, the first selective neuropeptide Y1 receptor antagonist: a review of its pharmacological properties. *Regul Pept* **65**: 71-7 [PMID:8876038]
53. Doods HN, Wiene W, Entzeroth M, Rudolf K, Eberlein W, Engel W and Wieland HA. (1995) Pharmacological characterization of the selective nonpeptide neuropeptide Y Y1 receptor antagonist BIBP 3226. *J Pharmacol Exp Ther* **275**: 136-42 [PMID:7562541]
54. Dumont Y, Cadieux A, Doods H, Pheng LH, Abounader R, Hamel E, Jacques D, Regoli D and Quirion R. (2000) BIIE0246, a potent and highly selective non-peptide neuropeptide Y Y(2) receptor antagonist. *Br J Pharmacol* **129**: 1075-88 [PMID:10725255]

55. Dumont Y, Fournier A and Quirion R. (1998) Expression and characterization of the neuropeptide Y Y5 receptor subtype in the rat brain. *J Neurosci* **18**: 5565-74 [PMID:9671648]
56. Dumont Y and Quirion R. (2000) [(125)I]-GR231118: a high affinity radioligand to investigate neuropeptide Y Y(1) and Y(4) receptors. *Br J Pharmacol* **129**: 37-46 [PMID:10694200]
57. Dumont Y, Thakur M, Beck-Sickinger A, Fournier A and Quirion R. (2004) Characterization of a new neuropeptide Y Y5 agonist radioligand: [125I][cPP(1-7), NPY(19-23), Ala31, Aib32, Gln34]hPP. *Neuropeptides* **38**: 163-74 [PMID:15337369]
58. Dumont Y, Thakur M, Beck-Sickinger A, Fournier A and Quirion R. (2003) Development and characterization of a highly selective neuropeptide Y Y5 receptor agonist radioligand: [125I][hPP1-17, Ala31, Aib32]NPY. *Br J Pharmacol* **139**: 1360-8 [PMID:12890716]
59. Eberlein GA, Eysselein VE, Schaeffer M, Layer P, Grandt D, Goebell H, Niebel W, Davis M, Lee TD and Shively JE *et al.* (1989) A new molecular form of PYY: structural characterization of human PYY(3-36) and PYY(1-36). *Peptides* **10**: 797-803 [PMID:2587421]
60. Ekstrand AJ, Cao R, Bjorndahl M, Nystrom S, Jonsson-Rylander AC, Hassani H, Hallberg B, Nordlander M and Cao Y. (2003) Deletion of neuropeptide Y (NPY) 2 receptor in mice results in blockage of NPY-induced angiogenesis and delayed wound healing. *Proc Natl Acad Sci USA* **100**: 6033-8 [PMID:12730369]
61. El Bahh B, Balosso S, Hamilton T, Herzog H, Beck-Sickinger AG, Sperk G, Gehlert DR, Vezzani A and Colmers WF. (2005) The anti-epileptic actions of neuropeptide Y in the hippocampus are mediated by Y and not Y receptors. *Eur J Neurosci* **22**: 1417-30 [PMID:16190896]
62. Eriksson H, Berglund MM, Holmberg SK, Kahl U, Gehlert DR and Larhammar D. (1998) The cloned guinea pig pancreatic polypeptide receptor Y4 resembles more the human Y4 than does the rat Y4. *Regul Pept* **75-76**: 29-37 [PMID:9802391]
63. Eva C, Keinänen K, Monyer H, Seeburg P and Sprengel R. (1990) Molecular cloning of a novel G protein-coupled receptor that may belong to the neuropeptide receptor family. *FEBS Lett* **271**: 81-4 [PMID:2172008]
64. Eva C, Oberto A, Sprengel R and Genazzani E. (1992) The murine NPY-1 receptor gene. Structure and delineation of tissue-specific expression. *FEBS Lett* **314**: 285-8 [PMID:1468559]
65. Ewald DA, Sternweis PC and Miller RJ. (1988) Guanine nucleotide-binding protein Go-induced coupling of neuropeptide Y receptors to Ca²⁺ channels in sensory neurons. *Proc Natl Acad Sci USA* **85**: 3633-7 [PMID:2453065]
66. Ferrier L, Segain JP, Bonnet C, Cherbut C, Lehur PA, Jarry A, Galmiche JP and Blottiere HM. (2002) Functional mapping of NPY/PYY receptors in rat and human gastro-intestinal tract. *Peptides* **23**: 1765-71 [PMID:12383864]
67. Fetissov SO, Byrne LC, Hassani H, Ernfors P and Hökfelt T. (2004) Characterization of neuropeptide Y Y2 and Y5 receptor expression in the mouse hypothalamus. *J Comp Neurol* **470**: 256-65 [PMID:14755515]
68. Fuhlendorff J, Gether U, Aakerlund L, Langeland-Johansen N, Thøgersen H, Melberg SG, Olsen UB, Thastrup O and Schwartz TW. (1990) [Leu31, Pro34]neuropeptide Y: a specific Y1 receptor agonist. *Proc Natl Acad Sci USA* **87**: 182-6 [PMID:2153286]
69. Fujimiya M, Itoh E, Kihara N, Yamamoto I, Fujimura M and Inui A. (2000) Neuropeptide Y induces fasted pattern of duodenal motility via Y(2) receptors in conscious fed rats. *Am J Physiol Gastrointest Liver Physiol* **278**: G32-8 [PMID:10644559]
70. Félétou M, Rodriguez M, Beauverger P, Germain M, Imbert J, Dromaint S, Macia C, Bourrienne A, Henlin JM and Nicolas JP *et al.* (1998) NPY receptor subtypes involved in the contraction of the proximal colon of the rat. *Regul Pept* **75-76**: 221-9 [PMID:9802413]
71. Gao J, Ghibaudi L and Hwa JJ. (2004) Selective activation of central NPY Y1 vs. Y5 receptor elicits hyperinsulinemia via distinct mechanisms. *Am J Physiol Endocrinol Metab* **287**: E706-11 [PMID:15187000]
72. Gehlert DR, Beavers LS, Johnson D, Gackenhaimer SL, Schober DA and Gadski RA. (1996) Expression cloning of a human brain neuropeptide Y Y2 receptor. *Mol Pharmacol* **49**: 224-8 [PMID:8632753]
73. Gehlert DR, Schober DA, Gackenhaimer SL, Beavers L, Gadski R, Lundell I and Larhammar D. (1997) [125I]Leu31, Pro34-PYY is a high affinity radioligand for rat PP1/Y4 and Y1 receptors: evidence for heterogeneity in pancreatic polypeptide receptors. *Peptides* **18**: 397-401 [PMID:9145427]
74. Gerald C, Walker MW, Criscione L, Gustafson EL, Batzl-Hartmann C, Smith KE, Vaysse P, Durkin MM, Laz TM and Linemeyer DL *et al.* (1996) A receptor subtype involved in neuropeptide-Y-induced food intake. *Nature* **382**: 168-71 [PMID:8700207]

75. Gerald C, Walker MW, Vaysse PJ, He C, Branchek TA and Weinshank RL. (1995) Expression cloning and pharmacological characterization of a human hippocampal neuropeptide Y/peptide YY Y2 receptor subtype. *J Biol Chem* **270**: 26758-61 [PMID:7592910]
76. Gonzales C, Voirol MJ, Giacomini M, Gaillard RC, Pedrazzini T and Pralong FP. (2004) The neuropeptide Y Y1 receptor mediates NPY-induced inhibition of the gonadotrope axis under poor metabolic conditions. *FASEB J* **18**: 137-9 [PMID:14597564]
77. Goumain M, Voisin T, Lorinet AM, Ducroc R, Tsocas A, Rozé C, Rouet-Benzineb P, Herzog H, Balasubramaniam A and Laburthe M. (2001) The peptide YY-preferring receptor mediating inhibition of small intestinal secretion is a peripheral Y(2) receptor: pharmacological evidence and molecular cloning. *Mol Pharmacol* **60**: 124-34 [PMID:11408607]
78. Goumain M, Voisin T, Lorinet AM and Laburthe M. (1998) Identification and distribution of mRNA encoding the Y1, Y2, Y4, and Y5 receptors for peptides of the PP-fold family in the rat intestine and colon. *Biochem Biophys Res Commun* **247**: 52-6 [PMID:9636652]
79. Grandt D, Feth F, Rascher W, Reeve Jr JR, Schlicker E, Schimiczek M, Layer P, Goebell H, Eysselein VE and Michel MC. (1994) [Pro34]peptide YY is a Y1-selective agonist at peptide YY/neuropeptide Y receptors. *Eur J Pharmacol* **269**: 127-32 [PMID:7851489]
80. Grandt D, Schimiczek M, Beglinger C, Layer P, Goebell H, Eysselein VE and Reeve Jr JR. (1994) Two molecular forms of peptide YY (PYY) are abundant in human blood: characterization of a radioimmunoassay recognizing PYY 1-36 and PYY 3-36. *Regul Pept* **51**: 151-9 [PMID:8059011]
81. Grandt D, Schimiczek M, Rascher W, Feth F, Shively J, Lee TD, Davis MT, Reeve Jr JR and Michel MC. (1996) Neuropeptide Y 3-36 is an endogenous ligand selective for Y2 receptors. *Regul Pept* **67**: 33-7 [PMID:8952003]
82. Greco B and Carli M. (2006) Reduced attention and increased impulsivity in mice lacking NPY Y2 receptors: relation to anxiolytic-like phenotype. *Behav Brain Res* **169**: 325-34 [PMID:16529827]
83. Gregor P, Feng Y, DeCarr LB, Cornfield LJ and McCaleb ML. (1996) Molecular characterization of a second mouse pancreatic polypeptide receptor and its inactivated human homologue. *J Biol Chem* **271**: 27776-27781 [PMID:8910373]
84. Gregor P, Millham ML, Feng Y, DeCarr LB, McCaleb ML and Cornfield LJ. (1996) Cloning and characterization of a novel receptor to pancreatic polypeptide, a member of the neuropeptide Y receptor family. *FEBS Lett* **381**: 58-62 [PMID:8641440]
85. Grundemar L, Wahlestedt C and Reis DJ. (1991) Neuropeptide Y acts at an atypical receptor to evoke cardiovascular depression and to inhibit glutamate responsiveness in the brainstem. *J Pharmacol Exp Ther* **258**: 633-8 [PMID:1678015]
86. Guo H, Castro PA, Palmiter RD and Baraban SC. (2002) Y5 receptors mediate neuropeptide Y actions at excitatory synapses in area CA3 of the mouse hippocampus. *J Neurophysiol* **87**: 558-66 [PMID:11784771]
87. Gustafson EL, Smith KE, Durkin MM, Walker MW, Gerald C, Weinshank R and Branchek TA. (1997) Distribution of the neuropeptide Y Y2 receptor mRNA in rat central nervous system. *Brain Res Mol Brain Res* **46**: 223-35 [PMID:9191097]
88. Han S, Chen X, Cox B, Yang CL, Wu YM, Naes L and Westfall T. (1998) Role of neuropeptide Y in cold stress-induced hypertension. *Peptides* **19**: 351-8 [PMID:9493868]
89. Hansel DE, Eipper BA and Ronnett GV. (2001) Neuropeptide Y functions as a neuroproliferative factor. *Nature* **410**: 940-4 [PMID:11309620]
90. Hastings JA, Morris MJ, Lambert G, Lambert E and Esler M. (2004) NPY and NPY Y1 receptor effects on noradrenaline overflow from the rat brain in vitro. *Regul Pept* **120**: 107-12 [PMID:15177927]
91. Haynes AC, Arch JR, Wilson S, McClue S and Buckingham RE. (1998) Characterisation of the neuropeptide Y receptor that mediates feeding in the rat: a role for the Y5 receptor? *Regul Pept* **75-76**: 355-61 [PMID:9802429]
92. Haynes JM, Hill SJ and Selbie LA. (1997) Neuropeptide Y (NPY) and peptide YY (PYY) effects in the epididymis of the guinea-pig: evidence of a pre-junctional PYY-selective receptor. *Br J Pharmacol* **122**: 1530-6 [PMID:9421306]
93. Hegde SS, Bonhaus DW, Stanley W, Eglen RM, Moy TM, Loeb M, Shetty SG, DeSouza A and Krstenansky J. (1995) Pharmacological evaluation of 1229U91, a novel high-affinity and selective neuropeptide Y-Y1 receptor antagonist. *J Pharmacol Exp Ther* **275**: 1261-6 [PMID:8531090]
94. Heilig M. (2004) The NPY system in stress, anxiety and depression. *Neuropeptides* **38**: 213-224 [PMID:15337373]

95. Herzog H, Baumgartner M, Vivero C, Selbie LA, Auer B and Shine J. (1993) Genomic organization, localization, and allelic differences in the gene for the human neuropeptide Y Y1 receptor. *J Biol Chem* **268**: 6703-7 [PMID:8095935]
96. Herzog H, Hort YJ, Ball HJ, Hayes G, Shine J and Selbie LA. (1992) Cloned human neuropeptide Y receptor couples to two different second messenger systems. *Proc Natl Acad Sci USA* **89**: 5794-8 [PMID:1321422]
97. Herzog H, Hort YJ, Shine J and Selbie LA. (1993) Molecular cloning, characterization, and localization of the human homolog to the reported bovine NPY Y3 receptor: lack of NPY binding and activation. *DNA Cell Biol* **12**: 465-71 [PMID:8329116]
98. Holliday ND and Cox HM. (1996) The functional investigation of a human adenocarcinoma cell line, stably transfected with the neuropeptide Y Y1 receptor. *Br J Pharmacol* **119**: 321-9 [PMID:8886416]
99. Horvath TL, Pu S, Dube MG, Diano S and Kalra SP. (2001) A GABA-neuropeptide Y (NPY) interplay in LH release. *Peptides* **22**: 473-81 [PMID:11287104]
100. Howell OW, Doyle K, Goodman JH, Scharfman HE, Herzog H, Pringle A, Beck-Sickinger AG and Gray WP. (2005) Neuropeptide Y stimulates neuronal precursor proliferation in the post-natal and adult dentate gyrus. *J Neurochem* **93**: 560-70 [PMID:15836615]
101. Hu Y, Bloomquist BT, Cornfield LJ, DeCarr LB, Flores-Riveros JR, Friedman L, Jiang P, Lewis-Higgins L, Sadlowski Y and Schaefer J *et al.*. (1996) Identification of a novel hypothalamic neuropeptide Y receptor associated with feeding behavior. *J Biol Chem* **271**: 26315-9 [PMID:8824284]
102. Hua XY, Boublik JH, Spicer MA, Rivier JE, Brown MR and Yaksh TL. (1991) The antinociceptive effects of spinally administered neuropeptide Y in the rat: systematic studies on structure-activity relationship. *J Pharmacol Exp Ther* **258**: 243-8 [PMID:1677040]
103. Hwa JJ, Witten MB, Williams P, Ghibaudi L, Gao J, Salisbury BG, Mullins D, Hamud F, Strader CD and Parker EM. (1999) Activation of the NPY Y5 receptor regulates both feeding and energy expenditure. *Am J Physiol* **277**: R1428-34 [PMID:10564216]
104. Hyland NP, Sjöberg F, Tough IR, Herzog H and Cox HM. (2003) Functional consequences of neuropeptide Y Y2 receptor knockout and Y2 antagonism in mouse and human colonic tissues. *Br J Pharmacol* **139**: 863-71 [PMID:12813010]
105. Ishihara A, Kanatani A, Mashiko S, Tanaka T, Hidaka M, Gomori A, Iwaasa H, Murai N, Egashira S and Murai T *et al.*. (2006) A neuropeptide Y Y5 antagonist selectively ameliorates body weight gain and associated parameters in diet-induced obese mice. *Proc Natl Acad Sci USA* **103**: 7154-8 [PMID:16636293]
106. Jain MR, Pu S, Kalra PS and Kalra SP. (1999) Evidence that stimulation of two modalities of pituitary luteinizing hormone release in ovarian steroid-primed ovariectomized rats may involve neuropeptide Y Y1 and Y4 receptors. *Endocrinology* **140**: 5171-7 [PMID:10537146]
107. Jazin EE, Yoo H, Blomqvist AG, Yee F, Weng G, Walker MW, Salon J, Larhammar D and Wahlestedt C. (1993) A proposed bovine neuropeptide Y (NPY) receptor cDNA clone, or its human homologue, confers neither NPY binding sites nor NPY responsiveness on transfected cells. *Regul Pept* **47**: 247-58 [PMID:8234909]
108. Jönsson-Rylander AC, Nordlander M, Svindland A and Ilebekk A. (2003) Distribution of neuropeptide Y Y1 and Y2 receptors in the postmortem human heart. *Peptides* **24**: 255-62 [PMID:12668210]
109. Kaga T, Fujimiya M and Inui A. (2001) Emerging functions of neuropeptide Y Y(2) receptors in the brain. *Peptides* **22**: 501-6 [PMID:11287107]
110. Kakui N, Tanaka J, Tabata Y, Asai K, Masuda N, Miyara T, Nakatani Y, Ohsawa F, Nishikawa N and Sugai M *et al.*. (2006) Pharmacological characterization and feeding-suppressive property of FMS586 [3-(5,6,7,8-tetrahydro-9-isopropyl-carbazol-3-yl)-1-methyl-1-(2-pyridin-4-yl-ethyl)-urea hydrochloride], a novel, selective, and orally active antagonist for neuropeptide Y Y5 receptor. *J Pharmacol Exp Ther* **317**: 562-70 [PMID:16436501]
111. Kanatani A, Hata M, Mashiko S, Ishihara A, Okamoto O, Haga Y, Ohe T, Kanno T, Murai N and Ishii Y *et al.*. (2001) A typical Y1 receptor regulates feeding behaviors: effects of a potent and selective Y1 antagonist, J-115814. *Mol Pharmacol* **59**: 501-5 [PMID:11179445]
112. Kanatani A, Ishihara A, Iwaasa H, Nakamura K, Okamoto O, Hidaka M, Ito J, Fukuroda T, MacNeil DJ and Van der Ploeg LH *et al.*. (2000) L-152,804: orally active and selective neuropeptide Y Y5 receptor antagonist. *Biochem Biophys Res Commun* **272**: 169-73 [PMID:10872822]
113. Kanatani A, Mashiko S, Murai N, Sugimoto N, Ito J, Fukuroda T, Fukami T, Morin N, MacNeil DJ and Van der Ploeg LH *et al.*. (2000) Role of the Y1 receptor in the regulation of neuropeptide Y-mediated feeding:

- comparison of wild-type, Y1 receptor-deficient, and Y5 receptor-deficient mice. *Endocrinology* **141**: 1011-6 [PMID:10698177]
114. Kang H, Park C, Choi YK, Bae J, Kwon S, Kim J, Choi C, Seok C, Im W and Choi HJ. (2023) Structural basis for Y2 receptor-mediated neuropeptide Y and peptide YY signaling. *Structure* **31**: 44-57.e6 [PMID:36525977]
115. Karl T, Burne TH and Herzog H. (2006) Effect of Y1 receptor deficiency on motor activity, exploration, and anxiety. *Behav Brain Res* **167**: 87-93 [PMID:16203045]
116. Karl T, Lin S, Schwarzer C, Sainsbury A, Couzens M, Wittmann W, Boey D, von Hörsten S and Herzog H. (2004) Y1 receptors regulate aggressive behavior by modulating serotonin pathways. *Proc Natl Acad Sci USA* **101**: 12742-7 [PMID:15314215]
117. Kask A, Rågo L and Harro J. (1998) Anxiogenic-like effect of the NPY Y1 receptor antagonist BIBP3226 administered into the dorsal periaqueductal gray matter in rats. *Regul Pept* **75-76**: 255-62 [PMID:9802417]
118. Kask A, Rågo L and Harro J. (1998) Anxiolytic-like effect of neuropeptide Y (NPY) and NPY13-36 microinjected into vicinity of locus coeruleus in rats. *Brain Res* **788**: 345-8 [PMID:9555090]
119. Kask A, Vasar E, Heidmets LT, Allikmets L and Wikberg JE. (2001) Neuropeptide Y Y(5) receptor antagonist CGP71683A: the effects on food intake and anxiety-related behavior in the rat. *Eur J Pharmacol* **414**: 215-24 [PMID:11239922]
120. Keffel S, Schmidt M, Bischoff A and Michel MC. (1999) Neuropeptide-Y stimulation of extracellular signal-regulated kinases in human erythroleukemia cells. *J Pharmacol Exp Ther* **291**: 1172-8 [PMID:10565839]
121. Klapstein GJ and Colmers WF. (1993) On the sites of presynaptic inhibition by neuropeptide Y in rat hippocampus in vitro. *Hippocampus* **3**: 103-11 [PMID:8395947]
122. Kojima S, Ueno N, Asakawa A, Sagiya K, Naruo T, Mizuno S and Inui A. (2007) A role for pancreatic polypeptide in feeding and body weight regulation. *Peptides* **28**: 459-63 [PMID:17207558]
123. Krause J, Eva C, Seeburg PH and Sprengel R. (1992) Neuropeptide Y1 subtype pharmacology of a recombinantly expressed neuropeptide receptor. *Mol Pharmacol* **41**: 817-21 [PMID:1316999]
124. Kushi A, Sasai H, Koizumi H, Takeda N, Yokoyama M and Nakamura M. (1998) Obesity and mild hyperinsulinemia found in neuropeptide Y-Y1 receptor-deficient mice. *Proc Natl Acad Sci USA* **95**: 15659-64 [PMID:9861026]
125. Larhammar D. (1996) Evolution of neuropeptide Y, peptide YY and pancreatic polypeptide. *Regul Pept* **62**: 1-11 [PMID:8738876]
126. Larhammar D, Blomqvist AG, Yee F, Jazin E, Yoo H and Wahlested C. (1992) Cloning and functional expression of a human neuropeptide Y/peptide YY receptor of the Y1 type. *J Biol Chem* **267**: 10935-8 [PMID:1317848]
127. Larhammar D and Salaneck E. (2004) Molecular evolution of NPY receptor subtypes. *Neuropeptides* **38**: 141-51 [PMID:15337367]
128. Larsen PJ and Kristensen P. (1998) Distribution of neuropeptide Y receptor expression in the rat suprachiasmatic nucleus. *Brain Res Mol Brain Res* **60**: 69-76 [PMID:9748510]
129. Larsen PJ and Kristensen P. (1997) The neuropeptide Y (Y4) receptor is highly expressed in neurones of the rat dorsal vagal complex. *Brain Res Mol Brain Res* **48**: 1-6 [PMID:9379829]
130. Lavebratt C, Alpman A, Persson B, Arner P and Hoffstedt J. (2006) Common neuropeptide Y2 receptor gene variant is protective against obesity among Swedish men. *Int J Obes (Lond.)* **30**: 453-9 [PMID:16331299]
131. Lee EW, Grant DS, Movafagh S and Zukowska Z. (2003) Impaired angiogenesis in neuropeptide Y (NPY)-Y2 receptor knockout mice. *Peptides* **24**: 99-106 [PMID:12576090]
132. Lee EW, Michalkiewicz M, Kitlinska J, Kalezic I, Switalska H, Yoo P, Sangkharat A, Ji H, Li L and Michalkiewicz T *et al.* (2003) Neuropeptide Y induces ischemic angiogenesis and restores function of ischemic skeletal muscles. *J Clin Invest* **111**: 1853-62 [PMID:12813021]
133. Levine AS and Morley JE. (1984) Neuropeptide Y: a potent inducer of consummatory behavior in rats. *Peptides* **5**: 1025-9 [PMID:6549409]
134. Li JJ, Zhou X and Yu LC. (2005) Involvement of neuropeptide Y and Y1 receptor in antinociception in the arcuate nucleus of hypothalamus, an immunohistochemical and pharmacological study in intact rats and rats with inflammation. *Pain* **118**: 232-42 [PMID:16216414]
135. Limbird LE. (1988) Receptors linked to inhibition of adenylate cyclase: additional signaling

- mechanisms. *FASEB J* **2**: 2686-95 [PMID:2840317]
136. Lin EJ, Young D, Baer K, Herzog H and During MJ. (2006) Differential actions of NPY on seizure modulation via Y1 and Y2 receptors: evidence from receptor knockout mice. *Epilepsia* **47**: 773-80 [PMID:16650144]
 137. Lin HC, Neevel C and Chen JH. (2004) Slowing intestinal transit by PYY depends on serotonergic and opioid pathways. *Am J Physiol Gastrointest Liver Physiol* **286**: G558-63 [PMID:15010361]
 138. Lin S, Boey D and Herzog H. (2004) NPY and Y receptors: lessons from transgenic and knockout models. *Neuropeptides* **38**: 189-200 [PMID:15337371]
 139. Loetscher M, Geiser T, O'Reilly T, Zwahlen R, Baggiolini M and Moser B. (1994) Cloning of a human seven-transmembrane domain receptor, LESTR, that is highly expressed in leukocytes. *J Biol Chem* **269**: 232-7 [PMID:8276799]
 140. Lundberg JM. (1996) Pharmacology of cotransmission in the autonomic nervous system: integrative aspects on amines, neuropeptides, adenosine triphosphate, amino acids and nitric oxide. *Pharmacol Rev* **48**: 113-78 [PMID:8685245]
 141. Lundberg JM and Tatemoto K. (1982) Pancreatic polypeptide family (APP, BPP, NPY and PYY) in relation to sympathetic vasoconstriction resistant to alpha-adrenoceptor blockade. *Acta Physiol Scand* **116**: 393-402 [PMID:6133408]
 142. Lundell I, Blomqvist AG, Berglund MM, Schober DA, Johnson D, Statnick MA, Gadski RA, Gehlert DR and Larhammar D. (1995) Cloning of a human receptor of the NPY receptor family with high affinity for pancreatic polypeptide and peptide YY. *J Biol Chem* **270**: 29123-8 [PMID:7493937]
 143. Lundell I, Statnick MA, Johnson D, Schober DA, Starbäck P, Gehlert DR and Larhammar D. (1996) The cloned rat pancreatic polypeptide receptor exhibits profound differences to the orthologous receptor. *Proc Natl Acad Sci USA* **93**: 5111-5 [PMID:8643536]
 144. Lutz CM, Frankel WN, Richards JE and Thompson DA. (1997) Neuropeptide Y receptor genes on human chromosome 4q31-q32 map to conserved linkage groups on mouse chromosomes 3 and 8. *Genomics* **41**: 498-500 [PMID:9169155]
 145. Lynch JW, Lemos VS, Bucher B, Stoclet JC and Takeda K. (1994) A pertussis toxin-insensitive calcium influx mediated by neuropeptide Y2 receptors in a human neuroblastoma cell line. *J Biol Chem* **269**: 8226-33 [PMID:8132547]
 146. Mahinda TB and Taylor BK. (2004) Intrathecal neuropeptide Y inhibits behavioral and cardiovascular responses to noxious inflammatory stimuli in awake rats. *Physiol Behav* **80**: 703-11 [PMID:14984805]
 147. Marsh DJ, Baraban SC, Holoopeter G and Palmiter RD. (1999) Role of the Y5 neuropeptide Y receptor in limbic seizures. *Proc Natl Acad Sci USA* **96**: 13518-23 [PMID:10557353]
 148. Marsh DJ, Holoopeter G, Kafer KE and Palmiter RD. (1998) Role of the Y5 neuropeptide Y receptor in feeding and obesity. *Nat Med* **4**: 718-21 [PMID:9623983]
 149. Martin SE and Patterson RE. (1989) Coronary constriction due to neuropeptide Y: alleviation with cyclooxygenase blockers. *Am J Physiol* **257**: H927-34 [PMID:2506768]
 150. Mashiko S, Ishihara A, Iwaasa H, Sano H, Oda Z, Ito J, Yumoto M, Okawa M, Suzuki J and Fukuroda T *et al.* (2003) Characterization of neuropeptide Y (NPY) Y5 receptor-mediated obesity in mice: chronic intracerebroventricular infusion of D-Trp(34)NPY. *Endocrinology* **144**: 1793-801 [PMID:12697685]
 151. Matsuda H, Brumovsky PR, Kopp J, Pedrazzini T and Hökfelt T. (2002) Distribution of neuropeptide Y Y1 receptors in rodent peripheral tissues. *J Comp Neurol* **449**: 390-404 [PMID:12115674]
 152. Matsumoto M, Nomura T, Momose K, Ikeda Y, Kondou Y, Akiho H, Togami J, Kimura Y, Okada M and Yamaguchi T. (1996) Inactivation of a novel neuropeptide Y/peptide YY receptor gene in primate species. *J Biol Chem* **271**: 27217-27220 [PMID:8910290]
 153. McCullough LA and Westfall TC. (1995) Neuropeptide Y inhibits depolarization-stimulated catecholamine synthesis in rat pheochromocytoma cells. *Eur J Pharmacol* **287**: 271-7 [PMID:8991801]
 154. McDonald JK, Lumpkin MD, Samson WK and McCann SM. (1985) Neuropeptide Y affects secretion of luteinizing hormone and growth hormone in ovariectomized rats. *Proc Natl Acad Sci USA* **82**: 561-4 [PMID:3855566]
 155. Medanic M and Gillette MU. (1993) Suprachiasmatic circadian pacemaker of rat shows two windows of sensitivity to neuropeptide Y in vitro. *Brain Res* **620**: 281-6 [PMID:8369959]
 156. Mentlein R, Dahms P, Grandt D and Krüger R. (1993) Proteolytic processing of neuropeptide Y and peptide YY by dipeptidyl peptidase IV. *Regul Pept* **49**: 133-44 [PMID:7907802]
 157. Michel MC. (2004) Neuropeptide Y and the Kidney. In *Neuropeptide Y and Related Peptides (Handbook of*

Experimental Pharmacology) Vol. 162 **162**: Edited by Michel MC: Springer-Verlag: 362-387 [ISBN: 354040581X]

158. Michel MC, Beck-Sickinge A, Cox H, Doods HN, Herzog H, Larhammar D, Quirion R, Schwartz T and Westfall T. (1998) XVI. International Union of Pharmacology recommendations for the nomenclature of neuropeptide Y, peptide YY, and pancreatic polypeptide receptors. *Pharmacol Rev* **50**: 143-50 [PMID:9549761]
159. Michel MC and Rascher W. (1995) Neuropeptide Y: a possible role in hypertension? *J Hypertens* **13**: 385-95 [PMID:7629398]
160. Millar BC, Weis T, Piper HM, Weber M, Borchard U, McDermott BJ and Balasubramaniam A. (1991) Positive and negative contractile effects of neuropeptide Y on ventricular cardiomyocytes. *Am J Physiol* **261**: H1727-33 [PMID:1661086]
161. Misra S, Murthy KS, Zhou H and Grider JR. (2004) Coexpression of Y1, Y2, and Y4 receptors in smooth muscle coupled to distinct signaling pathways. *J Pharmacol Exp Ther* **311**: 1154-62 [PMID:15308651]
162. Motulsky HJ and Michel MC. (1988) Neuropeptide Y mobilizes Ca²⁺ and inhibits adenylate cyclase in human erythroleukemia cells. *Am J Physiol* **255**: E880-5 [PMID:3202164]
163. Mousli M and Landry Y. (1994) Role of positive charges of neuropeptide Y fragments in mast cell activation. *Agents Actions* **41 Spec No**: C41-2 [PMID:7526655]
164. Nakajima M, Inui A, Asakawa A, Momose K, Ueno N, Teranishi A, Baba S and Kasuga M. (1998) Neuropeptide Y produces anxiety via Y2-type receptors. *Peptides* **19**: 359-63 [PMID:9493869]
165. Nakamura M, Aoki Y and Hirano D. (1996) Cloning and functional expression of a cDNA encoding a mouse type 2 neuropeptide Y receptor. *Biochim Biophys Acta* **1284**: 134-7 [PMID:8914576]
166. Nakamura M, Sakanaka C, Aoki Y, Ogasawara H, Tsuji T, Kodama H, Matsumoto T, Shimizu T and Noma M. (1995) Identification of two isoforms of mouse neuropeptide Y-Y1 receptor generated by alternative splicing. Isolation, genomic structure, and functional expression of the receptors. *J Biol Chem* **270**: 30102-30110 [PMID:8530415]
167. Nakamura M, Yokoyama M, Watanabe H and Matsumoto T. (1997) Molecular cloning, organization and localization of the gene for the mouse neuropeptide Y-Y5 receptor. *Biochim Biophys Acta* **1328**: 83-9 [PMID:9315606]
168. Naveilhan P, Canals JM, Arenas E and Ernfors P. (2001) Distinct roles of the Y1 and Y2 receptors on neuropeptide Y-induced sensitization to sedation. *J Neurochem* **78**: 1201-1207 [PMID:11579129]
169. Naveilhan P, Canals JM, Valjakka A, Vartiainen J, Arenas E and Ernfors P. (2001) Neuropeptide Y alters sedation through a hypothalamic Y1-mediated mechanism. *Eur J Neurosci* **13**: 2241-6 [PMID:11454027]
170. Naveilhan P, Hassani H, Lucas G, Blakeman KH, Hao JX, Xu XJ, Wiesenfeld-Hallin Z, Thorén P and Ernfors P. (2001) Reduced antinociception and plasma extravasation in mice lacking a neuropeptide Y receptor. *Nature* **409**: 513-7 [PMID:11206547]
171. Nörenberg W, Bek M, Limberger N, Takeda K and Illes P. (1995) Inhibition of nicotinic acetylcholine receptor channels in bovine adrenal chromaffin cells by Y3-type neuropeptide Y receptors via the adenylate cyclase/protein kinase A system. *Naunyn Schmiedebergs Arch Pharmacol* **351**: 337-47 [PMID:7543184]
172. Parker RM and Herzog H. (1999) Regional distribution of Y-receptor subtype mRNAs in rat brain. *Eur J Neurosci* **11**: 1431-1448 [PMID:10103138]
173. Pedrazzini T. (2004) Importance of NPY Y1 receptor-mediated pathways: assessment using NPY Y1 receptor knockouts. *Neuropeptides* **38**: 267-75 [PMID:15337379]
174. Pedrazzini T, Pralong F and Grouzmann E. (2003) Neuropeptide Y: the universal soldier. *Cell Mol Life Sci* **60**: 350-77 [PMID:12678499]
175. Pedrazzini T, Seydoux J, Künstner P, Aubert JF, Grouzmann E, Beermann F and Brunner HR. (1998) Cardiovascular response, feeding behavior and locomotor activity in mice lacking the NPY Y1 receptor. *Nat Med* **4**: 722-6 [PMID:9623984]
176. Perney TM and Miller RJ. (1989) Two different G-proteins mediate neuropeptide Y and bradykinin-stimulated phospholipid breakdown in cultured rat sensory neurons. *J Biol Chem* **264**: 7317-27 [PMID:2540185]
177. Petitto JM, Huang Z and McCarthy DB. (1994) Molecular cloning of NPY-Y1 receptor cDNA from rat splenic lymphocytes: evidence of low levels of mRNA expression and [125I]NPY binding sites. *J Neuroimmunol* **54**: 81-6 [PMID:7929806]
178. Pheng LH, Perron A, Quirion R, Cadieux A, Fauchère JL, Dumont Y and Regoli D. (1999) Neuropeptide Y-

- induced contraction is mediated by neuropeptide Y Y2 and Y4 receptors in the rat colon. *Eur J Pharmacol* **374**: 85-91 [PMID:10422644]
179. Polidori C, Ciccocioppo R, Regoli D and Massi M. (2000) Neuropeptide Y receptor(s) mediating feeding in the rat: characterization with antagonists. *Peptides* **21**: 29-35 [PMID:10704716]
 180. Pralong FP, Gonzales C, Voirol MJ, Palmiter RD, Brunner HR, Gaillard RC, Seydoux J and Pedrazzini T. (2002) The neuropeptide Y Y1 receptor regulates leptin-mediated control of energy homeostasis and reproductive functions. *FASEB J* **16**: 712-4 [PMID:11978737]
 181. Raposinho PD, Broqua P, Hayward A, Akinsanya K, Galyean R, Schteingart C, Junien J and Aubert ML. (2000) Stimulation of the gonadotropic axis by the neuropeptide Y receptor Y1 antagonist/Y4 agonist 1229U91 in the male rat. *Neuroendocrinology* **71**: 2-7 [PMID:10644893]
 182. Raposinho PD, Broqua P, Pierroz DD, Hayward A, Dumont Y, Quirion R, Junien JL and Aubert ML. (1999) Evidence that the inhibition of luteinizing hormone secretion exerted by central administration of neuropeptide Y (NPY) in the rat is predominantly mediated by the NPY-Y5 receptor subtype. *Endocrinology* **140**: 4046-55 [PMID:10465275]
 183. Redrobe JP, Dumont Y, Herzog H and Quirion R. (2003) Neuropeptide Y (NPY) Y2 receptors mediate behaviour in two animal models of anxiety: evidence from Y2 receptor knockout mice. *Behav Brain Res* **141**: 251-5 [PMID:12742262]
 184. Redrobe JP, Dumont Y, Herzog H and Quirion R. (2004) Characterization of neuropeptide Y, Y(2) receptor knockout mice in two animal models of learning and memory processing. *J Mol Neurosci* **22**: 159-66 [PMID:14997009]
 185. Renshaw D, Thomson LM, Carroll M, Kapas S and Hinson JP. (2000) Actions of neuropeptide Y on the rat adrenal cortex. *Endocrinology* **141**: 169-73 [PMID:10614636]
 186. Rimland J, Xin W, Sweetnam P, Saijoh K, Nestler EJ and Duman RS. (1991) Sequence and expression of a neuropeptide Y receptor cDNA. *Mol Pharmacol* **40**: 869-75 [PMID:1661837]
 187. Rimland JM, Seward EP, Humbert Y, Ratti E, Trist DG and North RA. (1996) Coexpression with potassium channel subunits used to clone the Y2 receptor for neuropeptide Y. *Mol Pharmacol* **49**: 387-90 [PMID:8643076]
 188. Rose PM, Fernandes P, Lynch JS, Frazier ST, Fisher SM, Kodukula K, Kienzle B and Seethala R. (1995) Cloning and functional expression of a cDNA encoding a human type 2 neuropeptide Y receptor. *J Biol Chem* **270**: 22661-4 [PMID:7559383]
 189. Sainsbury A, Bergen HT, Boey D, Bamming D, Cooney GJ, Lin S, Couzens M, Stroth N, Lee NJ and Lindner D *et al.* (2006) Y2Y4 receptor double knockout protects against obesity due to a high-fat diet or Y1 receptor deficiency in mice. *Diabetes* **55**: 19-26 [PMID:16380472]
 190. Sainsbury A, Rohner-Jeanrenaud F, Cusin I, Zakrzewska KE, Halban PA, Gaillard RC and Jeanrenaud B. (1997) Chronic central neuropeptide Y infusion in normal rats: status of the hypothalamo-pituitary-adrenal axis, and vagal mediation of hyperinsulinaemia. *Diabetologia* **40**: 1269-77 [PMID:9389418]
 191. Sainsbury A, Schwarzer C, Couzens M, Fetissov S, Furlinger S, Jenkins A, Cox HM, Sperk G, Hökfelt T and Herzog H. (2002) Important role of hypothalamic Y2 receptors in body weight regulation revealed in conditional knockout mice. *Proc Natl Acad Sci USA* **99**: 8938-43 [PMID:12072562]
 192. Sainsbury A, Schwarzer C, Couzens M, Jenkins A, Oakes SR, Ormandy CJ and Herzog H. (2002) Y4 receptor knockout rescues fertility in ob/ob mice. *Genes Dev* **16**: 1077-88 [PMID:12000791]
 193. Sajdyk TJ, Schober DA, Smiley DL and Gehlert DR. (2002) Neuropeptide Y-Y2 receptors mediate anxiety in the amygdala. *Pharmacol Biochem Behav* **71**: 419-23 [PMID:11830176]
 194. Schüß C, Vu O, Schubert M, Du Y, Mishra NM, Tough IR, Stichel J, Weaver CD, Emmitte KA and Cox HM *et al.* (2021) Highly Selective Y₄ Receptor Antagonist Binds in an Allosteric Binding Pocket. *J Med Chem* **64**: 2801-2814 [PMID:33595306]
 195. Schaffhauser AO, Stricker-Krongrad A, Brunner L, Cumin F, Gerald C, Whitebread S, Criscione L and Hofbauer KG. (1997) Inhibition of food intake by neuropeptide Y Y5 receptor antisense oligodeoxynucleotides. *Diabetes* **46**: 1792-8 [PMID:9356028]
 196. Schober DA, Van Abbema AM, Smiley DL, Bruns RF and Gehlert DR. (1998) The neuropeptide Y Y1 antagonist, 1229U91, a potent agonist for the human pancreatic polypeptide-preferring (NPY Y4) receptor. *Peptides* **19**: 537-42 [PMID:9533642]
 197. Schroeder JP, Overstreet DH and Hodge CW. (2005) The neuropeptide-Y Y5 receptor antagonist L-152,804 decreases alcohol self-administration in inbred alcohol-preferring (iP) rats. *Alcohol* **36**: 179-86 [PMID:16377459]

198. Schubert M, Stichel J, Du Y, Tough IR, Sliwoski G, Meiler J, Cox HM, Weaver CD and Beck-Sickingher AG. (2017) Identification and Characterization of the First Selective Y₄ Receptor Positive Allosteric Modulator. *J Med Chem* **60**: 7605-7612 [PMID:28795803]
199. Scott V, Kimura N, Stark JA and Luckman SM. (2005) Intravenous peptide YY3-36 and Y2 receptor antagonism in the rat: effects on feeding behaviour. *J Neuroendocrinol* **17**: 452-7 [PMID:15946163]
200. Shi TJ, Li J, Dahlström A, Theodorsson E, Ceccatelli S, Decosterd I, Pedrazzini T and Hökfelt T. (2006) Deletion of the neuropeptide Y Y1 receptor affects pain sensitivity, neuropeptide transport and expression, and dorsal root ganglion neuron numbers. *Neuroscience* **140**: 293-304 [PMID:16564642]
201. Shigeri Y and Fujimoto M. (1994) Y2 receptors for neuropeptide Y are coupled to three intracellular signal transduction pathways in a human neuroblastoma cell line. *J Biol Chem* **269**: 8842-8 [PMID:8132619]
202. Sjödin P, Holmberg SK, Akerberg H, Berglund MM, Mohell N and Larhammar D. (2006) Re-evaluation of receptor-ligand interactions of the human neuropeptide Y receptor Y1: a site-directed mutagenesis study. *Biochem J* **393**: 161-9 [PMID:16097949]
203. Smith-White MA, Herzog H and Potter EK. (2002) Cardiac function in neuropeptide Y Y4 receptor-knockout mice. *Regul Pept* **110**: 47-54 [PMID:12468109]
204. Soscia SJ and Harrington ME. (2005) Neuropeptide Y does not reset the circadian clock in NPY Y2-/- mice. *Neurosci Lett* **373**: 175-8 [PMID:15619538]
205. Sparta DR, Fee JR, Hayes DM, Knapp DJ, MacNeil DJ and Thiele TE. (2004) Peripheral and central administration of a selective neuropeptide Y Y1 receptor antagonist suppresses ethanol intake by C57BL/6J mice. *Alcohol Clin Exp Res* **28**: 1324-30 [PMID:15365302]
206. Stanic D, Brumovsky P, Fetissov S, Shuster S, Herzog H and Hökfelt T. (2006) Characterization of neuropeptide Y2 receptor protein expression in the mouse brain. I. Distribution in cell bodies and nerve terminals. *J Comp Neurol* **499**: 357-390 [PMID:16998904]
207. Stanley BG and Leibowitz SF. (1984) Neuropeptide Y: stimulation of feeding and drinking by injection into the paraventricular nucleus. *Life Sci* **35**: 2635-42 [PMID:6549039]
208. Sørensen G, Lindberg C, Wörtwein G, Bolwig TG and Woldbye DP. (2004) Differential roles for neuropeptide Y Y1 and Y5 receptors in anxiety and sedation. *J Neurosci Res* **77**: 723-9 [PMID:15352219]
209. Taiwo OB and Taylor BK. (2002) Antihyperalgesic effects of intrathecal neuropeptide Y during inflammation are mediated by Y1 receptors. *Pain* **96**: 353-63 [PMID:11973010]
210. Tang T, Hartig C, Chen Q, Zhao W, Kaiser A, Zhang X, Zhang H, Qu H, Yi C and Ma L *et al.*. (2021) Structural basis for ligand recognition of the neuropeptide Y Y₂ receptor. *Nat Commun* **12**: 737 [PMID:33531491]
211. Tang T, Tan Q, Han S, Diemar A, Löbner K, Wang H, Schüß C, Behr V, Mörl K and Wang M *et al.*. (2022) Receptor-specific recognition of NPY peptides revealed by structures of NPY receptors. *Sci Adv* **8**: eabm1232 [PMID:35507650]
212. Tang-Christensen M, Kristensen P, Stidsen CE, Brand CL and Larsen PJ. (1998) Central administration of Y5 receptor antisense decreases spontaneous food intake and attenuates feeding in response to exogenous neuropeptide Y. *J Endocrinol* **159**: 307-312 [PMID:9795372]
213. Thiele TE, Koh MT and Pedrazzini T. (2002) Voluntary alcohol consumption is controlled via the neuropeptide Y Y1 receptor. *J Neurosci* **22**: RC208-RC208 [PMID:11826154]
214. Thiele TE, Naveilhan P and Ernfors P. (2004) Assessment of ethanol consumption and water drinking by NPY Y(2) receptor knockout mice. *Peptides* **25**: 975-83 [PMID:15203244]
215. Thorsell A, Rimondini R and Heilig M. (2002) Blockade of central neuropeptide Y (NPY) Y2 receptors reduces ethanol self-administration in rats. *Neurosci Lett* **332**: 1-4 [PMID:12377370]
216. Toufexis DJ, Kyriazis D and Woodside B. (2002) Chronic neuropeptide Y Y5 receptor stimulation suppresses reproduction in virgin female and lactating rats. *J Neuroendocrinol* **14**: 492-497 [PMID:12047724]
217. Tough IR, Holliday ND and Cox HM. (2006) Y(4) receptors mediate the inhibitory responses of pancreatic polypeptide in human and mouse colon mucosa. *J Pharmacol Exp Ther* **319**: 20-30 [PMID:16807358]
218. Tschenett A, Singewald N, Carli M, Balducci C, Salchner P, Vezzani A, Herzog H and Sperk G. (2003) Reduced anxiety and improved stress coping ability in mice lacking NPY-Y2 receptors. *Eur J Neurosci* **18**: 143-8 [PMID:12859347]
219. Turnbull AV, Ellershaw L, Masters DJ, Birtles S, Boyer S, Carroll D, Clarkson P, Loxham SJ, McAulay P

- and Teague JL *et al.*. (2002) Selective antagonism of the NPY Y5 receptor does not have a major effect on feeding in rats. *Diabetes* **51**: 2441-9 [PMID:12145156]
220. Vettor R, Pagano C, Granzotto M, Englaro P, Angeli P, Blum WF, Federspil G, Rohner-Jeanrenaud F and Jeanrenaud B. (1998) Effects of intravenous neuropeptide Y on insulin secretion and insulin sensitivity in skeletal muscle in normal rats. *Diabetologia* **41**: 1361-7 [PMID:9833945]
221. Voisin T, Goumain M, Lorinet AM, Maoret JJ and Laburthe M. (2000) Functional and molecular properties of the human recombinant Y4 receptor: resistance to agonist-promoted desensitization. *J Pharmacol Exp Ther* **292**: 638-46 [PMID:10640301]
222. Wahlestedt C, Yanaihara N and Håkanson R. (1986) Evidence for different pre-and post-junctional receptors for neuropeptide Y and related peptides. *Regul Pept* **13**: 307-18 [PMID:3010387]
223. Walker MW, Smith KE, Bard J, Vaysse PJ, Gerald C, Daouti S, Weinshank RL and Branchek TA. (1997) A structure-activity analysis of the cloned rat and human Y4 receptors for pancreatic polypeptide. *Peptides* **18**: 609-12 [PMID:9210181]
224. Wang JZ, Lundeberg T and Yu L. (2000) Antinociceptive effects induced by intra-periaqueductal grey administration of neuropeptide Y in rats. *Brain Res* **859**: 361-3 [PMID:10719086]
225. Wang JZ, Lundeberg T and Yu LC. (2001) Anti-nociceptive effect of neuropeptide Y in periaqueductal grey in rats with inflammation. *Brain Res* **893**: 264-7 [PMID:11223015]
226. Wang ZL, Bennet WM, Wang RM, Ghatei MA and Bloom SR. (1994) Evidence of a paracrine role of neuropeptide-Y in the regulation of insulin release from pancreatic islets of normal and dexamethasone-treated rats. *Endocrinology* **135**: 200-6 [PMID:8013354]
227. Weng G, Yee F, Michl P, Reis D and Wahlestedt C. (1995) Studies on neuropeptide Y receptors in a mouse adrenocortical cell line. *Mol Pharmacol* **48**: 9-14 [PMID:7623780]
228. Wettstein JG, Earley B and Junien JL. (1995) Central nervous system pharmacology of neuropeptide Y. *Pharmacol Ther* **65**: 397-414 [PMID:7644568]
229. Wharton J, Gordon L, Byrne J, Herzog H, Selbie LA, Moore K, Sullivan MH, Elder MG, Moscoso G and Taylor KM *et al.*. (1993) Expression of the human neuropeptide tyrosine Y1 receptor. *Proc Natl Acad Sci USA* **90**: 687-91 [PMID:8421707]
230. Wheway J, Mackay CR, Newton RA, Sainsbury A, Boey D, Herzog H and Mackay F. (2005) A fundamental bimodal role for neuropeptide Y1 receptor in the immune system. *J Exp Med* **202**: 1527-38 [PMID:16330815]
231. Wieland HA, Engel W, Eberlein W, Rudolf K and Doods HN. (1998) Subtype selectivity of the novel nonpeptide neuropeptide Y Y1 receptor antagonist BIBO 3304 and its effect on feeding in rodents. *Br J Pharmacol* **125**: 549-555 [PMID:9806339]
232. Wieland HA, Willim KD, Entzeroth M, Wiene W, Rudolf K, Eberlein W, Engel W and Doods HN. (1995) Subtype selectivity and antagonistic profile of the nonpeptide Y1 receptor antagonist BIBP 3226. *J Pharmacol Exp Ther* **275**: 143-9 [PMID:7562543]
233. Woldbye DP, Nanobashvili A, Sørensen AT, Husum H, Bolwig TG, Sørensen G, Ernfors P and Kokaia M. (2005) Differential suppression of seizures via Y2 and Y5 neuropeptide Y receptors. *Neurobiol Dis* **20**: 760-72 [PMID:15979311]
234. Wultsch T, Painsipp E, Donner S, Sperk G, Herzog H, Peskar BA and Holzer P. (2006) Selective increase of dark phase water intake in neuropeptide-Y Y2 and Y4 receptor knockout mice. *Behav Brain Res* **168**: 255-60 [PMID:16364461]
235. Wyss P, Levens N and Stricker-Krongrad A. (1998) Stimulation of feeding in lean but not in obese Zucker rats by a selective neuropeptide Y Y5 receptor agonist. *Neuroreport* **9**: 2675-7 [PMID:9721954]
236. Wyss P, Stricker-Krongrad A, Brunner L, Miller J, Crossthwaite A, Whitebread S and Criscione L. (1998) The pharmacology of neuropeptide Y (NPY) receptor-mediated feeding in rats characterizes better Y5 than Y1, but not Y2 or Y4 subtypes. *Regul Pept* **75-76**: 363-371 [PMID:9802430]
237. Xiong Z and Cheung DW. (1995) ATP-Dependent inhibition of Ca²⁺-activated K⁺ channels in vascular smooth muscle cells by neuropeptide Y. *Pflugers Arch* **431**: 110-6 [PMID:8584407]
238. Yan H, Yang J, Marasco J, Yamaguchi K, Brenner S, Collins F and Karbon W. (1996) Cloning and functional expression of cDNAs encoding human and rat pancreatic polypeptide receptors. *Proc Natl Acad Sci USA* **93**: 4661-5 [PMID:8643460]
239. Yang SN, Bunnemann B, Cintra A and Fuxe K. (1996) Localization of neuropeptide Y Y1 receptor-like immunoreactivity in catecholaminergic neurons of the rat medulla oblongata. *Neuroscience* **73**: 519-30 [PMID:8783267]

240. Yang Z, Han S, Keller M, Kaiser A, Bender BJ, Bosse M, Burkert K, Kögler LM, Wifling D and Bernhardt G *et al.*. (2018) Structural basis of ligand binding modes at the neuropeptide Y Y₁ receptor. *Nature* **556**: 520-524 [PMID:29670288]
241. Yannielli P and Harrington ME. (2004) Let there be "more" light: enhancement of light actions on the circadian system through non-photic pathways. *Prog Neurobiol* **74**: 59-76 [PMID:15381317]
242. Yannielli PC and Harrington ME. (2001) Neuropeptide Y in the mammalian circadian system: effects on light-induced circadian responses. *Peptides* **22**: 547-56 [PMID:11287113]
243. Zhang W, Lundberg JM and Thorén P. (1997) Neuropeptide Y Y1 receptor antagonist (BIBP 3226) attenuates stress evoked tachycardia in conscious spontaneously hypertensive rats. *Cardiovasc Drugs Ther* **11**: 801-806 [PMID:9512876]
244. Zhang Y, Lundeberg T and Yu L. (2000) Involvement of neuropeptide Y and Y1 receptor in antinociception in nucleus raphe magnus of rats. *Regul Pept* **95**: 109-13 [PMID:11062340]
245. Zukowska-Grojec Z, Karwatowska-Prokopczuk E, Rose W, Rone J, Movafagh S, Ji H, Yeh Y, Chen WT, Kleinman HK and Grouzmann E *et al.*. (1998) Neuropeptide Y: a novel angiogenic factor from the sympathetic nerves and endothelium. *Circ Res* **83**: 187-95 [PMID:9686758]