

## Inwardly rectifying potassium channels (version 2019.4) in the IUPHAR/BPS Guide to Pharmacology Database

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### Abstract

The 2TM domain family of K channels are also known as the inward-rectifier K channel family. This family includes the strong inward-rectifier K channels ( $K_{ir2.x}$ ) that are constitutively active, the G-protein-activated inward-rectifier K channels ( $K_{ir3.x}$ ) and the ATP-sensitive K channels ( $K_{ir6.x}$ , which combine with sulphonylurea receptors (SUR1-3)). The pore-forming  $\alpha$  subunits form tetramers, and heteromeric channels may be formed within subfamilies (e.g.  $K_{ir3.2}$  with  $K_{ir3.3}$ ).

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## References

1. Abrams CJ, Davies NW, Shelton PA and Stanfield PR. (1996) The role of a single aspartate residue in ionic selectivity and block of a murine inward rectifier K<sup>+</sup> channel Kir2.1. *J. Physiol. (Lond.)* **493 ( Pt 3)**: 643-9 [PMID:8799888]

2. Adelbrecht C, Murer MG, Lauritzen I, Lesage F, Ladzunski M, Agid Y and Raisman-Vozari R. (1997) An immunocytochemical study of a G-protein-gated inward rectifier K<sup>+</sup> channel (GIRK2) in the weaver mouse mesencephalon. *Neuroreport* **8**: 969-74 [PMID:9141074]
3. Aguado C, Colón J, Ciruela F, Schlaudraff F, Cabañero MJ, Perry C, Watanabe M, Liss B, Wickman K and Luján R. (2008) Cell type-specific subunit composition of G protein-gated potassium channels in the cerebellum. *J. Neurochem.* **105**: 497-511 [PMID:18088366]
4. Aguilar-Bryan L, Nichols CG, Wechsler SW, Clement 4th JP, Boyd 3rd AE, González G, Herrera-Sosa H, Nguy K, Bryan J and Nelson DA. (1995) Cloning of the beta cell high-affinity sulfonylurea receptor: a regulator of insulin secretion. *Science* **268**: 423-6 [PMID:7716547]
5. Alagem N, Dvir M and Reuveny E. (2001) Mechanism of Ba(2<sup>+</sup>) block of a mouse inwardly rectifying K<sup>+</sup> channel: differential contribution by two discrete residues. *J. Physiol. (Lond.)* **534**: 381-93 [PMID:11454958]
6. Ando M and Takeuchi S. (1999) Immunological identification of an inward rectifier K<sup>+</sup> channel (Kir4.1) in the intermediate cell (melanocyte) of the cochlear stria vascularis of gerbils and rats. *Cell Tissue Res.* **298**: 179-83 [PMID:10555552]
7. Appleyard SM, Celver J, Pineda V, Kovoor A, Wayman GA and Chavkin C. (1999) Agonist-dependent desensitization of the kappa opioid receptor by G protein receptor kinase and beta-arrestin. *J. Biol. Chem.* **274**: 23802-7 [PMID:10446141]
8. Aretz CD, Vadukoot AK and Hopkins CR. (2019) Discovery of Small Molecule Renal Outer Medullary Potassium (ROMK) Channel Inhibitors: A Brief History of Medicinal Chemistry Approaches To Develop Novel Diuretic Therapeutics. *J. Med. Chem.* [PMID:31034224]
9. Armstrong A and Clapham DE. (2007) Pharmacology of Cardiac Rhythm. *In Principles of pharmacology: the pathophysiologic basis of drug therapy (2nd edition)* Edited by Dolan DE, Tashjian AH, Armstrong EJ, Armstrong AW: Lipponcott Williams and Wilkins: 307-324 [ISBN: 0781783550]
10. Arora D, Hearing M, Haluk DM, Mirkovic K, Fajardo-Serrano A, Wessendorf MW, Watanabe M, Luján R and Wickman K. (2011) Acute cocaine exposure weakens GABA(B) receptor-dependent G-protein-gated inwardly rectifying K<sup>+</sup> signaling in dopamine neurons of the ventral tegmental area. *J. Neurosci.* **31**: 12251-7 [PMID:21865468]
11. Aryal P, Dvir H, Choe S and Slesinger PA. (2009) A discrete alcohol pocket involved in GIRK channel activation. *Nat. Neurosci.* **12**: 988-95 [PMID:19561601]
12. AstraZeneca. AZD2927.
13. Balana B, Bahima L, Bodhinathan K, Taura JJ, Taylor NM, Nettleton MY, Ciruela F and Slesinger PA. (2013) Ras-association domain of sorting Nexin 27 is critical for regulating expression of GIRK potassium channels. *PLoS ONE* **8**: e59800 [PMID:23536889]
14. Balana B, Maslennikov I, Kwiatkowski W, Stern KM, Bahima L, Choe S and Slesinger PA. (2011) Mechanism underlying selective regulation of G protein-gated inwardly rectifying potassium channels by the psychostimulant-sensitive sorting nexin 27. *Proc. Natl. Acad. Sci. U.S.A.* **108**: 5831-6 [PMID:21422294]
15. Barajas-Martínez H, Hu D, Ferrer T, Onetti CG, Wu Y, Burashnikov E, Boyle M, Surman T, Urrutia J and Veltmann C *et al.*. (2012) Molecular genetic and functional association of Brugada and early repolarization syndromes with S422L missense mutation in KCNJ8. *Heart Rhythm* **9**: 548-55 [PMID:22056721]
16. Baukrowitz T, Schulte U, Oliver D, Herlitz S, Krauter T, Tucker SJ, Ruppersberg JP and Fakler B. (1998) PIP2 and PIP as determinants for ATP inhibition of KATP channels. *Science* **282**: 1141-4 [PMID:9804555]
17. Bhawe G, Chauder BA, Liu W, Dawson ES, Kadakia R, Nguyen TT, Lewis LM, Meiler J, Weaver CD and Satlin LM *et al.*. (2011) Development of a selective small-molecule inhibitor of Kir1.1, the renal outer medullary potassium channel. *Mol. Pharmacol.* **79**: 42-50 [PMID:20926757]
18. Bockenhauer D, Feather S, Stanescu HC, Bandulik S, Zdebik AA, Reichold M, Tobin J, Lieberer E, Sterner C and Landouere G *et al.*. (2009) Epilepsy, ataxia, sensorineural deafness, tubulopathy, and KCNJ10 mutations. *N. Engl. J. Med.* **360**: 1960-70 [PMID:19420365]
19. Boim MA, Ho K, Shuck ME, Bienkowski MJ, Block JH, Slightom JL, Yang Y, Brenner BM and Hebert SC. (1995) ROMK inwardly rectifying ATP-sensitive K<sup>+</sup> channel. II. Cloning and distribution of alternative forms. *Am. J. Physiol.* **268**: F1132-40 [PMID:7611454]

20. Bond CT, Pessia M, Xia XM, Lagrutta A, Kavanaugh MP and Adelman JP. (1994) Cloning and expression of a family of inward rectifier potassium channels. *Recept. Channels* **2**: 183-91 [PMID:7874445]
21. Brecht DS, Wang TL, Cohen NA, Guggino WB and Snyder SH. (1995) Cloning and expression of two brain-specific inwardly rectifying potassium channels. *Proc. Natl. Acad. Sci. U.S.A.* **92**: 6753-7 [PMID:7624316]
22. Breitwieser GE and Szabo G. (1985) Uncoupling of cardiac muscarinic and beta-adrenergic receptors from ion channels by a guanine nucleotide analogue. *Nature* **317**: 538-40 [PMID:2413368]
23. Brownstein CA, Towne MC, Luquette LJ, Harris DJ, Marinakis NS, Meinecke P, Kutsche K, Campeau PM, Yu TW and Margulies DM *et al.*. (2013) Mutation of KCNJ8 in a patient with Cantú syndrome with unique vascular abnormalities - support for the role of K(ATP) channels in this condition. *Eur J Med Genet* **56**: 678-82 [PMID:24176758]
24. Béguin P, Nagashima K, Nishimura M, Gono T and Seino S. (1999) PKA-mediated phosphorylation of the human K(ATP) channel: separate roles of Kir6.2 and SUR1 subunit phosphorylation. *EMBO J.* **18**: 4722-32 [PMID:10469651]
25. Cader ZM, Noble-Topham S, Dymont DA, Cherny SS, Brown JD, Rice GP and Ebers GC. (2003) Significant linkage to migraine with aura on chromosome 11q24. *Hum. Mol. Genet.* **12**: 2511-7 [PMID:12915447]
26. Choe H, Sackin H and Palmer LG. (2000) Permeation properties of inward-rectifier potassium channels and their molecular determinants. *J. Gen. Physiol.* **115**: 391-404 [PMID:10736307]
27. Ciruela F, Fernández-Dueñas V, Sahlholm K, Fernández-Alacid L, Nicolau JC, Watanabe M and Luján R. (2010) Evidence for oligomerization between GABAB receptors and GIRK channels containing the GIRK1 and GIRK3 subunits. *Eur. J. Neurosci.* **32**: 1265-77 [PMID:20846323]
28. Clancy SM, Fowler CE, Finley M, Suen KF, Arrabit C, Berton F, Kosaza T, Casey PJ and Slesinger PA. (2005) Pertussis-toxin-sensitive Galpha subunits selectively bind to C-terminal domain of neuronal GIRK channels: evidence for a heterotrimeric G-protein-channel complex. *Mol. Cell. Neurosci.* **28**: 375-89 [PMID:15691717]
29. Cohen NA, Brenman JE, Snyder SH and Brecht DS. (1996) Binding of the inward rectifier K<sup>+</sup> channel Kir 2.3 to PSD-95 is regulated by protein kinase A phosphorylation. *Neuron* **17**: 759-67 [PMID:8893032]
30. Connors NC, Adams ME, Froehner SC and Kofuji P. (2004) The potassium channel Kir4.1 associates with the dystrophin-glycoprotein complex via alpha-syntrophin in glia. *J. Biol. Chem.* **279**: 28387-92 [PMID:15102837]
31. Cooper PE, Reutter H, Woelfle J, Engels H, Grange DK, van Haften G, van Bon BW, Hoischen A and Nichols CG. (2014) Cantú syndrome resulting from activating mutation in the KCNJ8 gene. *Hum. Mutat.* **35**: 809-13 [PMID:24700710]
32. Corey S and Clapham DE. (1998) Identification of native atrial G-protein-regulated inwardly rectifying K<sup>+</sup> (GIRK4) channel homomultimers. *J. Biol. Chem.* **273**: 27499-504 [PMID:9765280]
33. Coulter KL, Périer F, Radeke CM and Vandenberg CA. (1995) Identification and molecular localization of a pH-sensing domain for the inward rectifier potassium channel HIR. *Neuron* **15**: 1157-68 [PMID:7576658]
34. Cruz HG, Berton F, Sollini M, Blanchet C, Pravetoni M, Wickman K and Lüscher C. (2008) Absence and rescue of morphine withdrawal in GIRK/Kir3 knock-out mice. *J. Neurosci.* **28**: 4069-77 [PMID:18400906]
35. Cruz HG, Ivanova T, Lunn ML, Stoffel M, Slesinger PA and Lüscher C. (2004) Bi-directional effects of GABA(B) receptor agonists on the mesolimbic dopamine system. *Nat. Neurosci.* **7**: 153-9 [PMID:14745451]
36. D'Adamo MC, Shang L, Imbrici P, Brown SD, Pessia M and Tucker SJ. (2011) Genetic inactivation of Kcnj16 identifies Kir5.1 as an important determinant of neuronal PCO<sub>2</sub>/pH sensitivity. *J. Biol. Chem.* **286**: 192-8 [PMID:21047793]
37. Dart C and Leyland ML. (2001) Targeting of an A kinase-anchoring protein, AKAP79, to an inwardly rectifying potassium channel, Kir2.1. *J. Biol. Chem.* **276**: 20499-505 [PMID:11287423]
38. Dascal N, Schreibmayer W, Lim NF, Wang W, Chavkin C, DiMugno L, Labarca C, Kieffer BL, Gaveriaux-Ruff C and Trollinger D *et al.*. (1993) Atrial G protein-activated K<sup>+</sup> channel: expression cloning and molecular properties. *Proc. Natl. Acad. Sci. U.S.A.* **90**: 10235-9 [PMID:8234283]

39. Day M, Carr DB, Ulrich S, Ilijic E, Tkatch T and Surmeier DJ. (2005) Dendritic excitability of mouse frontal cortex pyramidal neurons is shaped by the interaction among HCN, Kir2, and K<sub>leak</sub> channels. *J. Neurosci.* **25**: 8776-87 [PMID:16177047]
40. Denton JS, Weaver CD, Lewis LM, Chauder BA and Lindsley CW. (2010) Discovery of a small molecule inhibitor of ROMK and Kir7.1. In *Probe Reports from the NIH Molecular Libraries Program* National Center for Biotechnology Information (US): [PMID:21433378]
41. Derst C, Döring F, Preisig-Müller R, Daut J, Karschin A, Jeck N, Weber S, Engel H and Grzeschik KH. (1998) Partial gene structure and assignment to chromosome 2q37 of the human inwardly rectifying K<sup>+</sup> channel (Kir7.1) gene (KCNJ13). *Genomics* **54**: 560-3 [PMID:9878260]
42. Derst C, Karschin C, Wischmeyer E, Hirsch JR, Preisig-Müller R, Rajan S, Engel H, Grzeschik K, Daut J and Karschin A. (2001) Genetic and functional linkage of Kir5.1 and Kir2.1 channel subunits. *FEBS Lett.* **491**: 305-11 [PMID:11240146]
43. Dissmann E, Wischmeyer E, Spauschus A, Pfeil DV, Karschin C and Karschin A. (1996) Functional expression and cellular mRNA localization of a G protein-activated K<sup>+</sup> inward rectifier isolated from rat brain. *Biochem. Biophys. Res. Commun.* **223**: 474-9 [PMID:8670306]
44. Doi T, Fakler B, Schultz JH, Schulte U, Brändle U, Weidemann S, Zenner HP, Lang F and Ruppersberg JP. (1996) Extracellular K<sup>+</sup> and intracellular pH allosterically regulate renal Kir1.1 channels. *J. Biol. Chem.* **271**: 17261-6 [PMID:8663367]
45. Doupnik CA, Davidson N, Lester HA and Kofuji P. (1997) RGS proteins reconstitute the rapid gating kinetics of gbetagamma-activated inwardly rectifying K<sup>+</sup> channels. *Proc. Natl. Acad. Sci. U.S.A.* **94**: 10461-6 [PMID:9294233]
46. Duprat F, Guillemare E, Romey G, Fink M, Lesage F, Lazdunski M and Honore E. (1995) Susceptibility of cloned K<sup>+</sup> channels to reactive oxygen species. *Proc. Natl. Acad. Sci. U.S.A.* **92**: 11796-800 [PMID:8524851]
47. Döring F, Derst C, Wischmeyer E, Karschin C, Schneggenburger R, Daut J and Karschin A. (1998) The epithelial inward rectifier channel Kir7.1 displays unusual K<sup>+</sup> permeation properties. *J. Neurosci.* **18**: 8625-36 [PMID:9786970]
48. Edvinsson JM, Shah AJ and Palmer LG. (2011) Potassium-dependent activation of Kir4.2 K<sup>+</sup> channels. *J. Physiol. (Lond.)* **589**: 5949-63 [PMID:22025665]
49. Fakler B, Bond CT, Adelman JP and Ruppersberg JP. (1996) Heterooligomeric assembly of inward-rectifier K<sup>+</sup> channels from subunits of different subfamilies: Kir2.1 (IRK1) and Kir4.1 (BIR10). *Pflugers Arch.* **433**: 77-83 [PMID:9019734]
50. Fang Y, Schram G, Romanenko VG, Shi C, Conti L, Vandenberg CA, Davies PF, Nattel S and Levitan I. (2005) Functional expression of Kir2.x in human aortic endothelial cells: the dominant role of Kir2.2. *Am. J. Physiol., Cell Physiol.* **289**: C1134-44 [PMID:15958527]
51. Felix JP, Liu J, Schmalhofer WA, Bailey T, Bednarek MA, Kinkel S, Weinglass AB, Kohler M, Kaczorowski GJ, Priest BT and Garcia ML. (2006) Characterization of Kir1.1 channels with the use of a radiolabeled derivative of tertiapin. *Biochemistry* **45**: 10129-39 [PMID:16906771]
52. Fernández-Alacid L, Aguado C, Ciruela F, Martín R, Colón J, Cabañero MJ, Gassmann M, Watanabe M, Shigemoto R and Wickman K *et al.*. (2009) Subcellular compartment-specific molecular diversity of pre- and post-synaptic GABA-activated GIRK channels in Purkinje cells. *J. Neurochem.* **110**: 1363-76 [PMID:19558451]
53. Ferraro TN, Golden GT, Smith GG, Martin JF, Lohoff FW, Gieringer TA, Zamboni D, Schwebel CL, Press DM, Kratzer SO, Zhao H, Berrettini WH and Buono RJ. (2004) Fine mapping of a seizure susceptibility locus on mouse Chromosome 1: nomination of Kcnj10 as a causative gene. *Mamm. Genome* **15**: 239-51 [PMID:15112102]
54. Ferrer J, Nichols CG, Makhina EN, Salkoff L, Bernstein J, Gerhard D, Wasson J, Ramanadham S and Permutt A. (1995) Pancreatic islet cells express a family of inwardly rectifying K<sup>+</sup> channel subunits which interact to form G-protein-activated channels. *J. Biol. Chem.* **270**: 26086-91 [PMID:7592809]
55. Fowler CE, Aryal P, Suen KF and Slesinger PA. (2007) Evidence for association of GABA(B) receptors

- with Kir3 channels and regulators of G protein signalling (RGS4) proteins. *J. Physiol. (Lond.)* **580**: 51-65 [PMID:17185339]
56. Fujita A, Horio Y, Higashi K, Mouri T, Hata F, Takeguchi N and Kurachi Y. (2002) Specific localization of an inwardly rectifying K(+) channel, Kir4.1, at the apical membrane of rat gastric parietal cells; its possible involvement in K(+) recycling for the H(+)-K(+)-pump. *J. Physiol. (Lond.)* **540**: 85-92 [PMID:11927671]
  57. Fujita S, Inanobe A, Chachin M, Aizawa Y and Kurachi Y. (2000) A regulator of G protein signalling (RGS) protein confers agonist-dependent relaxation gating to a G protein-gated K+ channel. *J. Physiol. (Lond.)* **526 Pt 2**: 341-7 [PMID:10896722]
  58. Furutani K, Ohno Y, Inanobe A, Hibino H and Kurachi Y. (2009) Mutational and in silico analyses for antidepressant block of astroglial inward-rectifier Kir4.1 channel. *Mol. Pharmacol.* **75**: 1287-95 [PMID:19264848]
  59. Garcia ML and Kaczorowski GJ. (2014) Targeting the inward-rectifier potassium channel ROMK in cardiovascular disease. *Curr Opin Pharmacol* **15**: 1-6 [PMID:24721647]
  60. Garcia ML, Priest BT, Alonso-Galicia M, Zhou X, Felix JP, Brochu RM, Bailey T, Thomas-Fowlkes B, Liu J and Swensen A *et al.*. (2014) Pharmacologic inhibition of the renal outer medullary potassium channel causes diuresis and natriuresis in the absence of kaliuresis. *J. Pharmacol. Exp. Ther.* **348**: 153-64 [PMID:24142912]
  61. Giebisch G, Hebert SC and Wang WH. (2003) New aspects of renal potassium transport. *Pflugers Arch.* **446**: 289-97 [PMID:12684792]
  62. Gilliam D, O'Brien DP, Coates JR, Johnson GS, Johnson GC, Mhlanga-Mutangadura T, Hansen L, Taylor JF and Schnabel RD. (2014) A homozygous KCNJ10 mutation in Jack Russell Terriers and related breeds with spinocerebellar ataxia with myokymia, seizures, or both. *J. Vet. Intern. Med.* **28**: 871-7 [PMID:24708069]
  63. Gloyn AL, Pearson ER, Antcliff JF, Proks P, Bruining GJ, Slingerland AS, Howard N, Srinivasan S, Silva JM and Molnes J *et al.*. (2004) Activating mutations in the gene encoding the ATP-sensitive potassium-channel subunit Kir6.2 and permanent neonatal diabetes. *N. Engl. J. Med.* **350**: 1838-49 [PMID:15115830]
  64. Hampton C, Zhou X, Priest BT, Pai LY, Felix JP, Thomas-Fowlkes B, Liu J, Kohler M, Xiao J and Corona A *et al.*. (2016) The Renal Outer Medullary Potassium Channel Inhibitor, MK-7145, Lowers Blood Pressure, and Manifests Features of Bartter's Syndrome Type II Phenotype. *J. Pharmacol. Exp. Ther.* **359**: 194-206 [PMID:27432892]
  65. Hattori T, Makiyama T, Akao M, Ehara E, Ohno S, Iguchi M, Nishio Y, Sasaki K, Itoh H and Yokode M *et al.*. (2012) A novel gain-of-function KCNJ2 mutation associated with short-QT syndrome impairs inward rectification of Kir2.1 currents. *Cardiovasc. Res.* **93**: 666-73 [PMID:22155372]
  66. Hearing M, Kotecki L, Marron Fernandez de Velasco E, Fajardo-Serrano A, Chung HJ, Luján R and Wickman K. (2013) Repeated cocaine weakens GABA(B)-GIRK signaling in layer 5/6 pyramidal neurons in the prelimbic cortex. *Neuron* **80**: 159-70 [PMID:24094109]
  67. Hedin KE, Lim NF and Clapham DE. (1996) Cloning of a *Xenopus laevis* inwardly rectifying K+ channel subunit that permits GIRK1 expression of IKACH currents in oocytes. *Neuron* **16**: 423-9 [PMID:8789957]
  68. Hejtmančík JF, Jiao X, Li A, Sergeev YV, Ding X, Sharma AK, Chan CC, Medina I and Edwards AO. (2008) Mutations in KCNJ13 cause autosomal-dominant snowflake vitreoretinal degeneration. *Am. J. Hum. Genet.* **82**: 174-80 [PMID:18179896]
  69. Hibino H, Fujita A, Iwai K, Yamada M and Kurachi Y. (2004) Differential assembly of inwardly rectifying K+ channel subunits, Kir4.1 and Kir5.1, in brain astrocytes. *J. Biol. Chem.* **279**: 44065-73 [PMID:15310750]
  70. Hibino H, Higashi-Shingai K, Fujita A, Iwai K, Ishii M and Kurachi Y. (2004) Expression of an inwardly rectifying K+ channel, Kir5.1, in specific types of fibrocytes in the cochlear lateral wall suggests its functional importance in the establishment of endocochlear potential. *Eur. J. Neurosci.* **19**: 76-84 [PMID:14750965]
  71. Hibino H, Horio Y, Inanobe A, Doi K, Ito M, Yamada M, Gotow T, Uchiyama Y, Kawamura M and Kubo T *et al.*. (1997) An ATP-dependent inwardly rectifying potassium channel, KAB-2 (Kir4.1), in cochlear stria vascularis of inner ear: its specific subcellular localization and correlation with the formation of

- endocochlear potential. *J. Neurosci.* **17**: 4711-21 [PMID:9169531]
72. Higashi K, Fujita A, Inanobe A, Tanemoto M, Doi K, Kubo T and Kurachi Y. (2001) An inwardly rectifying K(+) channel, Kir4.1, expressed in astrocytes surrounds synapses and blood vessels in brain. *Am. J. Physiol., Cell Physiol.* **281**: C922-31 [PMID:11502569]
  73. Hilgemann DW and Ball R. (1996) Regulation of cardiac Na<sup>+</sup>,Ca<sup>2+</sup> exchange and KATP potassium channels by PIP<sub>2</sub>. *Science* **273**: 956-9 [PMID:8688080]
  74. Hill CE, Briggs MM, Liu J and Magtanong L. (2002) Cloning, expression, and localization of a rat hepatocyte inwardly rectifying potassium channel. *Am. J. Physiol. Gastrointest. Liver Physiol.* **282**: G233-40 [PMID:11804844]
  75. Ho IH and Murrell-Lagnado RD. (1999) Molecular determinants for sodium-dependent activation of G protein-gated K<sup>+</sup> channels. *J. Biol. Chem.* **274**: 8639-48 [PMID:10085101]
  76. Ho K, Nichols CG, Lederer WJ, Lytton J, Vassilev PM, Kanazirska MV and Hebert SC. (1993) Cloning and expression of an inwardly rectifying ATP-regulated potassium channel. *Nature* **362**: 31-8 [PMID:7680431]
  77. Horio Y, Hibino H, Inanobe A, Yamada M, Ishii M, Tada Y, Satoh E, Hata Y, Takai Y and Kurachi Y. (1997) Clustering and enhanced activity of an inwardly rectifying potassium channel, Kir4.1, by an anchoring protein, PSD-95/SAP90. *J. Biol. Chem.* **272**: 12885-8 [PMID:9148889]
  78. Horio Y, Morishige K, Takahashi N and Kurachi Y. (1996) Differential distribution of classical inwardly rectifying potassium channel mRNAs in the brain: comparison of IRK2 with IRK1 and IRK3. *FEBS Lett.* **379**: 239-43 [PMID:8603697]
  79. Huang C, Sindic A, Hill CE, Hujer KM, Chan KW, Sassen M, Wu Z, Kurachi Y, Nielsen S and Romero MF *et al.*. (2007) Interaction of the Ca<sup>2+</sup>-sensing receptor with the inwardly rectifying potassium channels Kir4.1 and Kir4.2 results in inhibition of channel function. *Am. J. Physiol. Renal Physiol.* **292**: F1073-81 [PMID:17122384]
  80. Huang CL, Feng S and Hilgemann DW. (1998) Direct activation of inward rectifier potassium channels by PIP<sub>2</sub> and its stabilization by Gbetagamma. *Nature* **391**: 803-6 [PMID:9486652]
  81. Huang CL, Slesinger PA, Casey PJ, Jan YN and Jan LY. (1995) Evidence that direct binding of G beta gamma to the GIRK1 G protein-gated inwardly rectifying K<sup>+</sup> channel is important for channel activation. *Neuron* **15**: 1133-43 [PMID:7576656]
  82. Hughes BA, Kumar G, Yuan Y, Swaminathan A, Yan D, Sharma A, Plumley L, Yang-Feng TL and Swaroop A. (2000) Cloning and functional expression of human retinal kir2.4, a pH-sensitive inwardly rectifying K(+) channel. *Am. J. Physiol., Cell Physiol.* **279**: C771-84 [PMID:10942728]
  83. Hugnot JP, Pedeutour F, Le Calvez C, Grosgeorge J, Passage E, Fontes M and Lazdunski M. (1997) The human inward rectifying K<sup>+</sup> channel Kir 2.2 (KCNJ12) gene: gene structure, assignment to chromosome 17p11.1, and identification of a simple tandem repeat polymorphism. *Genomics* **39**: 113-6 [PMID:9027495]
  84. Inagaki N, Gono T, Clement 4th JP, Namba N, Inazawa J, Gonzalez G, Aguilar-Bryan L, Seino S and Bryan J. (1995) Reconstitution of IKATP: an inward rectifier subunit plus the sulfonylurea receptor. *Science* **270**: 1166-70 [PMID:7502040]
  85. Inagaki N, Gono T, Clement JP, Wang CZ, Aguilar-Bryan L, Bryan J and Seino S. (1996) A family of sulfonylurea receptors determines the pharmacological properties of ATP-sensitive K<sup>+</sup> channels. *Neuron* **16**: 1011-7 [PMID:8630239]
  86. Inagaki N, Inazawa J and Seino S. (1995) cDNA sequence, gene structure, and chromosomal localization of the human ATP-sensitive potassium channel, uKATP-1, gene (KCNJ8). *Genomics* **30**: 102-4 [PMID:8595887]
  87. Inagaki N, Tsuura Y, Namba N, Masuda K, Gono T, Horie M, Seino Y, Mizuta M and Seino S. (1995) Cloning and functional characterization of a novel ATP-sensitive potassium channel ubiquitously expressed in rat tissues, including pancreatic islets, pituitary, skeletal muscle, and heart. *J. Biol. Chem.* **270**: 5691-4 [PMID:7890693]
  88. Inanobe A, Fujita A, Ito M, Tomoike H, Inageda K and Kurachi Y. (2002) Inward rectifier K<sup>+</sup> channel Kir2.3 is localized at the postsynaptic membrane of excitatory synapses. *Am. J. Physiol., Cell Physiol.* **282**: C1396-403 [PMID:11997254]

89. Inanobe A, Horio Y, Fujita A, Tanemoto M, Hibino H, Inageda K and Kurachi Y. (1999) Molecular cloning and characterization of a novel splicing variant of the Kir3.2 subunit predominantly expressed in mouse testis. *J. Physiol. (Lond.)* **521 Pt 1**: 19-30 [PMID:10562331]
90. Inanobe A, Yoshimoto Y, Horio Y, Morishige KI, Hibino H, Matsumoto S, Tokunaga Y, Maeda T, Hata Y and Takai Y *et al.* (1999) Characterization of G-protein-gated K<sup>+</sup> channels composed of Kir3.2 subunits in dopaminergic neurons of the substantia nigra. *J. Neurosci.* **19**: 1006-17 [PMID:9920664]
91. Ishihara K, Hiraoka M and Ochi R. (1996) The tetravalent organic cation spermine causes the gating of the IRK1 channel expressed in murine fibroblast cells. *J. Physiol. (Lond.)* **491 ( Pt 2)**: 367-81 [PMID:8866861]
92. Ishii M, Fujita A, Iwai K, Kusaka S, Higashi K, Inanobe A, Hibino H and Kurachi Y. (2003) Differential expression and distribution of Kir5.1 and Kir4.1 inwardly rectifying K<sup>+</sup> channels in retina. *Am. J. Physiol., Cell Physiol.* **285**: C260-7 [PMID:12686518]
93. Ishii M, Horio Y, Tada Y, Hibino H, Inanobe A, Ito M, Yamada M, Gotow T, Uchiyama Y and Kurachi Y. (1997) Expression and clustered distribution of an inwardly rectifying potassium channel, KAB-2/Kir4.1, on mammalian retinal Müller cell membrane: their regulation by insulin and laminin signals. *J. Neurosci.* **17**: 7725-35 [PMID:9315894]
94. Isomoto S, Kondo C, Takahashi N, Matsumoto S, Yamada M, Takumi T, Horio Y and Kurachi Y. (1996) A novel ubiquitously distributed isoform of GIRK2 (GIRK2B) enhances GIRK1 expression of the G-protein-gated K<sup>+</sup> current in *Xenopus* oocytes. *Biochem. Biophys. Res. Commun.* **218**: 286-91 [PMID:8573147]
95. Isomoto S, Kondo C, Yamada M, Matsumoto S, Higashiguchi O, Horio Y, Matsuzawa Y and Kurachi Y. (1996) A novel sulfonylurea receptor forms with BIR (Kir6.2) a smooth muscle type ATP-sensitive K<sup>+</sup> channel. *J. Biol. Chem.* **271**: 24321-4 [PMID:8798681]
96. Ito M, Inanobe A, Horio Y, Hibino H, Isomoto S, Ito H, Mori K, Tonosaki A, Tomoike H and Kurachi Y. (1996) Immunolocalization of an inwardly rectifying K<sup>+</sup> channel, K(AB)-2 (Kir4.1), in the basolateral membrane of renal distal tubular epithelia. *FEBS Lett.* **388**: 11-5 [PMID:8654579]
97. Jeck N, Derst C, Wischmeyer E, Ott H, Weber S, Rudin C, Seyberth HW, Daut J, Karschin A and Konrad M. (2001) Functional heterogeneity of ROMK mutations linked to hyperprostaglandin E syndrome. *Kidney Int.* **59**: 1803-11 [PMID:11318951]
98. Jelacic TM, Kennedy ME, Wickman K and Clapham DE. (2000) Functional and biochemical evidence for G-protein-gated inwardly rectifying K<sup>+</sup> (GIRK) channels composed of GIRK2 and GIRK3. *J. Biol. Chem.* **275**: 36211-6 [PMID:10956667]
99. Jelacic TM, Sims SM and Clapham DE. (1999) Functional expression and characterization of G-protein-gated inwardly rectifying K<sup>+</sup> channels containing GIRK3. *J. Membr. Biol.* **169**: 123-9 [PMID:10341034]
100. Jin W, Brown S, Roche JP, Hsieh C, Colver JP, Koovor A, Chavkin C and Mackie K. (1999) Distinct domains of the CB1 cannabinoid receptor mediate desensitization and internalization. *J. Neurosci.* **19**: 3773-80 [PMID:10234009]
101. Jin W, Klem AM, Lewis JH and Lu Z. (1999) Mechanisms of inward-rectifier K<sup>+</sup> channel inhibition by tertiapin-Q. *Biochemistry* **38**: 14294-301 [PMID:10572004]
102. Jin W and Lu Z. (1998) A novel high-affinity inhibitor for inward-rectifier K<sup>+</sup> channels *Biochemistry* **37**: 13291-9 [PMID:9748337]
103. Jin W and Lu Z. (1999) Synthesis of a stable form of tertiapin: a high-affinity inhibitor for inward-rectifier K<sup>+</sup> channels. *Biochemistry* **38**: 14286-93 [PMID:10572003]
104. Jin X, Yu L, Wu Y, Zhang S, Shi Z, Chen X, Yang Y, Zhang X and Jiang C. (2012) S-Glutathionylation underscores the modulation of the heteromeric Kir4.1-Kir5.1 channel in oxidative stress. *J. Physiol. (Lond.)* **590**: 5335-48 [PMID:22907060]
105. Kaiser M, Maletzki I, Hülsmann S, Holtmann B, Schulz-Schaeffer W, Kirchhoff F, Bähr M and Neusch C. (2006) Progressive loss of a glial potassium channel (KCNJ10) in the spinal cord of the SOD1 (G93A) transgenic mouse model of amyotrophic lateral sclerosis. *J. Neurochem.* **99**: 900-12 [PMID:16925593]
106. Kane GC, Lam CF, O'Coilain F, Hodgson DM, Reyes S, Liu XK, Miki T, Seino S, Katusic ZS and Terzic A. (2006) Gene knockout of the KCNJ8-encoded Kir6.1 K(ATP) channel imparts fatal susceptibility to endotoxemia. *FASEB J.* **20**: 2271-80 [PMID:17077304]



107. Karschin C, Dissmann E, Stühmer W and Karschin A. (1996) IRK(1-3) and GIRK(1-4) inwardly rectifying K<sup>+</sup> channel mRNAs are differentially expressed in the adult rat brain. *J. Neurosci.* **16**: 3559-70 [PMID:8642402]
108. Karschin C and Karschin A. (1997) Ontogeny of gene expression of Kir channel subunits in the rat *Mol. Cell. Neurosci.* **10**: 131-48 [PMID:9532576]
109. Kaufmann K, Romaine I, Days E, Pascual C, Malik A, Yang L, Zou B, Du Y, Sliwoski G and Morrison RD *et al.*. (2013) ML297 (VU0456810), the first potent and selective activator of the GIRK potassium channel, displays antiepileptic properties in mice. *ACS Chem Neurosci* **4**: 1278-86 [PMID:23730969]
110. Kim D, Lewis DL, Graziadei L, Neer EJ, Bar-Sagi D and Clapham DE. (1989) G-protein beta gamma-subunits activate the cardiac muscarinic K<sup>+</sup>-channel via phospholipase A2. *Nature* **337**: 557-60 [PMID:2492640]
111. Kobayashi T, Ikeda K, Ichikawa T, Abe S, Togashi S and Kumanishi T. (1995) Molecular cloning of a mouse G-protein-activated K<sup>+</sup> channel (mGIRK1) and distinct distributions of three GIRK (GIRK1, 2 and 3) mRNAs in mouse brain. *Biochem. Biophys. Res. Commun.* **208**: 1166-73 [PMID:7702616]
112. Kobayashi T, Ikeda K, Kojima H, Niki H, Yano R, Yoshioka T and Kumanishi T. (1999) Ethanol opens G-protein-activated inwardly rectifying K<sup>+</sup> channels. *Nat. Neurosci.* **2**: 1091-7 [PMID:10570486]
113. Kobayashi T, Ikeda K and Kumanishi T. (2000) Inhibition by various antipsychotic drugs of the G-protein-activated inwardly rectifying K(+) (GIRK) channels expressed in xenopus oocytes. *Br. J. Pharmacol.* **129**: 1716-22 [PMID:10780978]
114. Kobayashi T, Washiyama K and Ikeda K. (2004) Inhibition of G protein-activated inwardly rectifying K<sup>+</sup> channels by various antidepressant drugs. *Neuropsychopharmacology* **29**: 1841-51 [PMID:15150531]
115. Kobayashi T, Washiyama K and Ikeda K. (2003) Inhibition of G protein-activated inwardly rectifying K<sup>+</sup> channels by fluoxetine (Prozac). *Br. J. Pharmacol.* **138**: 1119-28 [PMID:12684268]
116. Kofuji P, Ceelen P, Zahs KR, Surbeck LW, Lester HA and Newman EA. (2000) Genetic inactivation of an inwardly rectifying potassium channel (Kir4.1 subunit) in mice: phenotypic impact in retina. *J. Neurosci.* **20**: 5733-40 [PMID:10908613]
117. Kofuji P, Davidson N and Lester HA. (1995) Evidence that neuronal G-protein-gated inwardly rectifying K<sup>+</sup> channels are activated by G beta gamma subunits and function as heteromultimers. *Proc. Natl. Acad. Sci. U.S.A.* **92**: 6542-6 [PMID:7604029]
118. Kofuji P, Hofer M, Millen KJ, Millonig JH, Davidson N, Lester HA and Hatten ME. (1996) Functional analysis of the weaver mutant GIRK2 K<sup>+</sup> channel and rescue of weaver granule cells. *Neuron* **16**: 941-52 [PMID:8630252]
119. Konstas AA, Korbmacher C and Tucker SJ. (2003) Identification of domains that control the heteromeric assembly of Kir5.1/Kir4.0 potassium channels. *Am. J. Physiol., Cell Physiol.* **284**: C910-7 [PMID:12456399]
120. Kooor A, Cerver JP, Wu A and Chavkin C. (1998) Agonist induced homologous desensitization of mu-opioid receptors mediated by G protein-coupled receptor kinases is dependent on agonist efficacy. *Mol. Pharmacol.* **54**: 704-11 [PMID:9765514]
121. Kooor P, Wickman K, Maguire CT, Pu W, Gehrman J, Berul CI and Clapham DE. (2001) Evaluation of the role of I(KACh) in atrial fibrillation using a mouse knockout model. *J. Am. Coll. Cardiol.* **37**: 2136-43 [PMID:11419900]
122. Koyama H, Morishige K, Takahashi N, Zanelli JS, Fass DN and Kurachi Y. (1994) Molecular cloning, functional expression and localization of a novel inward rectifier potassium channel in the rat brain. *FEBS Lett.* **341**: 303-7 [PMID:8137958]
123. Koyrakh L, Luján R, Colón J, Karschin C, Kurachi Y, Karschin A and Wickman K. (2005) Molecular and cellular diversity of neuronal G-protein-gated potassium channels. *J. Neurosci.* **25**: 11468-78 [PMID:16339040]
124. Koyrakh L, Roman MI, Brinkmann V and Wickman K. (2005) The heart rate decrease caused by acute FTY720 administration is mediated by the G protein-gated potassium channel I. *Am. J. Transplant.* **5**: 529-36 [PMID:15707407]
125. Kozell LB, Walter NA, Milner LC, Wickman K and Buck KJ. (2009) Mapping a barbiturate withdrawal locus

- to a 0.44 Mb interval and analysis of a novel null mutant identify a role for Kcnj9 (GIRK3) in withdrawal from pentobarbital, zolpidem, and ethanol. *J. Neurosci.* **29**: 11662-73 [PMID:19759313]
126. Krapivinsky G, Gordon EA, Wickman K, Velimirović B, Krapivinsky L and Clapham DE. (1995) The G-protein-gated atrial K<sup>+</sup> channel IKACH is a heteromultimer of two inwardly rectifying K<sup>(+)</sup>-channel proteins. *Nature* **374**: 135-41 [PMID:7877685]
  127. Krapivinsky G, Krapivinsky L, Wickman K and Clapham DE. (1995) G beta gamma binds directly to the G protein-gated K<sup>+</sup> channel, IKACH. *J. Biol. Chem.* **270**: 29059-62 [PMID:7493925]
  128. Krapivinsky G, Medina I, Eng L, Krapivinsky L, Yang Y and Clapham DE. (1998) A novel inward rectifier K<sup>+</sup> channel with unique pore properties. *Neuron* **20**: 995-1005 [PMID:9620703]
  129. Kubo Y, Baldwin TJ, Jan YN and Jan LY. (1993) Primary structure and functional expression of a mouse inward rectifier potassium channel. *Nature* **362**: 127-33 [PMID:7680768]
  130. Kubo Y, Reuveny E, Slesinger PA, Jan YN and Jan LY. (1993) Primary structure and functional expression of a rat G-protein-coupled muscarinic potassium channel. *Nature* **364**: 802-6 [PMID:8355805]
  131. Kurachi Y. (1995) G protein regulation of cardiac muscarinic potassium channel. *Am. J. Physiol.* **269**: C821-30 [PMID:7485449]
  132. Kurschner C, Mermelstein PG, Holden WT and Surmeier DJ. (1998) CIPP, a novel multivalent PDZ domain protein, selectively interacts with Kir4.0 family members, NMDA receptor subunits, neurexins, and neuroligins. *Mol. Cell. Neurosci.* **11**: 161-72 [PMID:9647694]
  133. Kusaka S, Inanobe A, Fujita A, Makino Y, Tanemoto M, Matsushita K, Tano Y and Kurachi Y. (2001) Functional Kir7.1 channels localized at the root of apical processes in rat retinal pigment epithelium. *J. Physiol. (Lond.)* **531**: 27-36 [PMID:11179389]
  134. Kuzhikandathil EV and Oxford GS. (2002) Classic D1 dopamine receptor antagonist R-(+)-7-chloro-8-hydroxy-3-methyl-1-phenyl-2,3,4,5-tetrahydro-1H-3-benzazepine hydrochloride (SCH23390) directly inhibits G protein-coupled inwardly rectifying potassium channels. *Mol. Pharmacol.* **62**: 119-26 [PMID:12065762]
  135. Károlyi L, Konrad M, Köckerling A, Ziegler A, Zimmermann DK, Roth B, Wieg C, Grzeschik K-H, Koch MC and Seyberth HW. (1997) Mutations in the gene encoding the inwardly-rectifying renal potassium channel, ROMK, cause the antenatal variant of Bartter syndrome: evidence for genetic heterogeneity. International Collaborative Study Group for Bartter-like Syndromes. *Hum. Mol. Genet.* **6**: 17-26 [PMID:9002665]
  136. Labouèbe G, Lomazzi M, Cruz HG, Creton C, Luján R, Li M, Yanagawa Y, Obata K, Watanabe M and Wickman K *et al.*. (2007) RGS2 modulates coupling between GABAB receptors and GIRK channels in dopamine neurons of the ventral tegmental area. *Nat. Neurosci.* **10**: 1559-68 [PMID:17965710]
  137. Lachheb S, Cluzeaud F, Bens M, Genete M, Hibino H, Lourdel S, Kurachi Y, Vandewalle A, Teulon J and Paulais M. (2008) Kir4.1/Kir5.1 channel forms the major K<sup>+</sup> channel in the basolateral membrane of mouse renal collecting duct principal cells. *Am. J. Physiol. Renal Physiol.* **294**: F1398-407 [PMID:18367659]
  138. Lalive AL, Munoz MB, Bellone C, Slesinger PA, Lüscher C and Tan KR. (2014) Firing modes of dopamine neurons drive bidirectional GIRK channel plasticity. *J. Neurosci.* **34**: 5107-14 [PMID:24719090]
  139. Leaney JL. (2003) Contribution of Kir3.1, Kir3.2A and Kir3.2C subunits to native G protein-gated inwardly rectifying potassium currents in cultured hippocampal neurons. *Eur. J. Neurosci.* **18**: 2110-8 [PMID:14622172]
  140. Lee WS and Hebert SC. (1995) ROMK inwardly rectifying ATP-sensitive K<sup>+</sup> channel. I. Expression in rat distal nephron segments. *Am. J. Physiol.* **268**: F1124-31 [PMID:7611453]
  141. Leonoudakis D, Conti LR, Anderson S, Radeke CM, McGuire LM, Adams ME, Froehner SC, Yates 3rd JR and Vandenberg CA. (2004) Protein trafficking and anchoring complexes revealed by proteomic analysis of inward rectifier potassium channel (Kir2.x)-associated proteins. *J. Biol. Chem.* **279**: 22331-46 [PMID:15024025]
  142. Leonoudakis D, Conti LR, Radeke CM, McGuire LM and Vandenberg CA. (2004) A multiprotein trafficking complex composed of SAP97, CASK, Veli, and Mint1 is associated with inward rectifier Kir2 potassium channels. *J. Biol. Chem.* **279**: 19051-63 [PMID:14960569]
  143. Leonoudakis D, Mailliard W, Wingerd K, Clegg D and Vandenberg C. (2001) Inward rectifier potassium

- channel Kir2.2 is associated with synapse-associated protein SAP97. *J. Cell. Sci.* **114**: 987-98  
[\[PMID:11181181\]](#)
144. Lesage F, Duprat F, Fink M, Guillemare E, Coppola T, Lazdunski M and Hugnot JP. (1994) Cloning provides evidence for a family of inward rectifier and G-protein coupled K<sup>+</sup> channels in the brain. *FEBS Lett.* **353**: 37-42 [\[PMID:7926018\]](#)
  145. Lesage F, Fink M, Barhanin J, Lazdunski M and Mattéi MG. (1995) Assignment of human G-protein-coupled inward rectifier K<sup>+</sup> channel homolog GIRK3 gene to chromosome 1q21-q23. *Genomics* **29**: 808-9 [\[PMID:8575783\]](#)
  146. Lesage F, Guillemare E, Fink M, Duprat F, Heurteaux C, Fosset M, Romey G, Barhanin J and Lazdunski M. (1995) Molecular properties of neuronal G-protein-activated inwardly rectifying K<sup>+</sup> channels. *J. Biol. Chem.* **270**: 28660-7 [\[PMID:7499385\]](#)
  147. Lewohl JM, Wilson WR, Mayfield RD, Brozowski SJ, Morrisett RA and Harris RA. (1999) G-protein-coupled inwardly rectifying potassium channels are targets of alcohol action. *Nat. Neurosci.* **2**: 1084-90 [\[PMID:10570485\]](#)
  148. Leyland ML and Dart C. (2004) An alternatively spliced isoform of PSD-93/chapsyn 110 binds to the inwardly rectifying potassium channel, Kir2.1. *J. Biol. Chem.* **279**: 43427-36 [\[PMID:15304517\]](#)
  149. Li A, Knutsen RH, Zhang H, Osei-Owusu P, Moreno-Dominguez A, Harter TM, Uchida K, Remedi MS, Dietrich HH and Bernal-Mizrachi C *et al.*. (2013) Hypotension due to Kir6.1 gain-of-function in vascular smooth muscle. *J Am Heart Assoc* **2**: e000365 [\[PMID:23974906\]](#)
  150. Li L, Head V and Timpe LC. (2001) Identification of an inward rectifier potassium channel gene expressed in mouse cortical astrocytes. *Glia* **33**: 57-71 [\[PMID:11169792\]](#)
  151. Li N, Wu JX, Ding D, Cheng J, Gao N and Chen L. (2017) Structure of a Pancreatic ATP-Sensitive Potassium Channel. *Cell* **168**: 101-110.e10 [\[PMID:28086082\]](#)
  152. Liao YJ, Jan YN and Jan LY. (1996) Heteromultimerization of G-protein-gated inwardly rectifying K<sup>+</sup> channel proteins GIRK1 and GIRK2 and their altered expression in weaver brain. *J. Neurosci.* **16**: 7137-50 [\[PMID:8929423\]](#)
  153. Liss B, Haeckel O, Wildmann J, Miki T, Seino S and Roeper J. (2005) K-ATP channels promote the differential degeneration of dopaminergic midbrain neurons. *Nat. Neurosci.* **8**: 1742-51 [\[PMID:16299504\]](#)
  154. Liu Y, Liu D, Heath L, Meyers DM, Krafft DS, Wagoner PK, Silvia CP, Yu W and Curran ME. (2001) Direct activation of an inwardly rectifying potassium channel by arachidonic acid. *Mol. Pharmacol.* **59**: 1061-8 [\[PMID:11306688\]](#)
  155. Liu Y, Liu D, Printzenhoff D, Coghlan MJ, Harris R and Krafft DS. (2002) Tenidap, a novel anti-inflammatory agent, is an opener of the inwardly rectifying K<sup>+</sup> channel hKir2.3. *Eur. J. Pharmacol.* **435**: 153-60 [\[PMID:11821021\]](#)
  156. Liu Y, McKenna E, Figueroa DJ, Blevins R, Austin CP, Bennett PB and Swanson R. (2000) The human inward rectifier K<sup>(+)</sup> channel subunit kir5.1 (KCNJ16) maps to chromosome 17q25 and is expressed in kidney and pancreas. *Cytogenet. Cell Genet.* **90**: 60-3 [\[PMID:11060447\]](#)
  157. Logothetis DE, Kurachi Y, Galper J, Neer EJ and Clapham DE. (1987) The beta gamma subunits of GTP-binding proteins activate the muscarinic K<sup>+</sup> channel in heart. *Nature* **325**: 321-6 [\[PMID:2433589\]](#)
  158. Lopatin AN, Makhina EN and Nichols CG. (1994) Potassium channel block by cytoplasmic polyamines as the mechanism of intrinsic rectification. *Nature* **372**: 366-9 [\[PMID:7969496\]](#)
  159. Lourdel S, Paulais M, Cluzeaud F, Bens M, Tanemoto M, Kurachi Y, Vandewalle A and Teulon J. (2002) An inward rectifier K<sup>(+)</sup> channel at the basolateral membrane of the mouse distal convoluted tubule: similarities with Kir4-Kir5.1 heteromeric channels. *J. Physiol. (Lond.)* **538**: 391-404 [\[PMID:11790808\]](#)
  160. Lu M, Leng Q, Egan ME, Caplan MJ, Boulpaep EL, Giebisch GH and Hebert SC. (2006) CFTR is required for PKA-regulated ATP sensitivity of Kir1.1 potassium channels in mouse kidney. *J. Clin. Invest.* **116**: 797-807 [\[PMID:16470247\]](#)
  161. Lu M, Wang T, Yan Q, Yang X, Dong K, Knepper MA, Wang W, Giebisch G, Shull GE and Hebert SC. (2002) Absence of small conductance K<sup>+</sup> channel (SK) activity in apical membranes of thick ascending limb and cortical collecting duct in ROMK (Barter's) knockout mice. *J. Biol. Chem.* **277**: 37881-7

[PMID:12130653]

162. Lunn ML, Nassirpour R, Arrabit C, Tan J, McLeod I, Arias CM, Sawchenko PE, Yates 3rd JR and Slesinger PA. (2007) A unique sorting nexin regulates trafficking of potassium channels via a PDZ domain interaction. *Nat. Neurosci.* **10**: 1249-59 [PMID:17828261]
163. Lüscher C, Jan LY, Stoffel M, Malenka RC and Nicoll RA. (1997) G protein-coupled inwardly rectifying K<sup>+</sup> channels (GIRKs) mediate postsynaptic but not presynaptic transmitter actions in hippocampal neurons. *Neuron* **19**: 687-95 [PMID:9331358]
164. Lüscher C and Slesinger PA. (2010) Emerging roles for G protein-gated inwardly rectifying potassium (GIRK) channels in health and disease. *Nat. Rev. Neurosci.* **11**: 301-15 [PMID:20389305]
165. Ma D, Tang XD, Rogers TB and Welling PA. (2007) An andersen-Tawil syndrome mutation in Kir2.1 (V302M) alters the G-loop cytoplasmic K<sup>+</sup> conduction pathway. *J. Biol. Chem.* **282**: 5781-9 [PMID:17166852]
166. Ma D, Zerangue N, Raab-Graham K, Fried SR, Jan YN and Jan LY. (2002) Diverse trafficking patterns due to multiple traffic motifs in G protein-activated inwardly rectifying potassium channels from brain and heart. *Neuron* **33**: 715-29 [PMID:11879649]
167. Makhina EN, Kelly AJ, Lopatin AN, Mercer RW and Nichols CG. (1994) Cloning and expression of a novel human brain inward rectifier potassium channel. *J. Biol. Chem.* **269**: 20468-74 [PMID:8051145]
168. Mao J, Wang X, Chen F, Wang R, Rojas A, Shi Y, Piao H and Jiang C. (2004) Molecular basis for the inhibition of G protein-coupled inward rectifier K<sup>(+)</sup> channels by protein kinase C. *Proc. Natl. Acad. Sci. U.S.A.* **101**: 1087-92 [PMID:14732702]
169. Marcus DC, Wu T, Wangemann P and Kofuji P. (2002) KCNJ10 (Kir4.1) potassium channel knockout abolishes endocochlear potential. *Am. J. Physiol., Cell Physiol.* **282**: C403-7 [PMID:11788352]
170. Matsuda T, Takeda K, Ito M, Yamagishi R, Tamura M, Nakamura H, Tsuruoka N, Saito T, Masumiya H and Suzuki T *et al.*. (2005) Atria selective prolongation by NIP-142, an antiarrhythmic agent, of refractory period and action potential duration in guinea pig myocardium. *J. Pharmacol. Sci.* **98**: 33-40 [PMID:15879679]
171. Mennitt PA, Wade JB, Ecelbarger CA, Palmer LG and Frindt G. (1997) Localization of ROMK channels in the rat kidney. *J. Am. Soc. Nephrol.* **8**: 1823-30 [PMID:9402083]
172. Mi H, Deerinck TJ, Jones M, Ellisman MH and Schwarz TL. (1996) Inwardly rectifying K<sup>+</sup> channels that may participate in K<sup>+</sup> buffering are localized in microvilli of Schwann cells. *J. Neurosci.* **16**: 2421-9 [PMID:8786419]
173. Miki T, Liss B, Minami K, Shiuchi T, Saraya A, Kashima Y, Horiuchi M, Ashcroft F, Minokoshi Y and Roeper J *et al.*. (2001) ATP-sensitive K<sup>+</sup> channels in the hypothalamus are essential for the maintenance of glucose homeostasis. *Nat. Neurosci.* **4**: 507-12 [PMID:11319559]
174. Miki T, Nagashima K and Seino S. (1999) The structure and function of the ATP-sensitive K<sup>+</sup> channel in insulin-secreting pancreatic beta-cells. *J. Mol. Endocrinol.* **22**: 113-23 [PMID:10194514]
175. Miki T, Nagashima K, Tashiro F, Kotake K, Yoshitomi H, Tamamoto A, Gono T, Iwanaga T, Miyazaki J and Seino S. (1998) Defective insulin secretion and enhanced insulin action in KATP channel-deficient mice. *Proc. Natl. Acad. Sci. U.S.A.* **95**: 10402-6 [PMID:9724715]
176. Miki T, Suzuki M, Shibasaki T, Uemura H, Sato T, Yamaguchi K, Koseki H, Iwanaga T, Nakaya H and Seino S. (2002) Mouse model of Prinzmetal angina by disruption of the inward rectifier Kir6.1. *Nat. Med.* **8**: 466-72 [PMID:11984590]
177. Miki T, Tashiro F, Iwanaga T, Nagashima K, Yoshitomi H, Aihara H, Nitta Y, Gono T, Inagaki N and Miyazaki Ji *et al.*. (1997) Abnormalities of pancreatic islets by targeted expression of a dominant-negative KATP channel. *Proc. Natl. Acad. Sci. U.S.A.* **94**: 11969-73 [PMID:9342346]
178. Morgan AD, Carroll ME, Loth AK, Stoffel M and Wickman K. (2003) Decreased cocaine self-administration in Kir3 potassium channel subunit knockout mice. *Neuropsychopharmacology* **28**: 932-8 [PMID:12637950]
179. Morishige K, Inanobe A, Yoshimoto Y, Kurachi H, Murata Y, Tokunaga Y, Maeda T, Maruyama Y and Kurachi Y. (1999) Secretagogue-induced exocytosis recruits G protein-gated K<sup>+</sup> channels to plasma membrane in endocrine cells. *J. Biol. Chem.* **274**: 7969-74 [PMID:10075694]

180. Morishige K, Takahashi N, Jahangir A, Yamada M, Koyama H, Zanelli JS and Kurachi Y. (1994) Molecular cloning and functional expression of a novel brain-specific inward rectifier potassium channel. *FEBS Lett.* **346**: 251-6 [PMID:8013643]
181. Mouri T, Kittaka N, Horio Y, Copeland NG, Gilbert DJ, Jenkins NA and Kurachi Y. (1998) Assignment of mouse inwardly rectifying potassium channel Kcnj16 to the distal region of mouse chromosome 11. *Genomics* **54**: 181-2 [PMID:9806850]
182. Munoz MB and Slesinger PA. (2014) Sorting nexin 27 regulation of G protein-gated inwardly rectifying K<sup>+</sup> channels attenuates in vivo cocaine response. *Neuron* **82**: 659-69 [PMID:24811384]
183. Murer G, Adelbrecht C, Lauritzen I, Lesage F, Lazdunski M, Agid Y and Raisman-Vozari R. (1997) An immunocytochemical study on the distribution of two G-protein-gated inward rectifier potassium channels (GIRK2 and GIRK4) in the adult rat brain. *Neuroscience* **80**: 345-57 [PMID:9284339]
184. Nagelhus EA, Horio Y, Inanobe A, Fujita A, Haug FM, Nielsen S, Kurachi Y and Ottersen OP. (1999) Immunogold evidence suggests that coupling of K<sup>+</sup> siphoning and water transport in rat retinal Müller cells is mediated by a coenrichment of Kir4.1 and AQP4 in specific membrane domains. *Glia* **26**: 47-54 [PMID:10088671]
185. Nakamura N, Suzuki Y, Ikeda Y, Notoya M and Hirose S. (2000) Complex structure and regulation of expression of the rat gene for inward rectifier potassium channel Kir7.1. *J. Biol. Chem.* **275**: 28276-84 [PMID:10871613]
186. Nakamura N, Suzuki Y, Sakuta H, Ookata K, Kawahara K and Hirose S. (1999) Inwardly rectifying K<sup>+</sup> channel Kir7.1 is highly expressed in thyroid follicular cells, intestinal epithelial cells and choroid plexus epithelial cells: implication for a functional coupling with Na<sup>+</sup>,K<sup>+</sup>-ATPase. *Biochem. J.* **342 ( Pt 2)**: 329-36 [PMID:10455019]
187. Navarro B, Kennedy ME, Velimirović B, Bhat D, Peterson AS and Clapham DE. (1996) Nonselective and G betagamma-insensitive weaver K<sup>+</sup> channels. *Science* **272**: 1950-3 [PMID:8658170]
188. Nehring RB, Wischmeyer E, Döring F, Veh RW, Sheng M and Karschin A. (2000) Neuronal inwardly rectifying K(+) channels differentially couple to PDZ proteins of the PSD-95/SAP90 family. *J. Neurosci.* **20**: 156-62 [PMID:10627592]
189. Nestorowicz A, Inagaki N, Gono T, Schoor KP, Wilson BA, Glaser B, Landau H, Stanley CA, Thornton PS and Seino S *et al.*. (1997) A nonsense mutation in the inward rectifier potassium channel gene, Kir6.2, is associated with familial hyperinsulinism. *Diabetes* **46**: 1743-8 [PMID:9356020]
190. Neusch C, Rozengurt N, Jacobs RE, Lester HA and Kofuji P. (2001) Kir4.1 potassium channel subunit is crucial for oligodendrocyte development and in vivo myelination. *J. Neurosci.* **21**: 5429-38 [PMID:11466414]
191. Nichols CG, Ho K and Hebert S. (1994) Mg(2+)-dependent inward rectification of ROMK1 potassium channels expressed in *Xenopus* oocytes. *J. Physiol. (Lond.)* **476**: 399-409 [PMID:8057249]
192. Nishida M, Cadene M, Chait BT and MacKinnon R. (2007) Crystal structure of a Kir3.1-prokaryotic Kir channel chimera. *EMBO J.* **26**: 4005-15 [PMID:17703190]
193. Nishida M and MacKinnon R. (2002) Structural basis of inward rectification: cytoplasmic pore of the G protein-gated inward rectifier GIRK1 at 1.8 Å resolution. *Cell* **111**: 957-65 [PMID:12507423]
194. Ohira M, Seki N, Nagase T, Suzuki E, Nomura N, Ohara O, Hattori M, Sakaki Y, Eki T, Murakami Y, Saito T, Ichikawa H and Ohki M. (1997) Gene identification in 1.6-Mb region of the Down syndrome region on chromosome 21. *Genome Res.* **7**: 47-58 [PMID:9037601]
195. Okamoto K, Iwasaki N, Doi K, Noiri E, Iwamoto Y, Uchigata Y, Fujita T and Tokunaga K. (2012) Inhibition of glucose-stimulated insulin secretion by KCNJ15, a newly identified susceptibility gene for type 2 diabetes. *Diabetes* **61**: 1734-41 [PMID:22566534]
196. Olsen O, Liu H, Wade JB, Merot J and Welling PA. (2002) Basolateral membrane expression of the Kir 2.3 channel is coordinated by PDZ interaction with Lin-7/CASK complex. *Am. J. Physiol., Cell Physiol.* **282**: C183-95 [PMID:11742811]
197. Ookata K, Tojo A, Suzuki Y, Nakamura N, Kimura K, Wilcox CS and Hirose S. (2000) Localization of inward rectifier potassium channel Kir7.1 in the basolateral membrane of distal nephron and collecting

- duct. *J. Am. Soc. Nephrol.* **11**: 1987-94 [PMID:11053473]
198. Padgett CL, Lalive AL, Tan KR, Terunuma M, Munoz MB, Pangalos MN, Martínez-Hernández J, Watanabe M, Moss SJ and Luján R *et al.*. (2012) Methamphetamine-evoked depression of GABA(B) receptor signaling in GABA neurons of the VTA. *Neuron* **73**: 978-89 [PMID:22405207]
  199. Partiseti M, Collura V, Agnel M, Culouscou JM and Graham D. (1998) Cloning and characterization of a novel human inwardly rectifying potassium channel predominantly expressed in small intestine. *FEBS Lett.* **434**: 171-6 [PMID:9738472]
  200. Patil N, Cox DR, Bhat D, Faham M, Myers RM and Peterson AS. (1995) A potassium channel mutation in weaver mice implicates membrane excitability in granule cell differentiation. *Nat. Genet.* **11**: 126-9 [PMID:7550338]
  201. Paulais M, Bloch-Faure M, Picard N, Jacques T, Ramakrishnan SK, Keck M, Sohet F, Eladari D, Houillier P and Lourdel S *et al.*. (2011) Renal phenotype in mice lacking the Kir5.1 (Kcnj16) K<sup>+</sup> channel subunit contrasts with that observed in SeSAME/EAST syndrome. *Proc. Natl. Acad. Sci. U.S.A.* **108**: 10361-6 [PMID:21633011]
  202. Pearson ER, Flechtner I, Njølstad PR, Malecki MT, Flanagan SE, Larkin B, Ashcroft FM, Klimes I, Codner E and Iotova V *et al.*. (2006) Switching from insulin to oral sulfonylureas in patients with diabetes due to Kir6.2 mutations. *N. Engl. J. Med.* **355**: 467-77 [PMID:16885550]
  203. Pearson WL, Dourado M, Schreiber M, Salkoff L and Nichols CG. (1999) Expression of a functional Kir4 family inward rectifier K<sup>+</sup> channel from a gene cloned from mouse liver. *J. Physiol. (Lond.)* **514 ( Pt 3)**: 639-53 [PMID:9882736]
  204. Pegan S, Arrabit C, Zhou W, Kwiatkowski W, Collins A, Slesinger PA and Choe S. (2005) Cytoplasmic domain structures of Kir2.1 and Kir3.1 show sites for modulating gating and rectification. *Nat. Neurosci.* **8**: 279-87 [PMID:15723059]
  205. Peleg S, Varon D, Ivanina T, Dessauer CW and Dascal N. (2002) G(α)(i) controls the gating of the G protein-activated K(+) channel, GIRK. *Neuron* **33**: 87-99 [PMID:11779482]
  206. Perillán PR, Li X, Potts EA, Chen M, Brecht DS and Simard JM. (2000) Inward rectifier K(+) channel Kir2.3 (IRK3) in reactive astrocytes from adult rat brain. *Glia* **31**: 181-92 [PMID:10878604]
  207. Pessia M, Imbrici P, D'Adamo MC, Salvatore L and Tucker SJ. (2001) Differential pH sensitivity of Kir4.1 and Kir4.2 potassium channels and their modulation by heteropolymerisation with Kir5.1. *J. Physiol. (Lond.)* **532**: 359-67 [PMID:11306656]
  208. Pessia M, Tucker SJ, Lee K, Bond CT and Adelman JP. (1996) Subunit positional effects revealed by novel heteromeric inwardly rectifying K<sup>+</sup> channels. *EMBO J.* **15**: 2980-7 [PMID:8670799]
  209. Pfaffinger PJ, Martin JM, Hunter DD, Nathanson NM and Hille B. (1985) GTP-binding proteins couple cardiac muscarinic receptors to a K channel. *Nature* **317**: 536-8 [PMID:2413367]
  210. Plaster NM, Tawil R, Tristani-Firouzi M, Canún S, Bendahhou S, Tsunoda A, Donaldson MR, Iannaccone ST, Brunt E and Barohn R *et al.*. (2001) Mutations in Kir2.1 cause the developmental and episodic electrical phenotypes of Andersen's syndrome. *Cell* **105**: 511-9 [PMID:11371347]
  211. Poopalasundaram S, Knott C, Shamotienko OG, Foran PG, Dolly JO, Ghiani CA, Gallo V and Wilkin GP. (2000) Glial heterogeneity in expression of the inwardly rectifying K(+) channel, Kir4.1, in adult rat CNS. *Glia* **30**: 362-72 [PMID:10797616]
  212. Pravetoni M and Wickman K. (2008) Behavioral characterization of mice lacking GIRK/Kir3 channel subunits. *Genes Brain Behav.* **7**: 523-31 [PMID:18194467]
  213. Preisig-Müller R, Schlichthörl G, Goerge T, Heinen S, Brüggemann A, Rajan S, Derst C, Veh RW and Daut J. (2002) Heteromerization of Kir2.x potassium channels contributes to the phenotype of Andersen's syndrome. *Proc. Natl. Acad. Sci. U.S.A.* **99**: 7774-9 [PMID:12032359]
  214. Priori SG, Pandit SV, Rivolta I, Berenfeld O, Ronchetti E, Dhamoon A, Napolitano C, Anumonwo J, di Barletta MR and Gudapakkam S *et al.*. (2005) A novel form of short QT syndrome (SQT3) is caused by a mutation in the KCNJ2 gene. *Circ. Res.* **96**: 800-7 [PMID:15761194]
  215. Prüss H, Derst C, Lommel R and Veh RW. (2005) Differential distribution of individual subunits of strongly inwardly rectifying potassium channels (Kir2 family) in rat brain. *Brain Res. Mol. Brain Res.* **139**: 63-79

[PMID:15936845]

216. Prüss H, Wenzel M, Eulitz D, Thomzig A, Karschin A and Veh RW. (2003) Kir2 potassium channels in rat striatum are strategically localized to control basal ganglia function. *Brain Res. Mol. Brain Res.* **110**: 203-19 [PMID:12591157]
217. Pérrier F, Radeke CM and Vandenberg CA. (1994) Primary structure and characterization of a small-conductance inwardly rectifying potassium channel from human hippocampus. *Proc. Natl. Acad. Sci. U.S.A.* **91**: 6240-4 [PMID:8016146]
218. Qu Z, Yang Z, Cui N, Zhu G, Liu C, Xu H, Chanchevalap S, Shen W, Wu J and Li Y *et al.*. (2000) Gating of inward rectifier K<sup>+</sup> channels by proton-mediated interactions of N- and C-terminal domains. *J. Biol. Chem.* **275**: 31573-80 [PMID:10896660]
219. Raab-Graham KF, Radeke CM and Vandenberg CA. (1994) Molecular cloning and expression of a human heart inward rectifier potassium channel. *Neuroreport* **5**: 2501-5 [PMID:7696590]
220. Rapedius M, Soom M, Shumilina E, Schulze D, Schönherr R, Kirsch C, Lang F, Tucker SJ and Baukrowitz T. (2005) Long chain CoA esters as competitive antagonists of phosphatidylinositol 4,5-bisphosphate activation in Kir channels. *J. Biol. Chem.* **280**: 30760-7 [PMID:15980413]
221. Raphemot R, Lonergan DF, Nguyen TT, Utley T, Lewis LM, Kadakia R, Weaver CD, Gogliotti R, Hopkins C and Lindsley CW *et al.*. (2011) Discovery, characterization, and structure-activity relationships of an inhibitor of inward rectifier potassium (Kir) channels with preference for Kir2.3, Kir3.x, and Kir7.1. *Front Pharmacol* **2**: 75 [PMID:22275899]
222. Reuveny E, Slesinger PA, Inglese J, Morales JM, Iñiguez-Lluhi JA, Lefkowitz RJ, Bourne HR, Jan YN and Jan LY. (1994) Activation of the cloned muscarinic potassium channel by G protein beta gamma subunits. *Nature* **370**: 143-6 [PMID:8022483]
223. Rojas A, Cui N, Su J, Yang L, Muhumuza JP and Jiang C. (2007) Protein kinase C dependent inhibition of the heteromeric Kir4.1-Kir5.1 channel. *Biochim. Biophys. Acta* **1768**: 2030-42 [PMID:17585871]
224. Rosenhouse-Dantsker A, Sui JL, Zhao Q, Rusinova R, Rodríguez-Menchaca AA, Zhang Z and Logothetis DE. (2008) A sodium-mediated structural switch that controls the sensitivity of Kir channels to PtdIns(4,5)P(2). *Nat. Chem. Biol.* **4**: 624-31 [PMID:18794864]
225. Sackin H, Vasilyev A, Palmer LG and Krambis M. (2003) Permeant cations and blockers modulate pH gating of ROMK channels. *Biophys. J.* **84**: 910-21 [PMID:12547773]
226. Saitoh O, Kubo Y, Miyatani Y, Asano T and Nakata H. (1997) RGS8 accelerates G-protein-mediated modulation of K<sup>+</sup> currents. *Nature* **390**: 525-9 [PMID:9394004]
227. Saitoh O, Masuho I, Terakawa I, Nomoto S, Asano T and Kubo Y. (2001) Regulator of G protein signaling 8 (RGS8) requires its NH2 terminus for subcellular localization and acute desensitization of G protein-gated K<sup>+</sup> channels. *J. Biol. Chem.* **276**: 5052-8 [PMID:11087736]
228. Sakura H, Bond C, Warren-Perry M, Horsley S, Kearney L, Tucker S, Adelman J, Turner R and Ashcroft FM. (1995) Characterization and variation of a human inwardly-rectifying-K-channel gene (KCNJ6): a putative ATP-sensitive K-channel subunit. *FEBS Lett.* **367**: 193-7 [PMID:7796919]
229. Sampson LJ, Leyland ML and Dart C. (2003) Direct interaction between the actin-binding protein filamin-A and the inwardly rectifying potassium channel, Kir2.1. *J. Biol. Chem.* **278**: 41988-97 [PMID:12923176]
230. Scholl UI, Choi M, Liu T, Ramaekers VT, Häusler MG, Grimmer J, Tobe SW, Farhi A, Nelson-Williams C and Lifton RP. (2009) Seizures, sensorineural deafness, ataxia, mental retardation, and electrolyte imbalance (SeSAME syndrome) caused by mutations in KCNJ10. *Proc. Natl. Acad. Sci. U.S.A.* **106**: 5842-7 [PMID:19289823]
231. Schoots O, Wilson JM, Ethier N, Bigras E, Hebert TE and Van Tol HH. (1999) Co-expression of human Kir3 subunits can yield channels with different functional properties. *Cell. Signal.* **11**: 871-83 [PMID:10659995]
232. Schoots O, Yue KT, MacDonald JF, Hampson DR, Nobrega JN, Dixon LM and Van Tol HH. (1996) Cloning of a G protein-activated inwardly rectifying potassium channel from human cerebellum. *Brain Res. Mol. Brain Res.* **39**: 23-30 [PMID:8804710]
233. Schram G, Melnyk P, Pourrier M, Wang Z and Nattel S. (2002) Kir2.4 and Kir2.1 K(+) channel subunits co-

- assemble: a potential new contributor to inward rectifier current heterogeneity. *J. Physiol. (Lond.)* **544**: 337-49 [PMID:12381809]
234. Schreibley W, Dessauer CW, Vorobiov D, Gilman AG, Lester HA, Davidson N and Dascal N. (1996) Inhibition of an inwardly rectifying K<sup>+</sup> channel by G-protein alpha-subunits. *Nature* **380**: 624-7 [PMID:8602262]
235. Sergouniotis PI, Davidson AE, Mackay DS, Li Z, Yang X, Plagnol V, Moore AT and Webster AR. (2011) Recessive mutations in KCNJ13, encoding an inwardly rectifying potassium channel subunit, cause leber congenital amaurosis. *Am. J. Hum. Genet.* **89**: 183-90 [PMID:21763485]
236. Shimura M, Yuan Y, Chang JT, Zhang S, Campochiaro PA, Zack DJ and Hughes BA. (2001) Expression and permeation properties of the K<sup>(+)</sup> channel Kir7.1 in the retinal pigment epithelium. *J. Physiol. (Lond.)* **531**: 329-46 [PMID:11230507]
237. Shuck ME, Bock JH, Benjamin CW, Tsai TD, Lee KS, Slightom JL and Bienkowski MJ. (1994) Cloning and characterization of multiple forms of the human kidney ROM-K potassium channel. *J. Biol. Chem.* **269**: 24261-70 [PMID:7929082]
238. Shuck ME, Piser TM, Bock JH, Slightom JL, Lee KS and Bienkowski MJ. (1997) Cloning and characterization of two K<sup>+</sup> inward rectifier (Kir) 1.1 potassium channel homologs from human kidney (Kir1.2 and Kir1.3). *J. Biol. Chem.* **272**: 586-93 [PMID:8995301]
239. Shumilina E, Klöcker N, Korniyuchuk G, Rapedius M, Lang F and Baukowitz T. (2006) Cytoplasmic accumulation of long-chain coenzyme A esters activates KATP and inhibits Kir2.1 channels. *J. Physiol. (Lond.)* **575**: 433-42 [PMID:16777940]
240. Sicca F, Imbrici P, D'Adamo MC, Moro F, Bonatti F, Brovedani P, Grottesi A, Guerrini R, Masi G and Santorelli FM *et al.*. (2011) Autism with seizures and intellectual disability: possible causative role of gain-of-function of the inwardly-rectifying K<sup>+</sup> channel Kir4.1. *Neurobiol. Dis.* **43**: 239-47 [PMID:21458570]
241. Signorini S, Liao YJ, Duncan SA, Jan LY and Stoffel M. (1997) Normal cerebellar development but susceptibility to seizures in mice lacking G protein-coupled, inwardly rectifying K<sup>+</sup> channel GIRK2. *Proc. Natl. Acad. Sci. U.S.A.* **94**: 923-7 [PMID:9023358]
242. Simon DB, Karet FE, Rodriguez-Soriano J, Hamdan JH, DiPietro A, Trachtman H, Sanjad SA and Lifton RP. (1996) Genetic heterogeneity of Bartter's syndrome revealed by mutations in the K<sup>+</sup> channel, ROMK. *Nat. Genet.* **14**: 152-6 [PMID:8841184]
243. Sindic A, Huang C, Chen AP, Ding Y, Miller-Little WA, Che D, Romero MF and Miller RT. (2009) MUPP1 complexes renal K<sup>+</sup> channels to alter cell surface expression and whole cell currents. *Am. J. Physiol. Renal Physiol.* **297**: F36-45 [PMID:19420109]
244. Slesinger PA, Patil N, Liao YJ, Jan YN, Jan LY and Cox DR. (1996) Functional effects of the mouse weaver mutation on G protein-gated inwardly rectifying K<sup>+</sup> channels. *Neuron* **16**: 321-31 [PMID:8789947]
245. Soom M, Schönherr R, Kubo Y, Kirsch C, Klinger R and Heinemann SH. (2001) Multiple PIP2 binding sites in Kir2.1 inwardly rectifying potassium channels. *FEBS Lett.* **490**: 49-53 [PMID:11172809]
246. Spauschus A, Lentjes KU, Wischmeyer E, Dissmann E, Karschin C and Karschin A. (1996) A G-protein-activated inwardly rectifying K<sup>+</sup> channel (GIRK4) from human hippocampus associates with other GIRK channels. *J. Neurosci.* **16**: 930-8 [PMID:8558261]
247. Srivastava S, Li D, Edwards N, Hynes AM, Wood K, Al-Hamed M, Wroe AC, Reich D, Mochhala SH and Welling PA *et al.*. (2013) Identification of compound heterozygous KCNJ1 mutations (encoding ROMK) in a kindred with Bartter's syndrome and a functional analysis of their pathogenicity. *Physiol Rep* **1**: e00160 [PMID:24400161]
248. Stoffel M, Tokuyama Y, Trabb JB, German MS, Tsar ML, Jan LY, Polonsky KS and Bell GI. (1995) Cloning of rat KATP-2 channel and decreased expression in pancreatic islets of male Zucker diabetic fatty rats. *Biochem. Biophys. Res. Commun.* **212**: 894-9 [PMID:7626127]
249. Strausberg RL, Feingold EA, Grouse LH, Derge JG, Klausner RD, Collins FS, Wagner L, Shenmen CM, Schuler GD and Altschul SF *et al.*. (2002) Generation and initial analysis of more than 15,000 full-length human and mouse cDNA sequences. *Proc. Natl. Acad. Sci. U.S.A.* **99**: 16899-903 [PMID:12477932]
250. Su S, Ohno Y, Lossin C, Hibino H, Inanobe A and Kurachi Y. (2007) Inhibition of astroglial inwardly



- rectifying Kir4.1 channels by a tricyclic antidepressant, nortriptyline. *J. Pharmacol. Exp. Ther.* **320**: 573-80 [PMID:17071817]
251. Suda S, Nibuya M, Suda H, Takamatsu K, Miyazaki T, Nomura S and Kawai N. (2002) Potassium channel mRNAs with AU-rich elements and brain-specific expression. *Biochem. Biophys. Res. Commun.* **291**: 1265-71 [PMID:11883954]
252. Sui JL, Chan KW and Logothetis DE. (1996) Na<sup>+</sup> activation of the muscarinic K<sup>+</sup> channel by a G-protein-independent mechanism. *J. Gen. Physiol.* **108**: 381-91 [PMID:8923264]
253. Suzuki M, Sasaki N, Miki T, Sakamoto N, Ohmoto-Sekine Y, Tamagawa M, Seino S, Marbán E and Nakaya H. (2002) Role of sarcolemmal K(ATP) channels in cardioprotection against ischemia/reperfusion injury in mice. *J. Clin. Invest.* **109**: 509-16 [PMID:11854323]
254. Suzuki Y, Yasuoka Y, Shimohama T, Nishikitani M, Nakamura N, Hirose S and Kawahara K. (2003) Expression of the K<sup>+</sup> channel Kir7.1 in the developing rat kidney: role in K<sup>+</sup> excretion. *Kidney Int.* **63**: 969-75 [PMID:12631077]
255. Takahashi N, Morishige K, Jahangir A, Yamada M, Findlay I, Koyama H and Kurachi Y. (1994) Molecular cloning and functional expression of cDNA encoding a second class of inward rectifier potassium channels in the mouse brain. *J. Biol. Chem.* **269**: 23274-9 [PMID:8083233]
256. Takumi T, Ishii T, Horio Y, Morishige K, Takahashi N, Yamada M, Yamashita T, Kiyama H, Sohmiya K and Nakanishi S *et al.*. (1995) A novel ATP-dependent inward rectifier potassium channel expressed predominantly in glial cells. *J. Biol. Chem.* **270**: 16339-46 [PMID:7608203]
257. Takumi T, Tsuji L, Kondo C, Takahashi N, Morishige K, Copeland NG, Gilbert DJ, Jenkins NA and Kurachi Y. (1996) Assignment of the murine inward rectifier potassium channel *Irk2* (Kir2.2) gene to the central region of mouse chromosome 11. *Genomics* **37**: 270-2 [PMID:8921409]
258. Tanemoto M, Fujita A, Higashi K and Kurachi Y. (2002) PSD-95 mediates formation of a functional homomeric Kir5.1 channel in the brain. *Neuron* **34**: 387-97 [PMID:11988170]
259. Tanemoto M, Kittaka N, Inanobe A and Kurachi Y. (2000) In vivo formation of a proton-sensitive K<sup>+</sup> channel by heteromeric subunit assembly of Kir5.1 with Kir4.1. *J. Physiol. (Lond.)* **525 Pt 3**: 587-92 [PMID:10856114]
260. Tanemoto M, Vanoye CG, Dong K, Welch R, Abe T, Hebert SC and Xu JZ. (2000) Rat homolog of sulfonylurea receptor 2B determines glibenclamide sensitivity of ROMK2 in *Xenopus laevis* oocyte. *Am. J. Physiol. Renal Physiol.* **278**: F659-66 [PMID:10751228]
261. Tang H, Zhu Y, Teumelsan N, Walsh SP, Shahripour A, Priest BT, Swensen AM, Felix JP, Brochu RM and Bailey T *et al.*. (2016) Discovery of MK-7145, an Oral Small Molecule ROMK Inhibitor for the Treatment of Hypertension and Heart Failure. *ACS Med Chem Lett* **7**: 697-701 [PMID:27437080]
262. Tang W and Yang XC. (1994) Cloning a novel human brain inward rectifier potassium channel and its functional expression in *Xenopus* oocytes. *FEBS Lett.* **348**: 239-43 [PMID:8034048]
263. Tennant BP, Cui Y, Tinker A and Clapp LH. (2006) Functional expression of inward rectifier potassium channels in cultured human pulmonary smooth muscle cells: evidence for a major role of Kir2.4 subunits. *J. Membr. Biol.* **213**: 19-29 [PMID:17347781]
264. Thiery E, Gosset P, Damotte D, Delezoide AL, de Saint-Sauveur N, Vayssettes C and Créau N. (2000) Developmentally regulated expression of the murine ortholog of the potassium channel KIR4.2 (KCNJ15). *Mech. Dev.* **95**: 313-6 [PMID:10906485]
265. Tong X, Ao Y, Faas GC, Nwaobi SE, Xu J, Hausteine MD, Anderson MA, Mody I, Olsen ML and Sofroniew MV *et al.*. (2014) Astrocyte Kir4.1 ion channel deficits contribute to neuronal dysfunction in Huntington's disease model mice. *Nat. Neurosci.* **17**: 694-703 [PMID:24686787]
266. Torrecilla M, Marker CL, Cintora SC, Stoffel M, Williams JT and Wickman K. (2002) G-protein-gated potassium channels containing Kir3.2 and Kir3.3 subunits mediate the acute inhibitory effects of opioids on locus ceruleus neurons. *J. Neurosci.* **22**: 4328-34 [PMID:12040038]
267. Torrecilla M, Quillinan N, Williams JT and Wickman K. (2008) Pre- and postsynaptic regulation of locus coeruleus neurons after chronic morphine treatment: a study of GIRK-knockout mice. *Eur. J. Neurosci.* **28**: 618-24 [PMID:18702733]

268. Trapp S, Tucker SJ and Gourine AV. (2011) Respiratory responses to hypercapnia and hypoxia in mice with genetic ablation of Kir5.1 (Kcnj16). *Exp. Physiol.* **96**: 451-9 [PMID:21239463]
269. Tsai TD, Shuck ME, Thompson DP, Bienkowski MJ and Lee KS. (1995) Intracellular H<sup>+</sup> inhibits a cloned rat kidney outer medulla K<sup>+</sup> channel expressed in *Xenopus* oocytes. *Am. J. Physiol.* **268**: C1173-8 [PMID:7762610]
270. Tucker SJ, Imbrici P, Salvatore L, D'Adamo MC and Pessia M. (2000) pH dependence of the inwardly rectifying potassium channel, Kir5.1, and localization in renal tubular epithelia. *J. Biol. Chem.* **275**: 16404-7 [PMID:10764726]
271. Töpert C, Döring F, Derst C, Daut J, Grzeschik KH and Karschin A. (2000) Cloning, structure and assignment to chromosome 19q13 of the human Kir2.4 inwardly rectifying potassium channel gene (KCNJ14). *Mamm. Genome* **11**: 247-9 [PMID:10723734]
272. Töpert C, Döring F, Wischmeyer E, Karschin C, Brockhaus J, Ballanyi K, Derst C and Karschin A. (1998) Kir2.4: a novel K<sup>+</sup> inward rectifier channel associated with motoneurons of cranial nerve nuclei. *J. Neurosci.* **18**: 4096-105 [PMID:9592090]
273. Vaughn J, Wolford JK, Prochazka M and Permana PA. (2000) Genomic structure and expression of human KCNJ9 (Kir3.3/GIRK3). *Biochem. Biophys. Res. Commun.* **274**: 302-9 [PMID:10913335]
274. Wade JB, Fang L, Coleman RA, Liu J, Grimm PR, Wang T and Welling PA. (2011) Differential regulation of ROMK (Kir1.1) in distal nephron segments by dietary potassium. *Am. J. Physiol. Renal Physiol.* **300**: F1385-93 [PMID:21454252]
275. Wei J, Hodes ME, Piva R, Feng Y, Wang Y, Ghetti B and Dlouhy SR. (1998) Characterization of murine GirK2 transcript isoforms: structure and differential expression. *Genomics* **51**: 379-90 [PMID:9721208]
276. Weigl LG and Schreibley W. (2001) G protein-gated inwardly rectifying potassium channels are targets for volatile anesthetics. *Mol. Pharmacol.* **60**: 282-9 [PMID:11455015]
277. Whorton MR and MacKinnon R. (2013) X-ray structure of the mammalian GIRK2- $\beta$  G-protein complex. *Nature* **498**: 190-7 [PMID:23739333]
278. Whorton MR and MacKinnon R. (2011) Crystal structure of the mammalian GIRK2 K<sup>+</sup> channel and gating regulation by G proteins, PIP<sub>2</sub>, and sodium. *Cell* **147**: 199-208 [PMID:21962516]
279. Wible BA, De Biasi M, Majumder K, Taglialatela M and Brown AM. (1995) Cloning and functional expression of an inwardly rectifying K<sup>+</sup> channel from human atrium. *Circ. Res.* **76**: 343-50 [PMID:7859381]
280. Wickman K, Karschin C, Karschin A, Picciotto MR and Clapham DE. (2000) Brain localization and behavioral impact of the G-protein-gated K<sup>+</sup> channel subunit GIRK4. *J. Neurosci.* **20**: 5608-15 [PMID:10908597]
281. Wickman K, Nemeč J, Gendler SJ and Clapham DE. (1998) Abnormal heart rate regulation in GIRK4 knockout mice. *Neuron* **20**: 103-14 [PMID:9459446]
282. Wickman K, Pu WT and Clapham DE. (2002) Structural characterization of the mouse GirK genes. *Gene* **284**: 241-50 [PMID:11891065]
283. Wickman KD, Iñiguez-Lluhl JA, Davenport PA, Taussig R, Krapivinsky GB, Linder ME, Gilman AG and Clapham DE. (1994) Recombinant G-protein beta gamma-subunits activate the muscarinic-gated atrial potassium channel. *Nature* **368**: 255-7 [PMID:8145826]
284. Wischmeyer E, Döring F and Karschin A. (1998) Acute suppression of inwardly rectifying Kir2.1 channels by direct tyrosine kinase phosphorylation. *J. Biol. Chem.* **273**: 34063-8 [PMID:9852063]
285. Wischmeyer E and Karschin A. (1996) Receptor stimulation causes slow inhibition of IRK1 inwardly rectifying K<sup>+</sup> channels by direct protein kinase A-mediated phosphorylation. *Proc. Natl. Acad. Sci. U.S.A.* **93**: 5819-23 [PMID:8650176]
286. Wischmeyer E, Lentz KU and Karschin A. (1995) Physiological and molecular characterization of an IRK-type inward rectifier K<sup>+</sup> channel in a tumour mast cell line. *Pflügers Arch.* **429**: 809-19 [PMID:7603835]
287. Wu J, Xu H, Shen W and Jiang C. (2004) Expression and coexpression of CO<sub>2</sub>-sensitive Kir channels in brainstem neurons of rats. *J. Membr. Biol.* **197**: 179-91 [PMID:15042349]
288. Wu JV, Krouse ME, Rustagi A, Joo NS and Wine JJ. (2004) An inwardly rectifying potassium channel in apical membrane of Calu-3 cells. *J. Biol. Chem.* **279**: 46558-65 [PMID:15328350]

289. Xu JZ, Hall AE, Peterson LN, Bienkowski MJ, Eessalu TE and Hebert SC. (1997) Localization of the ROMK protein on apical membranes of rat kidney nephron segments. *Am. J. Physiol.* **273**: F739-48 [PMID:9374837]
290. Yamada K, Ji JJ, Yuan H, Miki T, Sato S, Horimoto N, Shimizu T, Seino S and Inagaki N. (2001) Protective role of ATP-sensitive potassium channels in hypoxia-induced generalized seizure. *Science* **292**: 1543-6 [PMID:11375491]
291. Yamada M, Isomoto S, Matsumoto S, Kondo C, Shindo T, Horio Y and Kurachi Y. (1997) Sulphonylurea receptor 2B and Kir6.1 form a sulphonylurea-sensitive but ATP-insensitive K<sup>+</sup> channel. *J. Physiol. (Lond.)* **499 ( Pt 3)**: 715-20 [PMID:9130167]
292. Yamakura T, Lewohl JM and Harris RA. (2001) Differential effects of general anesthetics on G protein-coupled inwardly rectifying and other potassium channels. *Anesthesiology* **95**: 144-53 [PMID:11465552]
293. Yamamoto Y, Ishikawa R, Omoe K and Taniguchi K. (2008) Expression of inwardly rectifying K<sup>+</sup> channels in the carotid body of rat. *Histol. Histopathol.* **23**: 799-806 [PMID:18437678]
294. Yamashita T, Horio Y, Yamada M, Takahashi N, Kondo C and Kurachi Y. (1996) Competition between Mg<sup>2+</sup> and spermine for a cloned IRK2 channel expressed in a human cell line. *J. Physiol. (Lond.)* **493 ( Pt 1)**: 143-56 [PMID:8735700]
295. Yang D, Zhang X and Hughes BA. (2008) Expression of inwardly rectifying potassium channel subunits in native human retinal pigment epithelium. *Exp. Eye Res.* **87**: 176-83 [PMID:18653180]
296. Yang J, Jan YN and Jan LY. (1995) Control of rectification and permeation by residues in two distinct domains in an inward rectifier K<sup>+</sup> channel. *Neuron* **14**: 1047-54 [PMID:7748552]
297. Yang L, Frindt G and Palmer LG. (2010) Magnesium modulates ROMK channel-mediated potassium secretion. *J. Am. Soc. Nephrol.* **21**: 2109-16 [PMID:21030597]
298. Yang T, Gurrola 2nd JG, Wu H, Chiu SM, Wangemann P, Snyder PM and Smith RJ. (2009) Mutations of KCNJ10 together with mutations of SLC26A4 cause digenic nonsyndromic hearing loss associated with enlarged vestibular aqueduct syndrome. *Am. J. Hum. Genet.* **84**: 651-7 [PMID:19426954]
299. Yasuda K, Shimura M, Nakazawa T, Sato H, Tomita H, Sugano E and Tamai M. (2003) Expression and functional properties of unique inward rectifier K<sup>+</sup> channel Kir7.1 in the porcine iris and retinal pigment epithelium. *Curr. Eye Res.* **27**: 279-87 [PMID:14562164]
300. Yoo D, Flagg TP, Olsen O, Raghuram V, Foskett JK and Welling PA. (2004) Assembly and trafficking of a multiprotein ROMK (Kir 1.1) channel complex by PDZ interactions. *J. Biol. Chem.* **279**: 6863-73 [PMID:14604981]
301. Yoshimoto Y, Fukuyama Y, Horio Y, Inanobe A, Gotoh M and Kurachi Y. (1999) Somatostatin induces hyperpolarization in pancreatic islet alpha cells by activating a G protein-gated K<sup>+</sup> channel. *FEBS Lett.* **444**: 265-9 [PMID:10050772]
302. Zaritsky JJ, Redell JB, Tempel BL and Schwarz TL. (2001) The consequences of disrupting cardiac inwardly rectifying K(+) current (I(K1)) as revealed by the targeted deletion of the murine Kir2.1 and Kir2.2 genes. *J. Physiol. (Lond.)* **533**: 697-710 [PMID:11410627]
303. Zhang W, Zhang X, Wang H, Sharma AK, Edwards AO and Hughes BA. (2013) Characterization of the R162W Kir7.1 mutation associated with snowflake vitreoretinopathy. *Am. J. Physiol., Cell Physiol.* **304**: C440-9 [PMID:23255580]
304. Zhou H, Chepilko S, Schütt W, Choe H, Palmer LG and Sackin H. (1996) Mutations in the pore region of ROMK enhance Ba<sup>2+</sup> block. *Am. J. Physiol.* **271**: C1949-56 [PMID:8997197]
305. Zhou H, Tate SS and Palmer LG. (1994) Primary structure and functional properties of an epithelial K channel. *Am. J. Physiol.* **266**: C809-24 [PMID:8166245]
306. Zhou W, Arrabit C, Choe S and Slesinger PA. (2001) Mechanism underlying bupivacaine inhibition of G protein-gated inwardly rectifying K<sup>+</sup> channels. *Proc. Natl. Acad. Sci. U.S.A.* **98**: 6482-7 [PMID:11353868]
307. Zhu G, Chanchevalap S, Cui N and Jiang C. (1999) Effects of intra- and extracellular acidifications on single channel Kir2.3 currents. *J. Physiol. (Lond.)* **516 ( Pt 3)**: 699-710 [PMID:10200419]
308. Zingman LV, Hodgson DM, Bast PH, Kane GC, Perez-Terzic C, Gumina RJ, Pucar D, Bienengraeber M, Dzeja PP and Miki T *et al.* (2002) Kir6.2 is required for adaptation to stress. *Proc. Natl. Acad. Sci. U.S.A.*

99: 13278-83 [PMID:12271142]