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P2X receptors in GtoPdb v.2025.3

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Abstract

P2X receptors (**nomenclature as agreed by the NC-IUPHAR Subcommittee on P2X Receptors [49, 150]**) have a trimeric topology [121, 132, 148, 201] with two putative TM domains per P2X subunit, gating primarily Na^+, K^+ and Ca^{2+}, exceptionally Cl^-. The Nomenclature Subcommittee has recommended that for P2X receptors, structural criteria should be the initial basis for nomenclature where possible. X-ray crystallography indicates that functional P2X receptors are trimeric and three agonist molecules are required to bind to a single trimeric assembly in order to activate it [121, 148, 97, 105, 181]. Native receptors may occur as either homotrimers (*e.g.* P2X1 in smooth muscle) or heterotrimers (*e.g.* P2X2:P2X3 in the nodose ganglion [284], P2X1:P2X5 in mouse cortical astrocytes [166], and P2X2:P2X5 in mouse dorsal root ganglion, spinal cord and mid pons [53, 238]. P2X2, P2X4 and P2X7 receptor activation can lead to influx of large cationic molecules, such as $NMDG^+$, Yo-Pro, ethidium or propidium iodide [215]. The permeability of the P2X7 receptor is modulated by the amount of cholesterol in the plasma membrane [197]. The hemi-channel pannexin-1 was initially implicated in the action of P2X7 [216], but not P2X2, receptors [41], but this interpretation is probably misleading [219]. Convincing evidence now supports the view that the activated P2X7 receptor is immediately permeable to large cationic molecules, but influx proceeds at a much slower pace than that of the small cations Na^+, K^+, and Ca^{2+} [67].

Contents

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References

1. Abdi MH, Beswick PJ, Billinton A, Chambers LJ, Charlton A, Collins SD, Collis KL, Dean DK, Fonfria E and Gleave RJ *et al*.. (2010) Discovery and structure-activity relationships of a series of pyroglutamic acid amide antagonists of the P2X7 receptor. *Bioorg Med Chem Lett* **20**: 5080-4 [PMID:20673717]
2. Adinolfi E, Cirillo M, Woltersdorf R, Falzoni S, Chiozzi P, Pellegatti P, Callegari MG, Sandonà D, Markwardt F and Schmalzing G *et al*.. (2010) Trophic activity of a naturally occurring truncated isoform of the P2X7 receptor. *FASEB J* **24**: 3393-404 [PMID:20453110]
3. Adinolfi E, Giuliani AL, De Marchi E, Pegoraro A, Orioli E and Di Virgilio F. (2018) The P2X7 receptor: A main player in inflammation. *Biochem Pharmacol* **151**: 234-244 [PMID:29288626]
4. Adinolfi E, Melchiorri L, Falzoni S, Chiozzi P, Morelli A, Tieghi A, Cuneo A, Castoldi G, Di Virgilio F and Baricordi OR. (2002) P2X7 receptor expression in evolutive and indolent forms of chronic B lymphocytic leukemia. *Blood* **99**: 706-8 [PMID:11781259]
5. Adinolfi E, Raffaghello L, Giuliani AL, Cavazzini L, Capece M, Chiozzi P, Bianchi G, Kroemer G, Pistoia V and Di Virgilio F. (2012) Expression of P2X7 receptor increases in vivo tumor growth. *Cancer Res* **72**: 2957-69 [PMID:22505653]
6. Adriouch S, Dox C, Welge V, Seman M, Koch-Nolte F and Haag F. (2002) Cutting edge: a natural P451L mutation in the cytoplasmic domain impairs the function of the mouse P2X7 receptor. *J Immunol* **169**: 4108-12 [PMID:12370338]
7. Ase AR, Bernier LP, Blais D, Pankratov Y and Séguéla P. (2010) Modulation of heteromeric P2X1/5 receptors by phosphoinositides in astrocytes depends on the P2X1 subunit. *J Neurochem* **113**: 1676-84 [PMID:20374427]
8. Ashour F, Atterbury-Thomas M, Deuchars J and Evans RJ. (2006) An evaluation of antibody detection of the P2X1 receptor subunit in the CNS of wild type and P2X1-knockout mice. *Neurosci Lett* **397**: 120-5 [PMID:16384637]
9. AstraZeneca. AZ11657312. http://openinnovation.astrazeneca.com/what-we-offer/compound/az11657312/. Accessed on 12/09/2014.
10. Banks FC, Knight GE, Calvert RC, Thompson CS, Morgan RJ and Burnstock G. (2006) The purinergic component of human vas deferens contraction. *Fertil Steril* **85**: 932-9 [PMID:16580377]
11. Barclay J, Patel S, Dorn G, Wotherspoon G, Moffatt S, Eunson L, Abdel'al S, Natt F, Hall J and Winter J *et al*.. (2002) Functional downregulation of P2X3 receptor subunit in rat sensory neurons reveals a significant role in chronic neuropathic and inflammatory pain. *J Neurosci* **22**: 8139-47 [PMID:12223568]
12. Baricordi OR, Melchiorri L, Adinolfi E, Falzoni S, Chiozzi P, Buell G and Di Virgilio F. (1999) Increased proliferation rate of lymphoid cells transfected with the P2X(7) ATP receptor. *J Biol Chem* **274**: 33206-8 [PMID:10559192]
13. Basso AM, Bratcher NA, Harris RR, Jarvis MF, Decker MW and Rueter LE. (2009) Behavioral profile of P2X7 receptor knockout mice in animal models of depression and anxiety: relevance for neuropsychiatric disorders. *Behav Brain Res* **198**: 83-90 [PMID:18996151]
14. Beigi RD, Kertesy SB, Aquilina G and Dubyak GR. (2003) Oxidized ATP (oATP) attenuates proinflammatory signaling via P2 receptor-independent mechanisms. *Br J Pharmacol* **140**: 507-19 [PMID:14522842]
15. Benkó R, Undi S, Wolf M and Barthó L. (2005) Effects of acute administration of and tachyphylaxis to alpha,beta-methylene ATP in the guinea-pig small intestine. *Basic Clin Pharmacol Toxicol* **97**: 369-73 [PMID:16364052]
16. Berchtold S, Ogilvie AL, Bogdan C, Mühl-Zürbes P, Ogilvie A, Schuler G and Steinkasserer A. (1999) Human monocyte derived dendritic cells express functional P2X and P2Y receptors as

well as ecto-nucleotidases. *FEBS Lett* **458**: 424-8 [PMID:10570953]
17. Bernier LP, Ase AR and Séguéla P. (2013) Post-translational regulation of P2X receptor channels: modulation by phospholipids. *Front Cell Neurosci* **7**: 226 [PMID:24324400]
18. Berry DA, Barden JA, Balcar VJ, Keogh A and dos Remedios CG. (1999) Increase in expression of P2X1 receptors in the atria of patients suffering from dilated cardiomyopathy. *Electrophoresis* **20**: 2059-64 [PMID:10451115]
19. Bertrand PP and Bornstein JC. (2002) ATP as a putative sensory mediator: activation of intrinsic sensory neurons of the myenteric plexus via P2X receptors. *J Neurosci* **22**: 4767-75 [PMID:12077173]
20. Bhattacharya A, Wang Q, Ao H, Shoblock JR, Lord B, Aluisio L, Fraser I, Nepomuceno D, Neff RA and Welty N *et al.*. (2013) Pharmacological characterization of a novel centrally permeable P2X7 receptor antagonist: JNJ-47965567. *Br J Pharmacol* **170**: 624-40 [PMID:23889535]
21. Bian X, Ren J, DeVries M, Schnegelsberg B, Cockayne DA, Ford AP and Galligan JJ. (2003) Peristalsis is impaired in the small intestine of mice lacking the P2X3 subunit. *J Physiol (Lond.)* **551**: 309-22 [PMID:12813150]
22. Bianco F, Ceruti S, Colombo A, Fumagalli M, Ferrari D, Pizzirani C, Matteoli M, Di Virgilio F, Abbracchio MP and Verderio C. (2006) A role for P2X7 in microglial proliferation. *J Neurochem* **99**: 745-58 [PMID:16836656]
23. Bo X, Alavi A, Xiang Z, Oglesby I, Ford A and Burnstock G. (1999) Localization of ATP-gated P2X2 and P2X3 receptor immunoreactive nerves in rat taste buds. *Neuroreport* **10**: 1107-11 [PMID:10321492]
24. Bo X, Jiang LH, Wilson HL, Kim M, Burnstock G, Surprenant A and North RA. (2003) Pharmacological and biophysical properties of the human P2X5 receptor. *Mol Pharmacol* **63**: 1407-16 [PMID:12761352]
25. Bo X, Karoon P, Nori SL, Bardini M and Burnstock G. (1998) P2X purinoceptors in postmortem human cerebral arteries. *J Cardiovasc Pharmacol* **31**: 794-9 [PMID:9593081]
26. Bo X, Zhang Y, Nassar M, Burnstock G and Schoepfer R. (1995) A P2X purinoceptor cDNA conferring a novel pharmacological profile. *FEBS Lett* **375**: 129-33 [PMID:7498461]
27. Bradbury EJ, Burnstock G and McMahon SB. (1998) The expression of P2X3 purinoreceptors in sensory neurons: effects of axotomy and glial-derived neurotrophic factor. *Mol Cell Neurosci* **12**: 256-68 [PMID:9828090]
28. Brake AJ, Wagenbach MJ and Julius D. (1994) New structural motif for ligand-gated ion channels defined by an ionotropic ATP receptor. *Nature* **371**: 519-23 [PMID:7523952]
29. Brändle U, Kohler K and Wheeler-Schilling TH. (1998) Expression of the P2X7-receptor subunit in neurons of the rat retina. *Brain Res Mol Brain Res* **62**: 106-9 [PMID:9795168]
30. Buell G, Chessell IP, Michel AD, Collo G, Salazzo M, Herren S, Gretener D, Grahames C, Kaur R, Kosco-Vilbois MH and Humphrey PP. (1998) Blockade of human P2X7 receptor function with a monoclonal antibody. *Blood* **92**: 3521-8 [PMID:9808543]
31. Buell G, Lewis C, Collo G, North RA and Surprenant A. (1996) An antagonist-insensitive P2X receptor expressed in epithelia and brain. *EMBO J* **15**: 55-62 [PMID:8598206]
32. Buell GN, Talabot F, Gos A, Lorenz J, Lai E, Morris MA and Antonarakis SE. (1998) Gene structure and chromosomal localization of the human P2X7 receptor. *Recept Channels* **5**: 347-54 [PMID:9826911]
33. 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]
34. Burnstock G. (2001) Purine-mediated signalling in pain and visceral perception. *Trends Pharmacol Sci* **22**: 182-8 [PMID:11282418]
35. Burnstock G and Boeynaems JM. (2014) Purinergic signalling and immune cells. *Purinergic Signal* **10**: 529-64 [PMID:25352330]
36. Cabrini G, Falzoni S, Forchap SL, Pellegatti P, Balboni A, Agostini P, Cuneo A, Castoldi G, Baricordi OR and Di Virgilio F. (2005) A His-155 to Tyr polymorphism confers gain-of-function to the human P2X7 receptor of human leukemic lymphocytes. *J Immunol* **175**: 82-9 [PMID:15972634]
37. Calzaferri F, Narros-Fernández P, de Pascual R, de Diego AMG, Nicke A, Egea J, García AG and de Los Ríos C. (2021) Synthesis and Pharmacological Evaluation of Novel Non-nucleotide Purine Derivatives as P2X7 Antagonists for the Treatment of Neuroinflammation. *J Med Chem* **64**: 2272-2290 [PMID:33560845]
38. Castelucci P, Robbins HL, Poole DP and Furness JB. (2002) The distribution of purine P2X(2) receptors in the guinea-pig enteric nervous system. *Histochem Cell Biol* **117**: 415-22 [PMID:12029488]
39. Cekic C and Linden J. (2016) Purinergic regulation of the immune system. *Nat Rev Immunol* **16**: 177-92 [PMID:26922909]
40. Chan CM, Unwin RJ, Bardini M, Oglesby IB, Ford AP, Townsend-Nicholson A and Burnstock G. (1998) Localization of P2X1 purinoceptors by autoradiography and immunohistochemistry in rat

kidneys. *Am J Physiol* **274**: F799-804 [PMID:9575906]
41. Chaumont S and Khakh BS. (2008) Patch-clamp coordinated spectroscopy shows P2X2 receptor permeability dynamics require cytosolic domain rearrangements but not Panx-1 channels. *Proc Natl Acad Sci USA* **105**: 12063-8 [PMID:18689682]
42. Cheewatrakoolpong B, Gilchrest H, Anthes JC and Greenfeder S. (2005) Identification and characterization of splice variants of the human P2X7 ATP channel. *Biochem Biophys Res Commun* **332**: 17-27 [PMID:15896293]
43. Chen CC, Akopian AN, Sivilotti L, Colquhoun D, Burnstock G and Wood JN. (1995) A P2X purinoceptor expressed by a subset of sensory neurons. *Nature* **377**: 428-31 [PMID:7566119]
44. Chessell IP, Hatcher JP, Bountra C, Michel AD, Hughes JP, Green P, Egerton J, Murfin M, Richardson J, Peck WL, Grahames CB, Casula MA, Yiangou Y, Birch R, Anand P and Buell GN. (2005) Disruption of the P2X7 purinoceptor gene abolishes chronic inflammatory and neuropathic pain. *Pain* **114**: 386-96 [PMID:15777864]
45. Chessell IP, Simon J, Hibell AD, Michel AD, Barnard EA and Humphrey PP. (1998) Cloning and functional characterisation of the mouse P2X7 receptor. *FEBS Lett* **439**: 26-30 [PMID:9849870]
46. Chu YX, Zhang Y, Zhang YQ and Zhao ZQ. (2010) Involvement of microglial P2X7 receptors and downstream signaling pathways in long-term potentiation of spinal nociceptive responses. *Brain Behav Immun* **24**: 1176-89 [PMID:20554014]
47. Cockayne DA, Dunn PM, Zhong Y, Rong W, Hamilton SG, Knight GE, Ruan HZ, Ma B, Yip P, Nunn P, McMahon SB, Burnstock G and Ford AP. (2005) P2X2 knockout mice and P2X2/P2X3 double knockout mice reveal a role for the P2X2 receptor subunit in mediating multiple sensory effects of ATP. *J Physiol (Lond.)* **567**: 621-39 [PMID:15961431]
48. Cockayne DA, Hamilton SG, Zhu QM, Dunn PM, Zhong Y, Novakovic S, Malmberg AB, Cain G, Berson A and Kassotakis L *et al.*. (2000) Urinary bladder hyporeflexia and reduced pain-related behaviour in P2X3-deficient mice. *Nature* **407**: 1011-5 [PMID:11069181]
49. Collingridge GL, Olsen RW, Peters J and Spedding M. (2009) A nomenclature for ligand-gated ion channels. *Neuropharmacology* **56**: 2-5 [PMID:18655795]
50. Collo G, Neidhart S, Kawashima E, Kosco-Vilbois M, North RA and Buell G. (1997) Tissue distribution of the P2X7 receptor. *Neuropharmacology* **36**: 1277-83 [PMID:9364482]
51. Collo G, North RA, Kawashima E, Merlo-Pich E, Neidhart S, Surprenant A and Buell G. (1996) Cloning OF P2X5 and P2X6 receptors and the distribution and properties of an extended family of ATP-gated ion channels. *J Neurosci* **16**: 2495-507 [PMID:8786426]
52. Colomar A and Amédée T. (2001) ATP stimulation of P2X(7) receptors activates three different ionic conductances on cultured mouse Schwann cells. *Eur J Neurosci* **14**: 927-36 [PMID:11595031]
53. Compan V, Ulmann L, Stelmashenko O, Chemin J, Chaumont S and Rassendren F. (2012) P2X2 and P2X5 subunits define a new heteromeric receptor with P2X7-like properties. *J Neurosci* **32**: 4284-96 [PMID:22442090]
54. Cook SP, Vulchanova L, Hargreaves KM, Elde R and McCleskey EW. (1997) Distinct ATP receptors on pain-sensing and stretch-sensing neurons. *Nature* **387**: 505-8 [PMID:9168113]
55. Coutinho-Silva R, Parsons M, Robson T, Lincoln J and Burnstock G. (2003) P2X and P2Y purinoceptor expression in pancreas from streptozotocin-diabetic rats. *Mol Cell Endocrinol* **204**: 141-54 [PMID:12850289]
56. Cox JA, Barmina O and Voigt MM. (2001) Gene structure, chromosomal localization, cDNA cloning and expression of the mouse ATP-gated ionotropic receptor P2X5 subunit. *Gene* **270**: 145-52 [PMID:11404011]
57. Crack BE, Beukers MW, McKechnie KC, Ijzerman AP and Leff P. (1994) Pharmacological analysis of ecto-ATPase inhibition: evidence for combined enzyme inhibition and receptor antagonism in P2X-purinoceptor ligands. *Br J Pharmacol* **113**: 1432-8 [PMID:7889301]
58. Darbousset R, Delierneux C, Mezouar S, Hego A, Lecut C, Guillaumat I, Riederer MA, Evans RJ, Dignat-George F and Panicot-Dubois L *et al.*. (2014) P2X1 expressed on polymorphonuclear neutrophils and platelets is required for thrombosis in mice. *Blood* **124**: 2575-85 [PMID:25150292]
59. Davenport AJ, Braeuer N, Fischer OM, Rotgeri A, Rottmann A, Neagoe I, Nagel J and Godinho-Coelho Am. (2016) 1,3-thiazol-2-yl substituted benzamides Patent number: WO2016091776A1. Assignee: Evotec Ag. Priority date: 07/12/2015. Publication date: 16/06/2016.
60. Davenport AJ, Neagoe I, Bräuer N, Koch M, Rotgeri A, Nagel J, Laux-Biehlmann A, Machet F, Coelho AM and Boyce S *et al.*. (2021) Eliapixant is a selective P2X3 receptor antagonist for the treatment of disorders associated with hypersensitive nerve fibers. *Sci Rep* **11**: 19877 [PMID:34615939]
61. de Baaij JH, Kompatscher A, Viering DH, Bos C, Bindels RJ and Hoenderop JG. (2016) P2X6 Knockout Mice Exhibit Normal Electrolyte Homeostasis. *PLoS ONE* **11**: e0156803 [PMID:27254077]
62. Di Virgilio F. (2003) Novel data point to a broader mechanism of action of oxidized ATP: the P2X7 receptor is not the only target. *Br J Pharmacol* **140**: 441-3 [PMID:14522840]

63. Di Virgilio F. (2016) P2RX7: A receptor with a split personality in inflammation and cancer. *Mol Cell Oncol* **3**: e1010937 [PMID:27308580]
64. Di Virgilio F. (2012) Purines, purinergic receptors, and cancer. *Cancer Res* **72**: 5441-7 [PMID:23090120]
65. Di Virgilio F and Adinolfi E. (2017) Extracellular purines, purinergic receptors and tumor growth. *Oncogene* **36**: 293-303 [PMID:27321181]
66. Di Virgilio F, Dal Ben D, Sarti AC, Giuliani AL and Falzoni S. (2017) The P2X7 Receptor in Infection and Inflammation. *Immunity* **47**: 15-31 [PMID:28723547]
67. Di Virgilio F, Schmalzing G and Markwardt F. (2018) The Elusive P2X7 Macropore. *Trends Cell Biol* **28**: 392-404 [PMID:29439897]
68. Dombroski MA and Duplantier AJ. (2005) Benzamide inhibitors of the P2X7 receptor Patent number: US6974812 B2. Assignee: Pfizer Inc.. Priority date: 31/12/2002. Publication date: 13/12/2005.
69. Donnelly-Roberts DL and Jarvis MF. (2007) Discovery of P2X7 receptor-selective antagonists offers new insights into P2X7 receptor function and indicates a role in chronic pain states. *Br J Pharmacol* **151**: 571-9 [PMID:17471177]
70. Donnelly-Roberts DL, Namovic MT, Faltynek CR and Jarvis MF. (2004) Mitogen-activated protein kinase and caspase signaling pathways are required for P2X7 receptor (P2X7R)-induced pore formation in human THP-1 cells. *J Pharmacol Exp Ther* **308**: 1053-61 [PMID:14634045]
71. Donnelly-Roberts DL, Namovic MT, Han P and Jarvis MF. (2009) Mammalian P2X7 receptor pharmacology: comparison of recombinant mouse, rat and human P2X7 receptors. *Br J Pharmacol* **157**: 1203-14 [PMID:19558545]
72. Dowling P, Ranson RN and Santer RM. (2006) Age-associated changes in distribution of the P2X2 receptor in the major pelvic ganglion of the male rat. *Neurosci Lett* **404**: 320-3 [PMID:16969922]
73. Duplantier AJ, Dombroski MA, Subramanyam C, Beaulieu AM, Chang SP, Gabel CA, Jordan C, Kalgutkar AS, Kraus KG and Labasi JM *et al*.. (2011) Optimization of the physicochemical and pharmacokinetic attributes in a 6-azauracil series of P2X7 receptor antagonists leading to the discovery of the clinical candidate CE-224,535. *Bioorg Med Chem Lett* **21**: 3708-11 [PMID:21565499]
74. Díaz-Hernández M, Pintor J, Castro E and Miras-Portugal MT. (2002) Co-localisation of functional nicotinic and ionotropic nucleotide receptors in isolated cholinergic synaptic terminals. *Neuropharmacology* **42**: 20-33 [PMID:11750913]
75. Emmett DS, Feranchak A, Kilic G, Puljak L, Miller B, Dolovcak S, McWilliams R, Doctor RB and Fitz JG. (2008) Characterization of ionotrophic purinergic receptors in hepatocytes. *Hepatology* **47**: 698-705 [PMID:18027885]
76. Erhardt JA, Toomey JR, Douglas SA and Johns DG. (2006) P2X1 stimulation promotes thrombin receptor-mediated platelet aggregation. *J Thromb Haemost* **4**: 882-90 [PMID:16634759]
77. Esther Jr CR, Alexis NE, Clas ML, Lazarowski ER, Donaldson SH, Ribeiro CM, Moore CG, Davis SD and Boucher RC. (2008) Extracellular purines are biomarkers of neutrophilic airway inflammation. *Eur Respir J* **31**: 949-56 [PMID:18256064]
78. Fairbairn IP, Stober CB, Kumararatne DS and Lammas DA. (2001) ATP-mediated killing of intracellular mycobacteria by macrophages is a P2X(7)-dependent process inducing bacterial death by phagosome-lysosome fusion. *J Immunol* **167**: 3300-7 [PMID:11544318]
79. Falzoni S, Munerati M, Ferrari D, Spisani S, Moretti S and Di Virgilio F. (1995) The purinergic P2Z receptor of human macrophage cells. Characterization and possible physiological role. *J Clin Invest* **95**: 1207-16 [PMID:7883969]
80. Fantoni ER, Dal Ben D, Falzoni S, Di Virgilio F, Lovestone S and Gee A. (2017) Design, synthesis and evaluation in an LPS rodent model of neuroinflammation of a novel ^{18}F-labelled PET tracer targeting P2X7. *EJNMMI Res* **7**: 31 [PMID:28374288]
81. Ferrari D, Chiozzi P, Falzoni S, Dal Susino M, Collo G, Buell G and Di Virgilio F. (1997) ATP-mediated cytotoxicity in microglial cells. *Neuropharmacology* **36**: 1295-301 [PMID:9364484]
82. Ferrari D, Pizzirani C, Adinolfi E, Forchap S, Sitta B, Turchet L, Falzoni S, Minelli M, Baricordi R and Di Virgilio F. (2004) The antibiotic polymyxin B modulates P2X7 receptor function. *J Immunol* **173**: 4652-60 [PMID:15383600]
83. Ferrari D, Villalba M, Chiozzi P, Falzoni S, Ricciardi-Castagnoli P and Di Virgilio F. (1996) Mouse microglial cells express a plasma membrane pore gated by extracellular ATP. *J Immunol* **156**: 1531-9 [PMID:8568257]
84. Finger TE, Danilova V, Barrows J, Bartel DL, Vigers AJ, Stone L, Hellekant G and Kinnamon SC. (2005) ATP signaling is crucial for communication from taste buds to gustatory nerves. *Science* **310**: 1495-9 [PMID:16322458]
85. Fischer W, Franke H, Krügel U, Müller H, Dinkel K, Lord B, Letavic MA, Henshall DC and Engel T. (2016) Critical Evaluation of P2X7 Receptor Antagonists in Selected Seizure Models. *PLoS One* **11**: e0156468 [PMID:27281030]
86. Ford AP, Gever JR, Nunn PA, Zhong Y, Cefalu JS, Dillon MP and Cockayne DA. (2006)

Purinoceptors as therapeutic targets for lower urinary tract dysfunction. *Br J Pharmacol* **147 Suppl 2**: S132-43 [PMID:16465177]
87. Franke H, Günther A, Grosche J, Schmidt R, Rossner S, Reinhardt R, Faber-Zuschratter H, Schneider D and Illes P. (2004) P2X7 receptor expression after ischemia in the cerebral cortex of rats. *J Neuropathol Exp Neurol* **63**: 686-99 [PMID:15290894]
88. Franke H, Klimke K, Brinckmann U, Grosche J, Francke M, Sperlagh B, Reichenbach A, Liebert UG and Illes P. (2005) P2X(7) receptor-mRNA and -protein in the mouse retina; changes during retinal degeneration in BALBCrds mice. *Neurochem Int* **47**: 235-42 [PMID:15964665]
89. Garceau D and Chauret N. (2019) BLU-5937: A selective P2X3 antagonist with potent anti-tussive effect and no taste alteration. *Pulm Pharmacol Ther* **56**: 56-62 [PMID:30902655]
90. Garcia-Guzman M, Soto F, Gomez-Hernandez JM, Lund PE and Stühmer W. (1997) Characterization of recombinant human P2X4 receptor reveals pharmacological differences to the rat homologue. *Mol Pharmacol* **51**: 109-18 [PMID:9016352]
91. Garcia-Guzman M, Stühmer W and Soto F. (1997) Molecular characterization and pharmacological properties of the human P2X3 purinoceptor. *Brain Res Mol Brain Res* **47**: 59-66 [PMID:9221902]
92. Gargett CE and Wiley JS. (1997) The isoquinoline derivative KN-62 a potent antagonist of the P2Z-receptor of human lymphocytes. *Br J Pharmacol* **120**: 1483-90 [PMID:9113369]
93. Gartland A, Buckley KA, Bowler WB and Gallagher JA. (2003) Blockade of the pore-forming P2X7 receptor inhibits formation of multinucleated human osteoclasts in vitro. *Calcif Tissue Int* **73**: 361-9 [PMID:12874700]
94. Gever JR, Cockayne DA, Dillon MP, Burnstock G and Ford AP. (2006) Pharmacology of P2X channels. *Pflugers Arch* **452**: 513-37 [PMID:16649055]
95. Gever JR, Soto R, Henningsen RA, Martin RS, Hackos DH, Panicker S, Rubas W, Oglesby IB, Dillon MP and Milla ME *et al*.. (2010) AF-353, a novel, potent and orally bioavailable P2X3/P2X2/3 receptor antagonist. *Br J Pharmacol* **160**: 1387-98 [PMID:20590629]
96. Gicquel T, Le Daré B, Boichot E and Lagente V. (2017) Purinergic receptors: new targets for the treatment of gout and fibrosis. *Fundam Clin Pharmacol* **31**: 136-146 [PMID:27885718]
97. Gonzales EB, Kawate T and Gouaux E. (2009) Pore architecture and ion sites in acid-sensing ion channels and P2X receptors. *Nature* **460**: 599-604 [PMID:19641589]
98. Gonçalves RG, Gabrich L, Rosário A, Takiya CM, Ferreira ML, Chiarini LB, Persechini PM, Coutinho-Silva R and Leite M. (2006) The role of purinergic P2X7 receptors in the inflammation and fibrosis of unilateral ureteral obstruction in mice. *Kidney Int* **70**: 1599-606 [PMID:16969386]
99. Greco NJ, Tonon G, Chen W, Luo X, Dalal R and Jamieson GA. (2001) Novel structurally altered P(2X1) receptor is preferentially activated by adenosine diphosphate in platelets and megakaryocytic cells. *Blood* **98**: 100-7 [PMID:11418468]
100. Greig AV, Linge C, Terenghi G, McGrouther DA and Burnstock G. (2003) Purinergic receptors are part of a functional signaling system for proliferation and differentiation of human epidermal keratinocytes. *J Invest Dermatol* **120**: 1007-15 [PMID:12787128]
101. Grol MW, Panupinthu N, Korcok J, Sims SM and Dixon SJ. (2009) Expression, signaling, and function of P2X7 receptors in bone. *Purinergic Signal* **5**: 205-21 [PMID:19224395]
102. Gu BJ, Sluyter R, Skarratt KK, Shemon AN, Dao-Ung LP, Fuller SJ, Barden JA, Clarke AL, Petrou S and Wiley JS. (2004) An Arg307 to Gln polymorphism within the ATP-binding site causes loss of function of the human P2X7 receptor. *J Biol Chem* **279**: 31287-95 [PMID:15123679]
103. Gu BJ, Zhang W, Worthington RA, Sluyter R, Dao-Ung P, Petrou S, Barden JA and Wiley JS. (2001) A Glu-496 to Ala polymorphism leads to loss of function of the human P2X7 receptor. *J Biol Chem* **276**: 11135-42 [PMID:11150303]
104. Hardy LA, Harvey IJ, Chambers P and Gillespie JI. (2000) A putative alternatively spliced variant of the P2X(1) purinoreceptor in human bladder. *Exp Physiol* **85**: 461-3 [PMID:10918085]
105. Hattori M and Gouaux E. (2012) Molecular mechanism of ATP binding and ion channel activation in P2X receptors. *Nature* **485**: 207-12 [PMID:22535247]
106. Hechler B, Lenain N, Marchese P, Vial C, Heim V, Freund M, Cazenave JP, Cattaneo M, Ruggeri ZM and Evans R *et al*.. (2003) A role of the fast ATP-gated P2X1 cation channel in thrombosis of small arteries in vivo. *J Exp Med* **198**: 661-7 [PMID:12913094]
107. Hernandez-Olmos V, Abdelrahman A, El-Tayeb A, Freudendahl D, Weinhausen S and Müller CE. (2012) N-substituted phenoxazine and acridone derivatives: structure-activity relationships of potent P2X4 receptor antagonists. *J Med Chem* **55**: 9576-88 [PMID:23075067]
108. Hervás C, Pérez-Sen R and Miras-Portugal MT. (2005) Presence of diverse functional P2X receptors in rat cerebellar synaptic terminals. *Biochem Pharmacol* **70**: 770-85 [PMID:16018975]
109. Hillman KA, Johnson TM, Winyard PJ, Burnstock G, Unwin RJ and Woolf AS. (2002) P2X(7) receptors are expressed during mouse nephrogenesis and in collecting duct cysts of the cpk/cpk mouse. *Exp Nephrol* **10**: 34-42 [PMID:11803203]
110. Hillman KA, Woolf AS, Johnson TM, Wade A, Unwin RJ and Winyard PJ. (2004) The P2X7 ATP receptor modulates renal cyst development in vitro. *Biochem Biophys Res Commun* **322**: 434-9

[PMID:15325248]
111. Hodges RR, Vrouvlianis J, Shatos MA and Dartt DA. (2009) Characterization of P2X7 purinergic receptors and their function in rat lacrimal gland. *Invest Ophthalmol Vis Sci* **50**: 5681-9 [PMID:19608535]
112. Hoffrogge R, Karachunskaya A, Heitmann N, Pedreiturria X, Klöster K, Bader V, Winklhofer KF, Hamacher M, Klebl B and Gold R *et al.*. (2025) The P2X7R-antagonist AFC-5128 ameliorates chronic experimental autoimmune encephalomyelitis in a preventive and therapeutic paradigm. *Front Immunol* **16**: 1554999 [PMID:40308584]
113. Homerin G, Jawhara S, Dezitter X, Baudelet D, Dufrénoy P, Rigo B, Millet R, Furman C, Ragé G and Lipka E *et al.*. (2020) Pyroglutamide-Based P2X7 Receptor Antagonists Targeting Inflammatory Bowel Disease. *J Med Chem* **63**: 2074-2094 [PMID:31525963]
114. Honore P, Donnelly-Roberts D, Namovic M, Zhong C, Wade C, Chandran P, Zhu C, Carroll W, Perez-Medrano A and Iwakura Y *et al.*. (2009) The antihyperalgesic activity of a selective P2X7 receptor antagonist, A-839977, is lost in IL-1alphabeta knockout mice. *Behav Brain Res* **204**: 77-81 [PMID:19464323]
115. Honore P, Donnelly-Roberts D, Namovic MT, Hsieh G, Zhu CZ, Mikusa JP, Hernandez G, Zhong C, Gauvin DM and Chandran P *et al.*. (2006) A-740003 [N-(1-{[(cyanoimino)(5-quinolinylamino) methyl]amino}-2,2-dimethylpropyl)-2-(3,4-dimethoxyphenyl)acetamide], a novel and selective P2X7 receptor antagonist, dose-dependently reduces neuropathic pain in the rat. *J Pharmacol Exp Ther* **319**: 1376-85 [PMID:16982702]
116. Honore P, Kage K, Mikusa J, Watt AT, Johnston JF, Wyatt JR, Faltynek CR, Jarvis MF and Lynch K. (2002) Analgesic profile of intrathecal P2X(3) antisense oligonucleotide treatment in chronic inflammatory and neuropathic pain states in rats. *Pain* **99**: 11-9 [PMID:12237180]
117. Hou M, Malmsjö M, Möller S, Pantev E, Bergdahl A, Zhao XH, Sun XY, Hedner T, Edvinsson L and Erlinge D. (1999) Increase in cardiac P2X1-and P2Y2-receptor mRNA levels in congestive heart failure. *Life Sci* **65**: 1195-206 [PMID:10503935]
118. Housley GD, Kanjhan R, Raybould NP, Greenwood D, Salih SG, Järlebark L, Burton LD, Setz VC, Cannell MB and Soeller C *et al.*. (1999) Expression of the P2X(2) receptor subunit of the ATP-gated ion channel in the cochlea: implications for sound transduction and auditory neurotransmission. *J Neurosci* **19**: 8377-88 [PMID:10493739]
119. Hubscher CH, Petruska JC, Rau KK and Johnson RD. (2001) Co-expression of P2X receptor subunits on rat nodose neurons that bind the isolectin GS-I-B4. *Neuroreport* **12**: 2995-7 [PMID:11588618]
120. Idzko M, Hammad H, van Nimwegen M, Kool M, Willart MA, Muskens F, Hoogsteden HC, Luttmann W, Ferrari D and Di Virgilio F *et al.*. (2007) Extracellular ATP triggers and maintains asthmatic airway inflammation by activating dendritic cells. *Nat Med* **13**: 913-9 [PMID:17632526]
121. Illes P, Müller CE, Jacobson KA, Grutter T, Nicke A, Fountain SJ, Kennedy C, Schmalzing G, Jarvis MF and Stojilkovic SS *et al.*. (2021) Update of P2X receptor properties and their pharmacology: IUPHAR Review 30. *Br J Pharmacol* **178**: 489-514 [PMID:33125712]
122. Inscho EW, Cook AK, Imig JD, Vial C and Evans RJ. (2003) Physiological role for P2X1 receptors in renal microvascular autoregulatory behavior. *J Clin Invest* **112**: 1895-905 [PMID:14679185]
123. Ishikawa M, Hasanali ZS, Zhao Y, Das A, Lavaert M, Roman CJ, Londregan J, Allman D and Bhandoola A. (2024) Bone marrow plasma cells require P2RX4 to sense extracellular ATP. *Nature* **626**: 1102-1107 [PMID:38355795]
124. Ito K, Iwami A, Katsura H and Ikeda M. (2008) Therapeutic effects of the putative P2X3/P2X2/3 antagonist A-317491 on cyclophosphamide-induced cystitis in rats. *Naunyn Schmiedebergs Arch Pharmacol* **377**: 483-90 [PMID:17917716]
125. Jacobson KA, Ivanov AA, de Castro S, Harden TK and Ko H. (2009) Development of selective agonists and antagonists of P2Y receptors. *Purinergic Signal* **5**: 75-89 [PMID:18600475]
126. Jacobson KA, Jarvis MF and Williams M. (2002) Purine and pyrimidine (P2) receptors as drug targets. *J Med Chem* **45**: 4057-93 [PMID:12213051]
127. Jacobson KA, Kim YC, Wildman SS, Mohanram A, Harden TK, Boyer JL, King BF and Burnstock G. (1998) A pyridoxine cyclic phosphate and its 6-azoaryl derivative selectively potentiate and antagonize activation of P2X1 receptors. *J Med Chem* **41**: 2201-6 [PMID:9632352]
128. Jacobson KA and Müller CE. (2016) Medicinal chemistry of adenosine, P2Y and P2X receptors. *Neuropharmacology* **104**: 31-49 [PMID:26686393]
129. Jarvis MF, Burgard EC, McGaraughty S, Honore P, Lynch K, Brennan TJ, Subieta A, Van Biesen T, Cartmell J and Bianchi B *et al.*. (2002) A-317491, a novel potent and selective non-nucleotide antagonist of P2X3 and P2X2/3 receptors, reduces chronic inflammatory and neuropathic pain in the rat. *Proc Natl Acad Sci USA* **99**: 17179-84 [PMID:12482951]
130. Jiang J and Gu J. (2002) Expression of adenosine triphosphate P2X3 receptors in rat molar pulp and trigeminal ganglia. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **94**: 622-6 [PMID:12424458]
131. Jiang L, Bardini M, Keogh A, dos Remedios CG and Burnstock G. (2005) P2X1 receptors are

closely associated with connexin 43 in human ventricular myocardium. *Int J Cardiol* **98**: 291-7 [PMID:15686781]
132. Jiang LH, Kim M, Spelta V, Bo X, Surprenant A and North RA. (2003) Subunit arrangement in P2X receptors. *J Neurosci* **23**: 8903-10 [PMID:14523092]
133. Jiang LH, Mackenzie AB, North RA and Surprenant A. (2000) Brilliant blue G selectively blocks ATP-gated rat P2X(7) receptors. *Mol Pharmacol* **58**: 82-8 [PMID:10860929]
134. Jones CA, Chessell IP, Simon J, Barnard EA, Miller KJ, Michel AD and Humphrey PP. (2000) Functional characterization of the P2X(4) receptor orthologues. *Br J Pharmacol* **129**: 388-94 [PMID:10694247]
135. Jones CA, Vial C, Sellers LA, Humphrey PP, Evans RJ and Chessell IP. (2004) Functional regulation of P2X6 receptors by N-linked glycosylation: identification of a novel alpha beta-methylene ATP-sensitive phenotype. *Mol Pharmacol* **65**: 979-85 [PMID:15044628]
136. Järlebark LE, Housley GD, Raybould NP, Vlajkovic S and Thorne PR. (2002) ATP-gated ion channels assembled from P2X2 receptor subunits in the mouse cochlea. *Neuroreport* **13**: 1979-84 [PMID:12395104]
137. Järlebark LE, Housley GD and Thorne PR. (2000) Immunohistochemical localization of adenosine 5'-triphosphate-gated ion channel P2X(2) receptor subunits in adult and developing rat cochlea. *J Comp Neurol* **421**: 289-301 [PMID:10813788]
138. Kaczmarek-Hájek K, Lörinczi E, Hausmann R and Nicke A. (2012) Molecular and functional properties of P2X receptors--recent progress and persisting challenges. *Purinergic Signal* **8**: 375-417 [PMID:22547202]
139. Kai H, Horiguchi T, Kameyma T, Onodera N, Itoh N, Fujii Y, Ichihashi Y, Hirai K, Shintani T and Nakamura K *et al.*. (2021) Discovery of clinical candidate Sivopixant (S-600918): Lead optimization of dioxotriazine derivatives as selective P2X3 receptor antagonists. *Bioorg Med Chem Lett* **52**: 128384 [PMID:34587541]
140. Kamei J and Takahashi Y. (2006) Involvement of ionotropic purinergic receptors in the histamine-induced enhancement of the cough reflex sensitivity in guinea pigs. *Eur J Pharmacol* **547**: 160-4 [PMID:16935279]
141. Kamei J, Takahashi Y, Yoshikawa Y and Saitoh A. (2005) Involvement of P2X receptor subtypes in ATP-induced enhancement of the cough reflex sensitivity. *Eur J Pharmacol* **528**: 158-61 [PMID:16321375]
142. Kaneda M, Ishii K, Morishima Y, Akagi T, Yamazaki Y, Nakanishi S and Hashikawa T. (2004) OFF-cholinergic-pathway-selective localization of P2X2 purinoceptors in the mouse retina. *J Comp Neurol* **476**: 103-11 [PMID:15236470]
143. Kanjhan R, Housley GD, Burton LD, Christie DL, Kippenberger A, Thorne PR, Luo L and Ryan AF. (1999) Distribution of the P2X2 receptor subunit of the ATP-gated ion channels in the rat central nervous system. *J Comp Neurol* **407**: 11-32 [PMID:10213185]
144. Karasawa A and Kawate T. (2016) Structural basis for subtype-specific inhibition of the P2X7 receptor. *Elife* **5** [PMID:27935479]
145. Karmakar M, Katsnelson MA, Dubyak GR and Pearlman E. (2016) Neutrophil P2X7 receptors mediate NLRP3 inflammasome-dependent IL-1β secretion in response to ATP. *Nat Commun* **7**: 10555 [PMID:26877061]
146. Kassack MU, Braun K, Ganso M, Ullmann H, Nickel P, Böing B, Müller G and Lambrecht G. (2004) Structure-activity relationships of analogues of NF449 confirm NF449 as the most potent and selective known P2X1 receptor antagonist. *Eur J Med Chem* **39**: 345-57 [PMID:15072843]
147. Kawamura H, Aswad F, Minagawa M, Govindarajan S and Dennert G. (2006) P2X7 receptors regulate NKT cells in autoimmune hepatitis. *J Immunol* **176**: 2152-60 [PMID:16455971]
148. Kawate T, Michel JC, Birdsong WT and Gouaux E. (2009) Crystal structure of the ATP-gated P2X(4) ion channel in the closed state. *Nature* **460**: 592-8 [PMID:19641588]
149. Ke HZ, Qi H, Weidema AF, Zhang Q, Panupinthu N, Crawford DT, Grasser WA, Paralkar VM, Li M, Audoly LP, Gabel CA, Jee WS, Dixon SJ, Sims SM and Thompson DD. (2003) Deletion of the P2X7 nucleotide receptor reveals its regulatory roles in bone formation and resorption. *Mol Endocrinol* **17**: 1356-67 [PMID:12677010]
150. Khakh BS, Burnstock G, Kennedy C, King BF, North RA, Séguéla P, Voigt M and Humphrey PP. (2001) International union of pharmacology. XXIV. Current status of the nomenclature and properties of P2X receptors and their subunits. *Pharmacol Rev* **53**: 107-18 [PMID:11171941]
151. Khakh BS, Gittermann D, Cockayne DA and Jones A. (2003) ATP modulation of excitatory synapses onto interneurons. *J Neurosci* **23**: 7426-37 [PMID:12917379]
152. Khakh BS, Proctor WR, Dunwiddie TV, Labarca C and Lester HA. (1999) Allosteric control of gating and kinetics at P2X(4) receptor channels. *J Neurosci* **19**: 7289-99 [PMID:10460235]
153. Khalafalla MG, Woods LT, Camden JM, Khan AA, Limesand KH, Petris MJ, Erb L and Weisman GA. (2017) P2X7 receptor antagonism prevents IL-1β release from salivary epithelial cells and reduces inflammation in a mouse model of autoimmune exocrinopathy. *J Biol Chem* **292**: 16626-16637 [PMID:28798231]
154. Khanam T and Burnstock G. (2007) Changes in expression of P2X1 receptors and connexin 43 in

the rat myometrium during pregnancy. *Fertil Steril* **88**: 1174-9 [PMID:17561003]
155. Kim H, Walsh MC, Takegahara N, Middleton SA, Shin HI, Kim J and Choi Y. (2017) The purinergic receptor P2X5 regulates inflammasome activity and hyper-multinucleation of murine osteoclasts. *Sci Rep* **7**: 196 [PMID:28298636]
156. Kim YC, Brown SG, Harden TK, Boyer JL, Dubyak G, King BF, Burnstock G and Jacobson KA. (2001) Structure-activity relationships of pyridoxal phosphate derivatives as potent and selective antagonists of P2X1 receptors. *J Med Chem* **44**: 340-9 [PMID:11462975]
157. King BF. (2023) Rehabilitation of the P2X5 receptor: a re-evaluation of structure and function. *Purinergic Signal* **19**: 421-439 [PMID:36279087]
158. King BF, Liu M, Pintor J, Gualix J, Miras-Portugal MT and Burnstock G. (1999) Diinosine pentaphosphate (IP5I) is a potent antagonist at recombinant rat P2X1 receptors. *Br J Pharmacol* **128**: 981-8 [PMID:10556935]
159. King BF, Liu M, Townsend-Nicholson A, Pfister J, Padilla F, Ford AP, Gever JR, Oglesby IB, Schorge S and Burnstock G. (2005) Antagonism of ATP responses at P2X receptor subtypes by the pH indicator dye, Phenol red. *Br J Pharmacol* **145**: 313-22 [PMID:15778739]
160. Klapperstück M, Büttner C, Nickel P, Schmalzing G, Lambrecht G and Markwardt F. (2000) Antagonism by the suramin analogue NF279 on human P2X(1) and P2X(7) receptors. *Eur J Pharmacol* **387**: 245-52 [PMID:10650169]
161. Kobayashi K, Fukuoka T, Yamanaka H, Dai Y, Obata K, Tokunaga A and Noguchi K. (2005) Differential expression patterns of mRNAs for P2X receptor subunits in neurochemically characterized dorsal root ganglion neurons in the rat. *J Comp Neurol* **481**: 377-90 [PMID:15593340]
162. Kobayashi T, Soma T, Noguchi T, Nakagome K, Nakamoto H, Kita H and Nagata M. (2015) ATP drives eosinophil effector responses through P2 purinergic receptors. *Allergol Int* **64 Suppl**: S30-6 [PMID:26344078]
163. Kotnis S, Bingham B, Vasilyev DV, Miller SW, Bai Y, Yeola S, Chanda PK, Bowlby MR, Kaftan EJ and Samad TA *et al*.. (2010) Genetic and functional analysis of human P2X5 reveals a distinct pattern of exon 10 polymorphism with predominant expression of the nonfunctional receptor isoform. *Mol Pharmacol* **77**: 953-60 [PMID:20223879]
164. Labasi JM, Petrushova N, Donovan C, McCurdy S, Lira P, Payette MM, Brissette W, Wicks JR, Audoly L and Gabel CA. (2002) Absence of the P2X7 receptor alters leukocyte function and attenuates an inflammatory response. *J Immunol* **168**: 6436-45 [PMID:12055263]
165. Labrousse VF, Costes L, Aubert A, Darnaudéry M, Ferreira G, Amédée T and Layé S. (2009) Impaired interleukin-1beta and c-Fos expression in the hippocampus is associated with a spatial memory deficit in P2X(7) receptor-deficient mice. *PLoS ONE* **4**: e6006 [PMID:19547756]
166. Lalo U, Pankratov Y, Wichert SP, Rossner MJ, North RA, Kirchhoff F and Verkhratsky A. (2008) P2X1 and P2X5 subunits form the functional P2X receptor in mouse cortical astrocytes. *J Neurosci* **28**: 5473-80 [PMID:18495881]
167. Lamont C, Vainorius E and Wier WG. (2003) Purinergic and adrenergic Ca2+ transients during neurogenic contractions of rat mesenteric small arteries. *J Physiol (Lond.)* **549**: 801-8 [PMID:12740429]
168. Lecut C, Frederix K, Johnson DM, Deroanne C, Thiry M, Faccinetto C, Marée R, Evans RJ, Volders PG and Bours V *et al*.. (2009) P2X1 ion channels promote neutrophil chemotaxis through Rho kinase activation. *J Immunol* **183**: 2801-9 [PMID:19635923]
169. Lewis C, Neidhart S, Holy C, North RA, Buell G and Surprenant A. (1995) Coexpression of P2X2 and P2X3 receptor subunits can account for ATP-gated currents in sensory neurons. *Nature* **377**: 432-5 [PMID:7566120]
170. Lewis CJ and Evans RJ. (2001) P2X receptor immunoreactivity in different arteries from the femoral, pulmonary, cerebral, coronary and renal circulations. *J Vasc Res* **38**: 332-40 [PMID:11455204]
171. Liang SX, Jenkins NA, Gilbert DJ, Copeland NG and Phillips WD. (2001) Structure and chromosome location of the mouse P2X(1) purinoceptor gene (P2rx1). *Cytogenet Cell Genet* **92**: 333-6 [PMID:11435708]
172. Lister MF, Sharkey J, Sawatzky DA, Hodgkiss JP, Davidson DJ, Rossi AG and Finlayson K. (2007) The role of the purinergic P2X7 receptor in inflammation. *J Inflamm (Lond.)* **4**: 5 [PMID:17367517]
173. Llewellyn-Smith IJ and Burnstock G. (1998) Ultrastructural localization of P2X3 receptors in rat sensory neurons. *Neuroreport* **9**: 2545-50 [PMID:9721930]
174. Lommatzsch M, Cicko S, Müller T, Lucattelli M, Bratke K, Stoll P, Grimm M, Dürk T, Zissel G and Ferrari D *et al*.. (2010) Extracellular adenosine triphosphate and chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* **181**: 928-34 [PMID:20093639]
175. Longhurst PA, Schwegel T, Folander K and Swanson R. (1996) The human P2x1 receptor: molecular cloning, tissue distribution, and localization to chromosome 17. *Biochim Biophys Acta* **1308**: 185-8 [PMID:8809107]
176. Lord B, Ameriks MK, Wang Q, Fourgeaud L, Vliegen M, Verluyten W, Haspeslagh P, Carruthers

NI, Lovenberg TW and Bonaventure P *et al.*. (2015) A novel radioligand for the ATP-gated ion channel P2X7: [3H] JNJ-54232334. *Eur J Pharmacol* **765**: 551-9 [PMID:26386289]
177. Lucattelli M, S, T, M, G, S, W, M, R, T, G, S, D, F, JC, G and M. (2010) P2X7 Receptor Signalling in the Pathogenesis of Smoke-induced Lung Inflammation and Emphysema. *Am J Respir Cell Mol Biol* [PMID:20508069]
178. Lynch KJ, Touma E, Niforatos W, Kage KL, Burgard EC, van Biesen T, Kowaluk EA and Jarvis MF. (1999) Molecular and functional characterization of human P2X(2) receptors. *Mol Pharmacol* **56**: 1171-81 [PMID:10570044]
179. Lê KT, Paquet M, Nouel D, Babinski K and Séguéla P. (1997) Primary structure and expression of a naturally truncated human P2X ATP receptor subunit from brain and immune system. *FEBS Lett* **418**: 195-9 [PMID:9414125]
180. Ma B, Ruan HZ, Burnstock G and Dunn PM. (2005) Differential expression of P2X receptors on neurons from different parasympathetic ganglia. *Neuropharmacology* **48**: 766-77 [PMID:15814110]
181. Mansoor SE, Lü W, Oosterheert W, Shekhar M, Tajkhorshid E and Gouaux E. (2016) X-ray structures define human P2X(3) receptor gating cycle and antagonist action. *Nature* **538**: 66-71 [PMID:27626375]
182. Markham A. (2022) Gefapixant: First Approval. *Drugs* **82**: 691-695 [PMID:35347635]
183. Masin M, Kerschensteiner D, Dümke K, Rubio ME and Soto F. (2006) Fe65 interacts with P2X2 subunits at excitatory synapses and modulates receptor function. *J Biol Chem* **281**: 4100-8 [PMID:16330549]
184. Matsumura Y, Yamashita T, Sasaki A, Nakata E, Kohno K, Masuda T, Tozaki-Saitoh H, Imai T, Kuraishi Y and Tsuda M *et al.*. (2016) A novel P2X4 receptor-selective antagonist produces anti-allodynic effect in a mouse model of herpetic pain. *Sci Rep* **6**: 32461 [PMID:27576299]
185. Mayo C, Ren R, Rich C, Stepp MA and Trinkaus-Randall V. (2008) Regulation by P2X7: epithelial migration and stromal organization in the cornea. *Invest Ophthalmol Vis Sci* **49**: 4384-91 [PMID:18502993]
186. Maître B, Magnenat S, Heim V, Ravanat C, Evans RJ, de la Salle H, Gachet C and Hechler B. (2015) The P2X1 receptor is required for neutrophil extravasation during lipopolysaccharide-induced lethal endotoxemia in mice. *J Immunol* **194**: 739-49 [PMID:25480563]
187. McCarthy AE, Yoshioka C and Mansoor SE. (2019) Full-Length $P2X_7$ Structures Reveal How Palmitoylation Prevents Channel Desensitization. *Cell* **179**: 659-670.e13 [PMID:31587896]
188. Michel AD, Chambers LJ and Walter DS. (2008) Negative and positive allosteric modulators of the P2X(7) receptor. *Br J Pharmacol* **153**: 737-50 [PMID:18071294]
189. Michel AD, Chau NM, Fan TP, Frost EE and Humphrey PP. (1995) Evidence that [3H]-alpha,beta-methylene ATP may label an endothelial-derived cell line 5'-nucleotidase with high affinity. *Br J Pharmacol* **115**: 767-74 [PMID:8548175]
190. Michel AD, Clay WC, Ng SW, Roman S, Thompson K, Condreay JP, Hall M, Holbrook J, Livermore D and Senger S. (2008) Identification of regions of the P2X(7) receptor that contribute to human and rat species differences in antagonist effects. *Br J Pharmacol* **155**: 738-51 [PMID:18660826]
191. Michel AD, Ng SW, Roman S, Clay WC, Dean DK and Walter DS. (2009) Mechanism of action of species-selective P2X(7) receptor antagonists. *Br J Pharmacol* **156**: 1312-25 [PMID:19309360]
192. Michel AD, Thompson KM, Simon J, Boyfield I, Fonfria E and Humphrey PP. (2006) Species and response dependent differences in the effects of MAPK inhibitors on P2X(7) receptor function. *Br J Pharmacol* **149**: 948-57 [PMID:17031382]
193. Michel AD, Xing M, Thompson KM, Jones CA and Humphrey PP. (2006) Decavanadate, a P2X receptor antagonist, and its use to study ligand interactions with P2X7 receptors. *Eur J Pharmacol* **534**: 19-29 [PMID:16487507]
194. Mironneau J, Coussin F, Morel JL, Barbot C, Jeyakumar LH, Fleischer S and Mironneau C. (2001) Calcium signalling through nucleotide receptor P2X1 in rat portal vein myocytes. *J Physiol (Lond.)* **536**: 339-50 [PMID:11600670]
195. Mulryan K, Gitterman DP, Lewis CJ, Vial C, Leckie BJ, Cobb AL, Brown JE, Conley EC, Buell G and Pritchard CA *et al.*. (2000) Reduced vas deferens contraction and male infertility in mice lacking P2X1 receptors. *Nature* **403**: 86-9 [PMID:10638758]
196. Murgia M, Hanau S, Pizzo P, Rippa M and Di Virgilio F. (1993) Oxidized ATP. An irreversible inhibitor of the macrophage purinergic P2Z receptor. *J Biol Chem* **268**: 8199-203 [PMID:8463330]
197. Murrell-Lagnado RD and Kawate T. (2022) Methods for Studying Cholesterol-Dependent Regulation of P2X7 Receptors. *Methods Mol Biol* **2510**: 253-264 [PMID:35776329]
198. Naemsch LN, Dixon SJ and Sims SM. (2001) Activity-dependent development of P2X7 current and Ca2+ entry in rabbit osteoclasts. *J Biol Chem* **276**: 39107-14 [PMID:11495918]
199. Narcisse L, Scemes E, Zhao Y, Lee SC and Brosnan CF. (2005) The cytokine IL-1beta transiently enhances P2X7 receptor expression and function in human astrocytes. *Glia* **49**: 245-58 [PMID:15472991]

200. Nawa G, Urano T, Tokino T, Ochi T and Miyoshi Y. (1998) Cloning and characterization of the murine P2XM receptor gene. *J Hum Genet* **43**: 262-7 [PMID:9852680]
201. Nicke A, Bäumert HG, Rettinger J, Eichele A, Lambrecht G, Mutschler E and Schmalzing G. (1998) P2X1 and P2X3 receptors form stable trimers: a novel structural motif of ligand-gated ion channels. *EMBO J* **17**: 3016-28 [PMID:9606184]
202. Nicke A, Kuan YH, Masin M, Rettinger J, Marquez-Klaka B, Bender O, Górecki DC, Murrell-Lagnado RD and Soto F. (2009) A functional P2X7 splice variant with an alternative transmembrane domain 1 escapes gene inactivation in P2X7 knock-out mice. *J Biol Chem* **284**: 25813-22 [PMID:19546214]
203. Nori S, Fumagalli L, Bo X, Bogdanov Y and Burnstock G. (1998) Coexpression of mRNAs for P2X1, P2X2 and P2X4 receptors in rat vascular smooth muscle: an in situ hybridization and RT-PCR study. *J Vasc Res* **35**: 179-85 [PMID:9647332]
204. North RA and Jarvis MF. (2013) P2X receptors as drug targets. *Mol Pharmacol* **83**: 759-69 [PMID:23253448]
205. Nörenberg W, Hempel C, Urban N, Sobottka H, Illes P and Schaefer M. (2011) Clemastine potentiates the human P2X7 receptor by sensitizing it to lower ATP concentrations. *J Biol Chem* **286**: 11067-81 [PMID:21262970]
206. Nörenberg W, Sobottka H, Hempel C, Plötz T, Fischer W, Schmalzing G and Schaefer M. (2012) Positive allosteric modulation by ivermectin of human but not murine P2X7 receptors. *Br J Pharmacol* **167**: 48-66 [PMID:22506590]
207. O'Reilly BA, Kosaka AH, Chang TK, Ford AP, Popert R and McMahon SB. (2001) A quantitative analysis of purinoceptor expression in the bladders of patients with symptomatic outlet obstruction. *BJU Int* **87**: 617-22 [PMID:11350400]
208. O'Reilly BA, Kosaka AH, Chang TK, Ford AP, Popert R, Rymer JM and McMahon SB. (2001) A quantitative analysis of purinoceptor expression in human fetal and adult bladders. *J Urol* **165**: 1730-4 [PMID:11342965]
209. Ohkubo T, Yamazaki J, Nakashima Y and Kitamura K. (2000) Presence and possible role of the spliced isoform of the P2X1 receptor in rat vascular smooth muscle cells. *Pflugers Arch* **441**: 57-64 [PMID:11205062]
210. Oken AC, Krishnamurthy I, Savage JC, Lisi NE, Godsey MH and Mansoor SE. (2022) Molecular Pharmacology of P2X Receptors: Exploring Druggable Domains Revealed by Structural Biology. *Front Pharmacol* **13**: 925880 [PMID:35784697]
211. Ormond SJ, Barrera NP, Qureshi OS, Henderson RM, Edwardson JM and Murrell-Lagnado RD. (2006) An uncharged region within the N terminus of the P2X6 receptor inhibits its assembly and exit from the endoplasmic reticulum. *Mol Pharmacol* **69**: 1692-700 [PMID:16452399]
212. Oury C, Kuijpers MJ, Toth-Zsamboki E, Bonnefoy A, Danloy S, Vreys I, Feijge MA, De Vos R, Vermylen J and Heemskerk JW *et al.*. (2003) Overexpression of the platelet P2X1 ion channel in transgenic mice generates a novel prothrombotic phenotype. *Blood* **101**: 3969-76 [PMID:12521992]
213. Oury C, Toth-Zsamboki E, Van Geet C, Thys C, Wei L, Nilius B, Vermylen J and Hoylaerts MF. (2000) A natural dominant negative P2X1 receptor due to deletion of a single amino acid residue. *J Biol Chem* **275**: 22611-4 [PMID:10816552]
214. Parvathenani LK, Tertyshnikova S, Greco CR, Roberts SB, Robertson B and Posmantur R. (2003) P2X7 mediates superoxide production in primary microglia and is up-regulated in a transgenic mouse model of Alzheimer's disease. *J Biol Chem* **278**: 13309-17 [PMID:12551918]
215. Pelegrin P and Surprenant A. (2009) The P2X(7) receptor-pannexin connection to dye uptake and IL-1beta release. *Purinergic Signal* **5**: 129-37 [PMID:19212823]
216. Pelegrin P and Surprenant A. (2007) Pannexin-1 couples to maitotoxin- and nigericin-induced interleukin-1beta release through a dye uptake-independent pathway. *J Biol Chem* **282**: 2386-94 [PMID:17121814]
217. Pelleg A and Hurt CM. (1996) Mechanism of action of ATP on canine pulmonary vagal C fibre nerve terminals. *J Physiol (Lond.)* **490 (Pt 1)**: 265-75 [PMID:8745294]
218. Pelleg A, Schulman ES and Barnes PJ. (2016) Extracellular Adenosine 5'-Triphosphate in Obstructive Airway Diseases. *Chest* **150**: 908-915 [PMID:27568579]
219. Peverini L, Beudez J, Dunning K, Chataigneau T and Grutter T. (2018) New Insights Into Permeation of Large Cations Through ATP-Gated P2X Receptors. *Front Mol Neurosci* **11**: 265 [PMID:30108481]
220. Piyasirananda W, Beekman A, Ganesan A, Bidula S and Stokes L. (2021) Insights into the Structure-Activity Relationship of Glycosides as Positive Allosteric Modulators Acting on P2X7 Receptors. *Mol Pharmacol* **99**: 163-174 [PMID:33334897]
221. Poole DP, Castelucci P, Robbins HL, Chiocchetti R and Furness JB. (2002) The distribution of P2X3 purine receptor subunits in the guinea pig enteric nervous system. *Auton Neurosci* **101**: 39-47 [PMID:12462358]
222. Prasad M, Fearon IM, Zhang M, Laing M, Vollmer C and Nurse CA. (2001) Expression of P2X2 and P2X3 receptor subunits in rat carotid body afferent neurones: role in chemosensory

signalling. *J Physiol (Lond.)* **537**: 667-77 [PMID:11744746]
223. Przybyła T, Sakowicz-Burkiewicz M and Pawełczyk T. (2018) Purinergic signaling in B cells. *Acta Biochim Pol* **65**: 1-7 [PMID:29360885]
224. Raffaghello L, Chiozzi P, Falzoni S, Di Virgilio F and Pistoia V. (2006) The P2X7 receptor sustains the growth of human neuroblastoma cells through a substance P-dependent mechanism. *Cancer Res* **66**: 907-14 [PMID:16424024]
225. Rassendren F, Buell GN, Virginio C, Collo G, North RA and Surprenant A. (1997) The permeabilizing ATP receptor, P2X7. Cloning and expression of a human cDNA. *J Biol Chem* **272**: 5482-6 [PMID:9038151]
226. Rathinam VA and Fitzgerald KA. (2016) Inflammasome Complexes: Emerging Mechanisms and Effector Functions. *Cell* **165**: 792-800 [PMID:27153493]
227. Ren J, Bian X, DeVries M, Schnegelsberg B, Cockayne DA, Ford AP and Galligan JJ. (2003) P2X2 subunits contribute to fast synaptic excitation in myenteric neurons of the mouse small intestine. *J Physiol (Lond.)* **552**: 809-21 [PMID:12937291]
228. Rettinger J, Schmalzing G, Damer S, Müller G, Nickel P and Lambrecht G. (2000) The suramin analogue NF279 is a novel and potent antagonist selective for the P2X(1) receptor. *Neuropharmacology* **39**: 2044-53 [PMID:10963748]
229. Riteau N, Gasse P, Fauconnier L, Gombault A, Couegnat M, Fick L, Kanellopoulos J, Quesniaux VF, Marchand-Adam S and Crestani B *et al.*. (2010) Extracellular ATP is a danger signal activating P2X7 receptor in lung inflammation and fibrosis. *Am J Respir Crit Care Med* **182**: 774-83 [PMID:20522787]
230. Robinson LE and Murrell-Lagnado RD. (2013) The trafficking and targeting of P2X receptors. *Front Cell Neurosci* **7**: 233 [PMID:24319412]
231. Rodrigues RJ, Almeida T, Richardson PJ, Oliveira CR and Cunha RA. (2005) Dual presynaptic control by ATP of glutamate release via facilitatory P2X1, P2X2/3, and P2X3 and inhibitory P2Y1, P2Y2, and/or P2Y4 receptors in the rat hippocampus. *J Neurosci* **25**: 6286-95 [PMID:16000618]
232. Rong W, Gourine AV, Cockayne DA, Xiang Z, Ford AP, Spyer KM and Burnstock G. (2003) Pivotal role of nucleotide P2X2 receptor subunit of the ATP-gated ion channel mediating ventilatory responses to hypoxia. *J Neurosci* **23**: 11315-21 [PMID:14672995]
233. Ruan HZ, Birder LA, Xiang Z, Chopra B, Buffington T, Tai C, Roppolo JR, de Groat WC and Burnstock G. (2006) Expression of P2X and P2Y receptors in the intramural parasympathetic ganglia of the cat urinary bladder. *Am J Physiol Renal Physiol* **290**: F1143-52 [PMID:16332929]
234. Ruan HZ and Burnstock G. (2004) P2X2 and P2X3 receptor expression in the gallbladder of the guinea pig. *Auton Neurosci* **111**: 89-96 [PMID:15182738]
235. Ruan T, Lin YS, Lin KS and Kou YR. (2006) Mediator mechanisms involved in TRPV1 and P2X receptor-mediated, ROS-evoked bradypneic reflex in anesthetized rats. *J Appl Physiol* **101**: 644-54 [PMID:16627682]
236. Rubio ME and Soto F. (2001) Distinct Localization of P2X receptors at excitatory postsynaptic specializations. *J Neurosci* **21**: 641-53 [PMID:11160443]
237. Sanz JM, Chiozzi P, Ferrari D, Colaianna M, Idzko M, Falzoni S, Fellin R, Trabace L and Di Virgilio F. (2009) Activation of microglia by amyloid {beta} requires P2X7 receptor expression. *J Immunol* **182**: 4378-85 [PMID:19299738]
238. Saul A, Hausmann R, Kless A and Nicke A. (2013) Heteromeric assembly of P2X subunits. *Front Cell Neurosci* **7**: 250 [PMID:24391538]
239. Scase TJ, Heath MF, Allen JM, Sage SO and Evans RJ. (1998) Identification of a P2X1 purinoceptor expressed on human platelets. *Biochem Biophys Res Commun* **242**: 525-8 [PMID:9464249]
240. Schiller IC, Jacobson KA, Wen Z, Malisetty A, Schmalzing G and Markwardt F. (2022) Dihydropyridines Potentiate ATP-Induced Currents Mediated by the Full-Length Human P2X5 Receptor. *Molecules* **27** [PMID:35335209]
241. Schmidt S, Isaak A and Junker A. (2023) Spotlight on P2X7 Receptor PET Imaging: A Bright Target or a Failing Star? *Int J Mol Sci* **24** [PMID:36674884]
242. Sharp AJ, Polak PE, Simonini V, Lin SX, Richardson JC, Bongarzone ER and Feinstein DL. (2008) P2x7 deficiency suppresses development of experimental autoimmune encephalomyelitis. *J Neuroinflammation* **5**: 33 [PMID:18691411]
243. Shemon AN, Sluyter R, Conigrave AD and Wiley JS. (2004) Chelerythrine and other benzophenanthridine alkaloids block the human P2X7 receptor. *Br J Pharmacol* **142**: 1015-9 [PMID:15210579]
244. Shimizu I, Iida T, Guan Y, Zhao C, Raja SN, Jarvis MF, Cockayne DA and Caterina MJ. (2005) Enhanced thermal avoidance in mice lacking the ATP receptor P2X3. *Pain* **116**: 96-108 [PMID:15927378]
245. Silva AM, Rodrigues RJ, Tomé AR, Cunha RA, Misler S, Rosário LM and Santos RM. (2008) Electrophysiological and immunocytochemical evidence for P2X purinergic receptors in pancreatic beta cells. *Pancreas* **36**: 279-83 [PMID:18362842]
246. Sim JA, Park CK, Oh SB, Evans RJ and North RA. (2007) P2X1 and P2X4 receptor currents in

mouse macrophages. *Br J Pharmacol* **152**: 1283-90 [PMID:17934511]
247. Sim JA, Young MT, Sung HY, North RA and Surprenant A. (2004) Reanalysis of P2X7 receptor expression in rodent brain. *J Neurosci* **24**: 6307-14 [PMID:15254086]
248. Simon J, Kidd EJ, Smith FM, Chessell IP, Murrell-Lagnado R, Humphrey PP and Barnard EA. (1997) Localization and functional expression of splice variants of the P2X2 receptor. *Mol Pharmacol* **52**: 237-48 [PMID:9271346]
249. Skarratt KK, Fuller SJ, Sluyter R, Dao-Ung LP, Gu BJ and Wiley JS. (2005) A 5' intronic splice site polymorphism leads to a null allele of the P2X7 gene in 1-2% of the Caucasian population. *FEBS Lett* **579**: 2675-8 [PMID:15862308]
250. Sluyter R, Barden JA and Wiley JS. (2001) Detection of P2X purinergic receptors on human B lymphocytes. *Cell Tissue Res* **304**: 231-6 [PMID:11396717]
251. Sluyter R, Shemon AN, Barden JA and Wiley JS. (2004) Extracellular ATP increases cation fluxes in human erythrocytes by activation of the P2X7 receptor. *J Biol Chem* **279**: 44749-55 [PMID:15304508]
252. Solini A, Chiozzi P, Morelli A, Fellin R and Di Virgilio F. (1999) Human primary fibroblasts in vitro express a purinergic P2X7 receptor coupled to ion fluxes, microvesicle formation and IL-6 release. *J Cell Sci* **112 (Pt 3)**: 297-305 [PMID:9885283]
253. Solle M, Labasi J, Perregaux DG, Stam E, Petrushova N, Koller BH, Griffiths RJ and Gabel CA. (2001) Altered cytokine production in mice lacking P2X(7) receptors. *J Biol Chem* **276**: 125-32 [PMID:11016935]
254. Sorge RE, Trang T, Dorfman R, Smith SB, Beggs S, Ritchie J, Austin JS, Zaykin DV, Vander Meulen H and Costigan M *et al*.. (2012) Genetically determined P2X7 receptor pore formation regulates variability in chronic pain sensitivity. *Nat Med* **18**: 595-9 [PMID:22447075]
255. Soto F, Garcia-Guzman M, Gomez-Hernandez JM, Hollmann M, Karschin C and Stühmer W. (1996) P2X4: an ATP-activated ionotropic receptor cloned from rat brain. *Proc Natl Acad Sci USA* **93**: 3684-8 [PMID:8622997]
256. Soto F, Lambrecht G, Nickel P, Stühmer W and Busch AE. (1999) Antagonistic properties of the suramin analogue NF023 at heterologously expressed P2X receptors. *Neuropharmacology* **38**: 141-9 [PMID:10193905]
257. Souslova V, Cesare P, Ding Y, Akopian AN, Stanfa L, Suzuki R, Carpenter K, Dickenson A, Boyce S and Hill R *et al*.. (2000) Warm-coding deficits and aberrant inflammatory pain in mice lacking P2X3 receptors. *Nature* **407**: 1015-7 [PMID:11069182]
258. Souslova V, Ravenall S, Fox M, Wells D, Wood JN and Akopian AN. (1997) Structure and chromosomal mapping of the mouse P2X3 gene. *Gene* **195**: 101-11 [PMID:9300827]
259. Staikopoulos V, Sessle BJ, Furness JB and Jennings EA. (2007) Localization of P2X2 and P2X3 receptors in rat trigeminal ganglion neurons. *Neuroscience* **144**: 208-16 [PMID:17110047]
260. Stokes L, Jiang LH, Alcaraz L, Bent J, Bowers K, Fagura M, Furber M, Mortimore M, Lawson M and Theaker J *et al*.. (2006) Characterization of a selective and potent antagonist of human P2X(7) receptors, AZ11645373. *Br J Pharmacol* **149**: 880-7 [PMID:17031385]
261. Sugiyama T, Oku H, Shibata M, Fukuhara M, Yoshida H and Ikeda T. (2010) Involvement of P2X7 receptors in the hypoxia-induced death of rat retinal neurons. *Invest Ophthalmol Vis Sci* **51**: 3236-43 [PMID:20071682]
262. Surprenant A, Rassendren F, Kawashima E, North RA and Buell G. (1996) The cytolytic P2Z receptor for extracellular ATP identified as a P2X receptor (P2X7). *Science* **272**: 735-8 [PMID:8614837]
263. Sánchez-Nogueiro J, Marín-García P, León D, León-Otegui M, Salas E, Gómez-Villafuertes R, Gualix J and Miras-Portugal MT. (2009) Axodendritic fibres of mouse cerebellar granule neurons exhibit a diversity of functional P2X receptors. *Neurochem Int* **55**: 671-82 [PMID:19560503]
264. Séguéla P, Haghighi A, Soghomonian JJ and Cooper E. (1996) A novel neuronal P2x ATP receptor ion channel with widespread distribution in the brain. *J Neurosci* **16**: 448-55 [PMID:8551329]
265. Taschenberger H, Jüttner R and Grantyn R. (1999) Ca2+-permeable P2X receptor channels in cultured rat retinal ganglion cells. *J Neurosci* **19**: 3353-66 [PMID:10212295]
266. Taylor SR, Turner CM, Elliott JI, McDaid J, Hewitt R, Smith J, Pickering MC, Whitehouse DL, Cook HT, Burnstock G, Pusey CD, Unwin RJ and Tam FW. (2009) P2X7 deficiency attenuates renal injury in experimental glomerulonephritis. *J Am Soc Nephrol* **20**: 1275-81 [PMID:19389853]
267. Tenneti L, Gibbons SJ and Talamo BR. (1998) Expression and trans-synaptic regulation of P2x4 and P2z receptors for extracellular ATP in parotid acinar cells. Effects of parasympathetic denervation. *J Biol Chem* **273**: 26799-808 [PMID:9756924]
268. Territo PR, Meyer JA, Peters JS, Riley AA, McCarthy BP, Gao M, Wang M, Green MA, Zheng QH and Hutchins GD. (2017) Characterization of ^{11}C-GSK1482160 for Targeting the P2X7 Receptor as a Biomarker for Neuroinflammation. *J Nucl Med* **58**: 458-465 [PMID:27765863]
269. Tomasinsig L, Pizzirani C, Skerlavaj B, Pellegatti P, Gulinelli S, Tossi A, Di Virgilio F and Zanetti M. (2008) The human cathelicidin LL-37 modulates the activities of the P2X7 receptor in a

structure-dependent manner. *J Biol Chem* **283**: 30471-81 [PMID:18765670]
270. Townsend-Nicholson A, King BF, Wildman SS and Burnstock G. (1999) Molecular cloning, functional characterization and possible cooperativity between the murine P2X4 and P2X4a receptors. *Brain Res Mol Brain Res* **64**: 246-54 [PMID:9931497]
271. Urano T, Nishimori H, Han H, Furuhata T, Kimura Y, Nakamura Y and Tokino T. (1997) Cloning of P2XM, a novel human P2X receptor gene regulated by p53. *Cancer Res* **57**: 3281-7 [PMID:9242461]
272. Vaeth M and Feske S. (2018) Ion channelopathies of the immune system. *Curr Opin Immunol* **52**: 39-50 [PMID:29635109]
273. Valera S, Hussy N, Evans RJ, Adami N, North RA, Surprenant A and Buell G. (1994) A new class of ligand-gated ion channel defined by P2x receptor for extracellular ATP. *Nature* **371**: 516-9 [PMID:7523951]
274. Valera S, Talabot F, Evans RJ, Gos A, Antonarakis SE, Morris MA and Buell GN. (1995) Characterization and chromosomal localization of a human P2X receptor from the urinary bladder. *Recept Channels* **3**: 283-9 [PMID:8834001]
275. Van Nassauw L, Brouns I, Adriaensen D, Burnstock G and Timmermans JP. (2002) Neurochemical identification of enteric neurons expressing P2X(3) receptors in the guinea-pig ileum. *Histochem Cell Biol* **118**: 193-203 [PMID:12271355]
276. Vial C and Evans RJ. (2000) P2X receptor expression in mouse urinary bladder and the requirement of P2X(1) receptors for functional P2X receptor responses in the mouse urinary bladder smooth muscle. *Br J Pharmacol* **131**: 1489-95 [PMID:11090125]
277. Vial C and Evans RJ. (2001) Smooth muscle does not have a common P2x receptor phenotype: expression, ontogeny and function of P2x1 receptors in mouse ileum, bladder and reproductive systems. *Auton Neurosci* **92**: 56-64 [PMID:11570704]
278. Vial C and Evans RJ. (2002) P2X(1) receptor-deficient mice establish the native P2X receptor and a P2Y6-like receptor in arteries. *Mol Pharmacol* **62**: 1438-45 [PMID:12435812]
279. Vial C, Hechler B, Léon C, Cazenave JP and Gachet C. (1997) Presence of P2X1 purinoceptors in human platelets and megakaryoblastic cell lines. *Thromb Haemost* **78**: 1500-4 [PMID:9423802]
280. Vial C, Rolf MG, Mahaut-Smith MP and Evans RJ. (2002) A study of P2X1 receptor function in murine megakaryocytes and human platelets reveals synergy with P2Y receptors. *Br J Pharmacol* **135**: 363-72 [PMID:11815371]
281. Virginio C, Robertson G, Surprenant A and North RA. (1998) Trinitrophenyl-substituted nucleotides are potent antagonists selective for P2X1, P2X3, and heteromeric P2X2/3 receptors. *Mol Pharmacol* **53**: 969-73 [PMID:9614197]
282. Vonend O, Turner CM, Chan CM, Loesch A, Dell'Anna GC, Srai KS, Burnstock G and Unwin RJ. (2004) Glomerular expression of the ATP-sensitive P2X receptor in diabetic and hypertensive rat models. *Kidney Int* **66**: 157-66 [PMID:15200422]
283. Vulchanova L, Arvidsson U, Riedl M, Wang J, Buell G, Surprenant A, North RA and Elde R. (1996) Differential distribution of two ATP-gated channels (P2X receptors) determined by immunocytochemistry. *Proc Natl Acad Sci USA* **93**: 8063-7 [PMID:8755603]
284. Vulchanova L, Riedl MS, Shuster SJ, Buell G, Surprenant A, North RA and Elde R. (1997) Immunohistochemical study of the P2X2 and P2X3 receptor subunits in rat and monkey sensory neurons and their central terminals. *Neuropharmacology* **36**: 1229-42 [PMID:9364478]
285. Wang CZ, Namba N, Gonoi T, Inagaki N and Seino S. (1996) Cloning and pharmacological characterization of a fourth P2X receptor subtype widely expressed in brain and peripheral tissues including various endocrine tissues. *Biochem Biophys Res Commun* **220**: 196-202 [PMID:8602843]
286. Wang L, Andersson M, Karlsson L, Watson MA, Cousens DJ, Jern S and Erlinge D. (2003) Increased mitogenic and decreased contractile P2 receptors in smooth muscle cells by shear stress in human vessels with intact endothelium. *Arterioscler Thromb Vasc Biol* **23**: 1370-6 [PMID:12791671]
287. Wang L, Karlsson L, Moses S, Hultgårdh-Nilsson A, Andersson M, Borna C, Gudbjartsson T, Jern S and Erlinge D. (2002) P2 receptor expression profiles in human vascular smooth muscle and endothelial cells. *J Cardiovasc Pharmacol* **40**: 841-53 [PMID:12451317]
288. Wang X, Qin W, Xu X, Xiong Y, Zhang Y, Zhang H and Sun B. (2017) Endotoxin-induced autocrine ATP signaling inhibits neutrophil chemotaxis through enhancing myosin light chain phosphorylation. *Proc Natl Acad Sci USA* **114**: 4483-4488 [PMID:28396412]
289. Wareham K, Vial C, Wykes RC, Bradding P and Seward EP. (2009) Functional evidence for the expression of P2X1, P2X4 and P2X7 receptors in human lung mast cells. *Br J Pharmacol* **157**: 1215-24 [PMID:19552691]
290. Wareham KJ and Seward EP. (2016) P2X7 receptors induce degranulation in human mast cells. *Purinergic Signal* **12**: 235-46 [PMID:26910735]
291. Werner S, Mesch S, Hillig RC, Ter Laak A, Klint J, Neagoe I, Laux-Biehlmann A, Dahllöf H, Bräuer N and Puetter V *et al.*. (2019) Discovery and Characterization of the Potent and Selective P2X4 Inhibitor *N*-[4-(3-Chlorophenoxy)-3-sulfamoylphenyl]-2-phenylacetamide (BAY-1797) and

Structure-Guided Amelioration of Its CYP3A4 Induction Profile. *J Med Chem* **62**: 11194-11217 [PMID:31746599]
292. Wiley JS, Dao-Ung LP, Li C, Shemon AN, Gu BJ, Smart ML, Fuller SJ, Barden JA, Petrou S and Sluyter R. (2003) An Ile-568 to Asn polymorphism prevents normal trafficking and function of the human P2X7 receptor. *J Biol Chem* **278**: 17108-13 [PMID:12586825]
293. Wright A, Mahaut-Smith M, Symon F, Sylvius N, Ran S, Bafadhel M, Muessel M, Bradding P, Wardlaw A and Vial C. (2016) Impaired P2X1 Receptor-Mediated Adhesion in Eosinophils from Asthmatic Patients. *J Immunol* **196**: 4877-84 [PMID:27183585]
294. Xiang Z, Bo X and Burnstock G. (1999) P2X receptor immunoreactivity in the rat cochlea, vestibular ganglion and cochlear nucleus. *Hear Res* **128**: 190-6 [PMID:10082298]
295. Xiang Z, Bo X and Burnstock G. (1998) Localization of ATP-gated P2X receptor immunoreactivity in rat sensory and sympathetic ganglia. *Neurosci Lett* **256**: 105-8 [PMID:9853714]
296. Xiang Z and Burnstock G. (2004) P2X2 and P2X3 purinoceptors in the rat enteric nervous system. *Histochem Cell Biol* **121**: 169-79 [PMID:14767775]
297. Xiang Z and Burnstock G. (2004) Development of nerves expressing P2X3 receptors in the myenteric plexus of rat stomach. *Histochem Cell Biol* **122**: 111-9 [PMID:15258768]
298. Xu J, Kussmaul W, Kurnik PB, Al-Ahdav M and Pelleg A. (2005) Electrophysiological-anatomic correlates of ATP-triggered vagal reflex in the dog. V. Role of purinergic receptors. *Am J Physiol Regul Integr Comp Physiol* **288**: R651-5 [PMID:15539614]
299. Yiangou Y, Facer P, Durrenberger P, Chessell IP, Naylor A, Bountra C, Banati RR and Anand P. (2006) COX-2, CB2 and P2X7-immunoreactivities are increased in activated microglial cells/macrophages of multiple sclerosis and amyotrophic lateral sclerosis spinal cord. *BMC Neurol* **6**: 12 [PMID:16512913]
300. Yip L, Woehrle T, Corriden R, Hirsh M, Chen Y, Inoue Y, Ferrari V, Insel PA and Junger WG. (2009) Autocrine regulation of T-cell activation by ATP release and P2X7 receptors. *FASEB J* **23**: 1685-93 [PMID:19211924]
301. Yu Y, Ugawa S, Ueda T, Ishida Y, Inoue K, Kyaw Nyunt A, Umemura A, Mase M, Yamada K and Shimada S. (2008) Cellular localization of P2X7 receptor mRNA in the rat brain. *Brain Res* **1194**: 45-55 [PMID:18177631]
302. Zdobnov EM, Tegenfeldt F, Kuznetsov D, Waterhouse RM, Simão FA, Ioannidis P, Seppey M, Loetscher A and Kriventseva EV. (2017) OrthoDB v9.1: cataloging evolutionary and functional annotations for animal, fungal, plant, archaeal, bacterial and viral orthologs. *Nucleic Acids Res* **45**: D744-D749 [PMID:27899580]
303. Zhang M, Zhong H, Vollmer C and Nurse CA. (2000) Co-release of ATP and ACh mediates hypoxic signalling at rat carotid body chemoreceptors. *J Physiol (Lond.)* **525 Pt 1**: 143-58 [PMID:10811733]
304. Zheng QH. (2020) Radioligands targeting purinergic P2X7 receptor. *Bioorg Med Chem Lett* **30**: 127169 [PMID:32273217]
305. Zhong Y, Dunn PM, Bardini M, Ford AP, Cockayne DA and Burnstock G. (2001) Changes in P2X receptor responses of sensory neurons from P2X3-deficient mice. *Eur J Neurosci* **14**: 1784-92 [PMID:11860473]
306. Zhong Y, Dunn PM and Burnstock G. (2000) Guinea-pig sympathetic neurons express varying proportions of two distinct P2X receptors. *J Physiol (Lond.)* **523 Pt 2**: 391-402 [PMID:10699083]
307. Zhong Y, Dunn PM and Burnstock G. (2001) Multiple P2X receptors on guinea-pig pelvic ganglion neurons exhibit novel pharmacological properties. *Br J Pharmacol* **132**: 221-33 [PMID:11156581]