

## Voltage-gated calcium channels in GtoPdb v.2021.2

William A. Catterall<sup>1</sup>, Edward Perez-Reyes<sup>2</sup>, Terrance P. Snutch<sup>3</sup> and Jörg Striessnig<sup>4</sup>

1. University of Washington, USA
2. University of Virginia, USA
3. University of British Columbia, Canada
4. University of Innsbruck, Austria

### Abstract

Calcium (Ca<sup>2+</sup>) channels are voltage-gated ion channels present in the membrane of most excitable cells. The nomenclature for Ca<sup>2+</sup> channels was proposed by [127] and **approved by the NC-IUPHAR Subcommittee on Ca<sup>2+</sup> channels [70]**. Most Ca<sup>2+</sup> channels form hetero-oligomeric complexes. The  $\alpha$ 1 subunit is pore-forming and provides the binding site(s) for practically all agonists and antagonists. The 10 cloned  $\alpha$ 1-subunits can be grouped into three families: (1) the high-voltage activated dihydropyridine-sensitive (L-type, Ca<sub>v</sub>1.x) channels; (2) the high- to moderate-voltage activated dihydropyridine-insensitive (Ca<sub>v</sub>2.x) channels and (3) the low-voltage-activated (T-type, Ca<sub>v</sub>3.x) channels. Each  $\alpha$ 1 subunit has four homologous repeats (I-IV), each repeat having six transmembrane domains and a pore-forming region between transmembrane domains S5 and S6. Voltage-dependent gating is driven by the membrane spanning S4 segment, which contains highly conserved positive charges that respond to changes in membrane potential. All of the  $\alpha$ 1-subunit genes give rise to alternatively spliced products. At least for high-voltage activated channels, it is likely that native channels comprise co-assemblies of  $\alpha$ 1,  $\beta$  and  $\alpha$ 2- $\delta$  subunits. The  $\gamma$  subunits have not been proven to associate with channels other than the  $\alpha$ 1s skeletal muscle Cav1.1 channel. The  $\alpha$ 2- $\delta$ 1 and  $\alpha$ 2- $\delta$ 2 subunits bind [gabapentin](#) and [pregabalin](#).

### Contents

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

[GtoPdb](#) is an expert-driven guide to pharmacological targets and the substances that act on them. GtoPdb is a reference work which is most usefully represented as an on-line database. As in any publication this work should be appropriately cited, and the papers it cites should also be recognized. This document provides a citation for the relevant parts of the database, and also provides a reference list for the research cited by those parts. For further details see [47].

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

### Database links

#### [Voltage-gated calcium channels](#)

<https://www.guidetopharmacology.org/GRAC/FamilyDisplayForward?familyId=80>

#### [Introduction to Voltage-gated calcium channels](#)

<https://www.guidetopharmacology.org/GRAC/FamilyIntroductionForward?familyId=80>

#### Channels and Subunits

##### [Ca<sub>v</sub>1.1](#)

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=528>

##### [Ca<sub>v</sub>1.2](#)

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=529>  
Ca<sub>v</sub>1.3

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=530>  
Ca<sub>v</sub>1.4

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=531>  
Ca<sub>v</sub>2.1

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=532>  
Ca<sub>v</sub>2.2

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=533>  
Ca<sub>v</sub>2.3

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=534>  
Ca<sub>v</sub>3.1

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=535>  
Ca<sub>v</sub>3.2

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=536>  
Ca<sub>v</sub>3.3

<https://www.guidetopharmacology.org/GRAC/ObjectDisplayForward?objectId=537>

## References

1. Abbadie C, McManus OB, Sun SY, Bugianesi RM, Dai G, Haedo RJ, Herrington JB, Kaczorowski GJ, Smith MM and Swensen AM *et al.* (2010) Analgesic effects of a substituted N-triazole oxindole (TROX-1), a state-dependent, voltage-gated calcium channel 2 blocker. *J Pharmacol Exp Ther* **334**: 545-55 [PMID:20439438]
2. Adams ME, Mintz IM, Reily MD, Thanabal V and Bean BP. (1993) Structure and properties of omega-agatoxin IVB, a new antagonist of P-type calcium channels. *Mol Pharmacol* **44**: 681-8 [PMID:8232218]
3. Adams PJ, Garcia E, David LS, Mulatz KJ, Spacey SD and Snutch TP. (2009) Ca(V)<sub>2</sub>.1 P/Q-type calcium channel alternative splicing affects the functional impact of familial hemiplegic migraine mutations: implications for calcium channelopathies. *Channels (Austin)* **3**: 110-21 [PMID:19242091]
4. Adams PJ, Rungta RL, Garcia E, van den Maagdenberg AM, MacVicar BA and Snutch TP. (2010) Contribution of calcium-dependent facilitation to synaptic plasticity revealed by migraine mutations in the P/Q-type calcium channel. *Proc Natl Acad Sci USA* **107**: 18694-9 [PMID:20937883]
5. Adams PJ and Snutch TP. (2007) Calcium channelopathies: voltage-gated calcium channels. *Subcell Biochem* **45**: 215-51 [PMID:18193639]
6. Albillos A, Neher E and Moser T. (2000) R-Type Ca<sup>2+</sup> channels are coupled to the rapid component of secretion in mouse adrenal slice chromaffin cells. *J Neurosci* **20**: 8323-30 [PMID:11069939]
7. ALLHAT Officers and Coordinators for the ALLHAT Collaborative Research Group. The Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial. (2002) Major outcomes in high-risk hypertensive patients randomized to angiotensin-converting enzyme inhibitor or calcium channel blocker vs diuretic: The Antihypertensive and Lipid-Lowering Treatment to Prevent Heart Attack Trial (ALLHAT). *JAMA* **288**: 2981-97 [PMID:12479763]
8. Andreasen D, Friis UG, Uhrenholt TR, Jensen BL, Skøtt O and Hansen PB. (2006) Coexpression of voltage-dependent calcium channels Cav1.2, 2.1a, and 2.1b in vascular myocytes. *Hypertension* **47**: 735-41 [PMID:16505211]
9. Antzelevitch C, Pollevick GD, Cordeiro JM, Casis O, Sanguinetti MC, Aizawa Y, Guerchicoff A, Pfeiffer R, Oliva A and Wollnik B *et al.* (2007) Loss-of-function mutations in the cardiac calcium channel underlie a new clinical entity characterized by ST-segment elevation, short QT intervals, and sudden cardiac death. *Circulation* **115**: 442-9 [PMID:17224476]
10. Atluri N, Joksimovic SM, Oklopčić A, Milanovic D, Klawitter J, Eggan P, Krishnan K, Covey DF, Todorovic SM and Jevtovic-Todorovic V. (2018) A neurosteroid analogue with T-type calcium channel blocking properties is an effective hypnotic, but is not harmful to neonatal rat brain. *Br J Anaesth* **120**: 768-778 [PMID:29576117]
11. Audo I, Bujakowska KM, Léveillard T, Mohand-Saïd S, Lancelot ME, Germain A, Antonio A, Michiels C, Saraiva JP and Letexier M *et al.* (2012) Development and application of a next-generation-sequencing (NGS) approach to detect known and novel gene defects underlying retinal diseases. *Orphanet J Rare Dis* **7**: 8 [PMID:22277662]
12. Azizan EA, Poulsen H, Tuluc P, Zhou J, Clausen MV, Lieb A, Maniero C, Garg S, Bochukova EG and Zhao W *et al.* (2013) Somatic mutations in ATP1A1 and CACNA1D underlie a common subtype of adrenal hypertension. *Nat Genet* **45**: 1055-60 [PMID:23913004]
13. Bader PL, Faizi M, Kim LH, Owen SF, Tadross MR, Alfa RW, Bett GC, Tsien RW, Rasmusson RL

- and Shamloo M. (2011) Mouse model of Timothy syndrome recapitulates triad of autistic traits. *Proc Natl Acad Sci USA* **108**: 15432-7 [PMID:21878566]
14. Badou A, Jha MK, Matza D, Mehal WZ, Freichel M, Flockerzi V and Flavell RA. (2006) Critical role for the beta regulatory subunits of Cav channels in T lymphocyte function. *Proc Natl Acad Sci USA* **103**: 15529-34 [PMID:17028169]
  15. Baig SM, Koschak A, Lieb A, Gebhart M, Dafinger C, Nürnberg G, Ali A, Ahmad I, Sinnegger-Brauns MJ and Brandt N *et al.*. (2011) Loss of Ca(v)1.3 (CACNA1D) function in a human channelopathy with bradycardia and congenital deafness. *Nat Neurosci* **14**: 77-84 [PMID:21131953]
  16. Balijepalli RC, Foell JD, Hall DD, Hell JW and Kamp TJ. (2006) Localization of cardiac L-type Ca(2+) channels to a caveolar macromolecular signaling complex is required for beta(2)-adrenergic regulation. *Proc Natl Acad Sci USA* **103**: 7500-5 [PMID:16648270]
  17. Ball SL, Powers PA, Shin HS, Morgans CW, Peachey NS and Gregg RG. (2002) Role of the beta(2) subunit of voltage-dependent calcium channels in the retinal outer plexiform layer. *Invest Ophthalmol Vis Sci* **43**: 1595-603 [PMID:11980879]
  18. Barg S, Ma X, Eliasson L, Galvanovskis J, Göpel SO, Obermüller S, Platzer J, Renström E, Trus M and Atlas D *et al.*. (2001) Fast exocytosis with few Ca(2+) channels in insulin-secreting mouse pancreatic B cells. *Biophys J* **81**: 3308-23 [PMID:11720994]
  19. Barrett CF, Cao YQ and Tsien RW. (2005) Gating deficiency in a familial hemiplegic migraine type 1 mutant P/Q-type calcium channel. *J Biol Chem* **280**: 24064-71 [PMID:15795222]
  20. Baumann L, Gerstner A, Zong X, Biel M and Wahl-Schott C. (2004) Functional characterization of the L-type Ca<sup>2+</sup> channel Cav1.4alpha1 from mouse retina. *Invest Ophthalmol Vis Sci* **45**: 708-13 [PMID:14744918]
  21. Baur CP, Klingler W, Jurkat-Rott K, Froeba G, Schoch E, Marx T, Georgieff M and Lehmann-Horn F. (2000) Xenon does not induce contracture in human malignant hyperthermia muscle. *Br J Anaesth* **85**: 712-6 [PMID:11094586]
  22. Beam KG and Knudson CM. (1988) Effect of postnatal development on calcium currents and slow charge movement in mammalian skeletal muscle. *J Gen Physiol* **91**: 799-815 [PMID:2458430]
  23. Beam KG and Knudson CM. (1988) Calcium currents in embryonic and neonatal mammalian skeletal muscle. *J Gen Physiol* **91**: 781-98 [PMID:2458429]
  24. Bean BP. (1984) Nitrendipine block of cardiac calcium channels: high-affinity binding to the inactivated state. *Proc Natl Acad Sci USA* **81**: 6388-92 [PMID:6093100]
  25. Bech-Hansen NT, Naylor MJ, Maybaum TA, Pearce WG, Koop B, Fishman GA, Mets M, Musarella MA and Boycott KM. (1998) Loss-of-function mutations in a calcium-channel alpha1-subunit gene in Xp11.23 cause incomplete X-linked congenital stationary night blindness. *Nat Genet* **19**: 264-7 [PMID:9662400]
  26. Bech-Hansen T and Naylor MJ. (1999) Retinal calcium channel (alpha)1f-subunit gene. Patent number: CA2299611 A1.
  27. Bell TJ, Thaler C, Castiglioni AJ, Helton TD and Lipscombe D. (2004) Cell-specific alternative splicing increases calcium channel current density in the pain pathway. *Neuron* **41**: 127-38 [PMID:14715140]
  28. Benjamin ER, Pruthi F, Olanrewaju S, Shan S, Hanway D, Liu X, Cerne R, Lavery D, Valenzano KJ and Woodward RM *et al.*. (2006) Pharmacological characterization of recombinant N-type calcium channel (Cav2.2) mediated calcium mobilization using FLIPR. *Biochem Pharmacol* **72**: 770-82 [PMID:16844100]
  29. Beuckelmann DJ, Näbauer M and Erdmann E. (1991) Characteristics of calcium-current in isolated human ventricular myocytes from patients with terminal heart failure. *J Mol Cell Cardiol* **23**: 929-37 [PMID:1658345]
  30. Beuckmann CT, Sinton CM, Miyamoto N, Ino M and Yanagisawa M. (2003) N-type calcium channel alpha1B subunit (Cav2.2) knock-out mice display hyperactivity and vigilance state differences. *J Neurosci* **23**: 6793-7 [PMID:12890773]
  31. Bijveld MM, Florijn RJ, Bergen AA, van den Born LI, Kamermans M, Prick L, Riemsdag FC, van Schooneveld MJ, Kappers AM and van Genderen MM. (2013) Genotype and phenotype of 101 dutch patients with congenital stationary night blindness. *Ophthalmology* **120**: 2072-81 [PMID:23714322]
  32. Birnbaumer L, Campbell KP, Catterall WA, Harpold MM, Hofmann F, Horne WA, Mori Y, Schwartz A, Snutch TP and Tanabe T *et al.*. (1994) The naming of voltage-gated calcium channels. *Neuron* **13**: 505-6 [PMID:7917287]
  33. Blaich A, Pahlavan S, Tian Q, Oberhofer M, Poomvanicha M, Lenhardt P, Domes K, Wegener JW, Moosmang S and Ruppenthal S *et al.*. (2012) Mutation of the calmodulin binding motif IQ of the L-type Ca(v)1.2 Ca<sup>2+</sup> channel to EQ induces dilated cardiomyopathy and death. *J Biol Chem* **287**: 22616-25 [PMID:22589547]
  34. Bleakman D, Bowman D, Bath CP, Brust PF, Johnson EC, Deal CR, Miller RJ, Ellis SB, Harpold MM and Hans M *et al.*. (1995) Characteristics of a human N-type calcium channel expressed in

- HEK293 cells. *Neuropharmacology* **34**: 753-65 [PMID:8532142]
35. Bock G, Gebhart M, Scharinger A, Jangsangthong W, Busquet P, Poggiani C, Sartori S, Mangoni ME, Sinnegger-Brauns MJ and Herzig S *et al.*. (2011) Functional properties of a newly identified C-terminal splice variant of Cav1.3 L-type Ca<sup>2+</sup> channels. *J Biol Chem* **286**: 42736-48 [PMID:21998310]
  36. Boczek NJ, Best JM, Tester DJ, Giudicessi JR, Middha S, Evans JM, Kamp TJ and Ackerman MJ. (2013) Exome sequencing and systems biology converge to identify novel mutations in the L-type calcium channel, CACNA1C, linked to autosomal dominant long QT syndrome. *Circ Cardiovasc Genet* **6**: 279-89 [PMID:23677916]
  37. Bourinet E, Soong TW, Sutton K, Slaymaker S, Mathews E, Monteil A, Zamponi GW, Nargeot J and Snutch TP. (1999) Splicing of alpha 1A subunit gene generates phenotypic variants of P- and Q-type calcium channels. *Nat Neurosci* **2**: 407-15 [PMID:10321243]
  38. Bourinet E, Stotz SC, Spaetgens RL, Dayanithi G, Lemos J, Nargeot J and Zamponi GW. (2001) Interaction of SNX482 with domains III and IV inhibits activation gating of alpha(1E) (Ca(V)2.3) calcium channels. *Biophys J* **81**: 79-88 [PMID:11423396]
  39. Bowersox SS, Gadbois T, Singh T, Pettus M, Wang YX and Luther RR. (1996) Selective N-type neuronal voltage-sensitive calcium channel blocker, SNX-111, produces spinal antinociception in rat models of acute, persistent and neuropathic pain. *J Pharmacol Exp Ther* **279**: 1243-9 [PMID:8968347]
  40. Bowersox SS, Miljanich GP, Sugiura Y, Li C, Nadasdi L, Hoffman BB, Ramachandran J and Ko CP. (1995) Differential blockade of voltage-sensitive calcium channels at the mouse neuromuscular junction by novel omega-conopeptides and omega-agatoxin-IVA. *J Pharmacol Exp Ther* **273**: 248-56 [PMID:7714772]
  41. Boycott KM, Maybaum TA, Naylor MJ, Weleber RG, Robitaille J, Miyake Y, Bergen AA, Pierpont ME, Pearce WG and Bech-Hansen NT. (2001) A summary of 20 CACNA1F mutations identified in 36 families with incomplete X-linked congenital stationary night blindness, and characterization of splice variants. *Hum Genet* **108**: 91-7 [PMID:11281458]
  42. Boycott KM, Pearce WG and Bech-Hansen NT. (2000) Clinical variability among patients with incomplete X-linked congenital stationary night blindness and a founder mutation in CACNA1F. *Can J Ophthalmol* **35**: 204-13 [PMID:10900517]
  43. Brandt A, Khimich D and Moser T. (2005) Few CaV1.3 channels regulate the exocytosis of a synaptic vesicle at the hair cell ribbon synapse. *J Neurosci* **25**: 11577-85 [PMID:16354915]
  44. Brandt A, Striessnig J and Moser T. (2003) CaV1.3 channels are essential for development and presynaptic activity of cochlear inner hair cells. *J Neurosci* **23**: 10832-40 [PMID:14645476]
  45. Brennan SC, Finney BA, Lazarou M, Rosser AE, Scherf C, Adriaensen D, Kemp PJ and Riccardi D. (2013) Fetal calcium regulates branching morphogenesis in the developing human and mouse lung: involvement of voltage-gated calcium channels. *PLoS ONE* **8**: e80294 [PMID:24282533]
  46. Brose WG, Gutlove DP, Luther RR, Bowersox SS and McGuire D. (1997) Use of intrathecal SNX-111, a novel, N-type, voltage-sensitive, calcium channel blocker, in the management of intractable brachial plexus avulsion pain. *Clin J Pain* **13**: 256-9 [PMID:9303259]
  47. 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]
  48. Buraei Z and Yang J. (2015) Inhibition of Voltage-Gated Calcium Channels by RGK Proteins. *Curr Mol Pharmacol* **8**: 180-7 [PMID:25966691]
  49. Burashnikov E, Pfeiffer R, Barajas-Martinez H, Delpón E, Hu D, Desai M, Borggrefe M, Häissaguerre M, Kanter R and Pollevick GD *et al.*. (2010) Mutations in the cardiac L-type calcium channel associated with inherited J-wave syndromes and sudden cardiac death. *Heart Rhythm* **7**: 1872-82 [PMID:20817017]
  50. Burtscher V, Schicker K, Novikova E, Pöhn B, Stockner T, Kugler C, Singh A, Zeitz C, Lancelot ME and Audo I *et al.*. (2014) Spectrum of Cav1.4 dysfunction in congenital stationary night blindness type 2. *Biochim Biophys Acta* **1838**: 2053-65 [PMID:24796500]
  51. Busquet P, Nguyen NK, Schmid E, Tanimoto N, Seeliger MW, Ben-Yosef T, Mizuno F, Akopian A, Striessnig J and Singewald N. (2010) CaV1.3 L-type Ca<sup>2+</sup> channels modulate depression-like behaviour in mice independent of deaf phenotype. *Int J Neuropsychopharmacol* **13**: 499-513 [PMID:19664321]
  52. Béguin P, Nagashima K, Gonoï T, Shibasaki T, Takahashi K, Kashima Y, Ozaki N, Geering K, Iwanaga T and Seino S. (2001) Regulation of Ca<sup>2+</sup> channel expression at the cell surface by the small G-protein kir/Gem. *Nature* **411**: 701-6 [PMID:11395774]
  53. Bénitah JP, Bailly P, D'Agrosa MC, Da Ponte JP, Delgado C and Lorente P. (1992) Slow inward current in single cells isolated from adult human ventricles. *Pflugers Arch* **421**: 176-87 [PMID:1356263]
  54. Cabral MD, Paulet PE, Robert V, Gomes B, Renoud ML, Savignac M, Leclerc C, Moreau M, Lair D and Langelot M *et al.*. (2010) Knocking down Cav1 calcium channels implicated in Th2 cell activation prevents experimental asthma. *Am J Respir Crit Care Med* **181**: 1310-7



[PMID:20167851]

55. Caciotti A, Morrone A, Domenici R, Donati MA and Zammarchi E. (2003) Severe prognosis in a large family with hypokalemic periodic paralysis. *Muscle Nerve* **27**: 165-9 [PMID:12548523]
56. Calin-Jageman I, Yu K, Hall RA, Mei L and Lee A. (2007) Erbin enhances voltage-dependent facilitation of Ca(v)1.3 Ca<sup>2+</sup> channels through relief of an autoinhibitory domain in the Ca(v)1.3 alpha1 subunit. *J Neurosci* **27**: 1374-85 [PMID:17287512]
57. Campiglio M, Costé de Bagneaux P, Ortner NJ, Tuluc P, Van Petegem F and Flucher BE. (2018) STAC proteins associate to the IQ domain of Ca<sub>v</sub>1.2 and inhibit calcium-dependent inactivation. *Proc Natl Acad Sci U S A* **115**: 1376-1381 [PMID:29363593]
58. Cannell MB, Cheng H and Lederer WJ. (1995) The control of calcium release in heart muscle. *Science* **268**: 1045-9 [PMID:7754384]
59. Cao YQ and Tsien RW. (2005) Effects of familial hemiplegic migraine type 1 mutations on neuronal P/Q-type Ca<sup>2+</sup> channel activity and inhibitory synaptic transmission. *Proc Natl Acad Sci USA* **102**: 2590-5 [PMID:15699344]
60. Carabelli V, Lovallo M, Magnelli V, Zucker H and Carbone E. (1996) Voltage-dependent modulation of single N-Type Ca<sup>2+</sup> channel kinetics by receptor agonists in IMR32 cells. *Biophys J* **70**: 2144-54 [PMID:9172738]
61. Carbone E and Lux HD. (1984) A low voltage-activated, fully inactivating Ca channel in vertebrate sensory neurones. *Nature* **310**: 501-2 [PMID:6087159]
62. Carpenter D, Ringrose C, Leo V, Morris A, Robinson RL, Halsall PJ, Hopkins PM and Shaw MA. (2009) The role of CACNA1S in predisposition to malignant hyperthermia. *BMC Med Genet* **10**: 104 [PMID:19825159]
63. Carrera P, Piatti M, Stenirri S, Grimaldi LM, Marchioni E, Curcio M, Righetti PG, Ferrari M and Gelfi C. (1999) Genetic heterogeneity in Italian families with familial hemiplegic migraine. *Neurology* **53**: 26-33 [PMID:10408532]
64. Cassola AC, Jaffe H, Fales HM, Afeche SC, Magnoli F and Cipolla-Neto J. (1998) ω-Phonetoxin-IIA: a calcium channel blocker from the spider *Phoneutria nigriventer*. *Pflugers Arch* **436**: 545-52 [PMID:9683727]
65. Catterall WA. (2010) Ion channel voltage sensors: structure, function, and pathophysiology. *Neuron* **67**: 915-28 [PMID:20869590]
66. Catterall WA. (2011) Voltage-gated calcium channels. *Cold Spring Harb Perspect Biol* **3**: a003947 [PMID:21746798]
67. Catterall WA. (2015) Regulation of Cardiac Calcium Channels in the Fight-or-Flight Response. *Curr Mol Pharmacol* **8**: 12-21 [PMID:25966697]
68. Catterall WA. (2000) Structure and regulation of voltage-gated Ca<sup>2+</sup> channels. *Annu Rev Cell Dev Biol* **16**: 521-55 [PMID:11031246]
69. Catterall WA and Few AP. (2008) Calcium channel regulation and presynaptic plasticity. *Neuron* **59**: 882-901 [PMID:18817729]
70. Catterall WA, Perez-Reyes E, Snutch TP and Striessnig J. (2005) International Union of Pharmacology. XLVIII. Nomenclature and structure-function relationships of voltage-gated calcium channels. *Pharmacol Rev* **57**: 411-25 [PMID:16382099]
71. Cavelier P, Lohof AM, Lonchamp E, Beekenkamp H, Mariani J and Bossu JL. (2008) Participation of low-threshold Ca<sup>2+</sup> spike in the Purkinje cells complex spike. *Neuroreport* **19**: 299-303 [PMID:18303570]
72. Chabrier S, Monnier N and Lunardi J. (2008) Early onset of hypokalaemic periodic paralysis caused by a novel mutation of the CACNA1S gene. *J Med Genet* **45**: 686-8 [PMID:18835861]
73. Chandy KG and Gutman GA. (1993) Nomenclature for mammalian potassium channel genes. *Trends Pharmacol Sci* **14**: 434 [PMID:8122319]
74. Chang B, Heckenlively JR, Bayley PR, Brecha NC, Davisson MT, Hawes NL, Hirano AA, Hurd RE, Ikeda A and Johnson BA *et al.*. (2006) The nob2 mouse, a null mutation in *Cacna1f*: anatomical and functional abnormalities in the outer retina and their consequences on ganglion cell visual responses. *Vis Neurosci* **23**: 11-24 [PMID:16597347]
75. Charnet P, Bourinet E, Dubel SJ, Snutch TP and Nargeot J. (1994) Calcium currents recorded from a neuronal alpha 1C L-type calcium channel in *Xenopus* oocytes. *FEBS Lett* **344**: 87-90 [PMID:7514140]
76. Chaudhuri N. (1992) A single nucleotide deletion in the skeletal muscle-specific calcium channel transcript of muscular dysgenesis (mdg) mice. *J Biol Chem* **267**: 25636-9 [PMID:1281468]
77. Chaudhuri D, Chang SY, DeMaria CD, Alvania RS, Soong TW and Yue DT. (2004) Alternative splicing as a molecular switch for Ca<sup>2+</sup>/calmodulin-dependent facilitation of P/Q-type Ca<sup>2+</sup> channels. *J Neurosci* **24**: 6334-42 [PMID:15254089]
78. Chemin J, Monteil A, Bourinet E, Nargeot J and Lory P. (2001) Alternatively spliced alpha(1G) (Ca(V)3.1) intracellular loops promote specific T-type Ca(2+) channel gating properties. *Biophys J* **80**: 1238-50 [PMID:11222288]
79. Chemin J, Monteil A, Dubel S, Nargeot J and Lory P. (2001) The alpha1I T-type calcium channel exhibits faster gating properties when overexpressed in neuroblastoma/glioma NG 108-15 cells.

*Eur J Neurosci* **14**: 1678-86 [PMID:11860462]

80. Chemin J, Monteil A, Perez-Reyes E, Bourinet E, Nargeot J and Lory P. (2002) Specific contribution of human T-type calcium channel isoforms (alpha(1G), alpha(1H) and alpha(1I)) to neuronal excitability. *J Physiol (Lond.)* **540**: 3-14 [PMID:11927664]
81. Chemin J, Monteil A, Perez-Reyes E, Nargeot J and Lory P. (2001) Direct inhibition of T-type calcium channels by the endogenous cannabinoid anandamide. *EMBO J* **20**: 7033-40 [PMID:11742980]
82. Chemin J, Siquier-Pernet K, Nicouleau M, Barcia G, Ahmad A, Medina-Cano D, Hanein S, Altin N, Hubert L and Bole-Feysot C *et al.*. (2018) De novo mutation screening in childhood-onset cerebellar atrophy identifies gain-of-function mutations in the CACNA1G calcium channel gene. *Brain* **141**: 1998-2013 [PMID:29878067]
83. Chen CC, Lamping KG, Nuno DW, Barresi R, Prouty SJ, Lavoie JL, Cribbs LL, England SK, Sigmund CD, Weiss RM, Williamson RA, Hill JA and Campbell KP. (2003) Abnormal coronary function in mice deficient in alpha1H T-type Ca<sup>2+</sup> channels. *Science* **302**: 1416-8 [PMID:14631046]
84. Chen F, Liu Y, Sugiura Y, Allen PD, Gregg RG and Lin W. (2011) Neuromuscular synaptic patterning requires the function of skeletal muscle dihydropyridine receptors. *Nat Neurosci* **14**: 570-7 [PMID:21441923]
85. Chen WC, Xue HZ, Hsu YL, Liu Q, Patel S and Davis RL. (2011) Complex distribution patterns of voltage-gated calcium channel  $\alpha$ -subunits in the spiral ganglion. *Hear Res* **278**: 52-68 [PMID:21281707]
86. Chen Y, Lu J, Pan H, Zhang Y, Wu H, Xu K, Liu X, Jiang Y, Bao X and Yao Z *et al.*. (2003) Association between genetic variation of CACNA1H and childhood absence epilepsy. *Ann Neurol* **54**: 239-43 [PMID:12891677]
87. Chin H, Krall M, Kim HL, Kozak CA and Mock B. (1992) The gene for the alpha 1 subunit of the skeletal muscle dihydropyridine-sensitive calcium channel (Cchl1a3) maps to mouse chromosome 1. *Genomics* **14**: 1089-91 [PMID:1335956]
88. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo Jr JL, Jones DW, Materson BJ, Oparil S and Wright Jr JT *et al.*. (2003) Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Hypertension* **42**: 1206-52 [PMID:14656957]
89. Choe W, Messinger RB, Leach E, Eckle VS, Obradovic A, Salajegheh R, Jevtovic-Todorovic V and Todorovic SM. (2011) TTA-P2 is a potent and selective blocker of T-type calcium channels in rat sensory neurons and a novel antinociceptive agent. *Mol Pharmacol* **80**: 900-10 [PMID:21821734]
90. Choi S, Na HS, Kim J, Lee J, Lee S, Kim D, Park J, Chen CC, Campbell KP and Shin HS. (2007) Attenuated pain responses in mice lacking Ca(V)<sub>3.2</sub> T-type channels. *Genes Brain Behav* **6**: 425-31 [PMID:16939637]
91. Chuang RS, Jaffe H, Cribbs L, Perez-Reyes E and Swartz KJ. (1998) Inhibition of T-type voltage-gated calcium channels by a new scorpion toxin. *Nat Neurosci* **1**: 668-74 [PMID:10196582]
92. Clark NC, Nagano N, Kuenzi FM, Jarolimek W, Huber I, Walter D, Wietzorrek G, Boyce S, Kullmann DM and Striessnig J *et al.*. (2003) Neurological phenotype and synaptic function in mice lacking the CaV1.3 alpha subunit of neuronal L-type voltage-dependent Ca<sup>2+</sup> channels. *Neuroscience* **120**: 435-42 [PMID:12890513]
93. Coulter DA, Huguenard JR and Prince DA. (1989) Calcium currents in rat thalamocortical relay neurones: kinetic properties of the transient, low-threshold current. *J Physiol (Lond.)* **414**: 587-604 [PMID:2607443]
94. Coulter DA, Huguenard JR and Prince DA. (1989) Characterization of ethosuximide reduction of low-threshold calcium current in thalamic neurons. *Ann Neurol* **25**: 582-93 [PMID:2545161]
95. Coutelier M, Blesneac I, Monteil A, Monin ML, Ando K, Mundwiller E, Brusco A, Le Ber I, Anheim M and Castrioto A *et al.*. (2015) A Recurrent Mutation in CACNA1G Alters Cav3.1 T-Type Calcium-Channel Conduction and Causes Autosomal-Dominant Cerebellar Ataxia. *Am J Hum Genet* **97**: 726-37 [PMID:26456284]
96. Craig PJ, Beattie RE, Folly EA, Banerjee MD, Reeves MB, Priestley JV, Carney SL, Sher E, Perez-Reyes E and Volsen SG. (1999) Distribution of the voltage-dependent calcium channel alpha1G subunit mRNA and protein throughout the mature rat brain. *Eur J Neurosci* **11**: 2949-64 [PMID:10457190]
97. Cribbs LL, Lee JH, Yang J, Satin J, Zhang Y, Daud A, Barclay J, Williamson MP, Fox M, Rees M and Perez-Reyes E. (1998) Cloning and characterization of alpha1H from human heart, a member of the T-type Ca<sup>2+</sup> channel gene family. *Circ Res* **83**: 103-9 [PMID:9670923]
98. Cross-Disorder Group of the Psychiatric Genomics Consortium and Genetic Risk Outcome of Psychosis (GROUP) Consortium. (2013) Identification of risk loci with shared effects on five major psychiatric disorders: a genome-wide analysis. *Lancet* **381**: 1371-9 [PMID:23453885]
99. Cui G, Meyer AC, Calin-Jageman I, Neef J, Haeseleer F, Moser T and Lee A. (2007) Ca<sup>2+</sup>-binding proteins tune Ca<sup>2+</sup>-feedback to Cav1.3 channels in mouse auditory hair cells. *J Physiol*

- (Lond.) **585**: 791-803 [PMID:17947313]
100. Cunha SR, Hund TJ, Hashemi S, Voigt N, Li N, Wright P, Koval O, Li J, Gudmundsson H and Gumina RJ *et al.*. (2011) Defects in ankyrin-based membrane protein targeting pathways underlie atrial fibrillation. *Circulation* **124**: 1212-22 [PMID:21859974]
  101. D'Ascenzo M, Vairano M, Andreassi C, Navarra P, Azzena GB and Grassi C. (2004) Electrophysiological and molecular evidence of L-(Cav1), N- (Cav2.2), and R- (Cav2.3) type Ca<sup>2+</sup> channels in rat cortical astrocytes. *Glia* **45**: 354-63 [PMID:14966867]
  102. Dai G, Haedo RJ, Warren VA, Ratliff KS, Bugianesi RM, Rush A, Williams ME, Herrington J, Smith MM and McManus OB *et al.*. (2008) A high-throughput assay for evaluating state dependence and subtype selectivity of Cav2 calcium channel inhibitors. *Assay Drug Dev Technol* **6**: 195-212 [PMID:18471074]
  103. Davare MA, Dong F, Rubin CS and Hell JW. (1999) The A-kinase anchor protein MAP2B and cAMP-dependent protein kinase are associated with class C L-type calcium channels in neurons. *J Biol Chem* **274**: 30280-7 [PMID:10514522]
  104. Day NC, Shaw PJ, McCormack AL, Craig PJ, Smith W, Beattie R, Williams TL, Ellis SB, Ince PG and Harpold MM *et al.*. (1996) Distribution of alpha 1A, alpha 1B and alpha 1E voltage-dependent calcium channel subunits in the human hippocampus and parahippocampal gyrus. *Neuroscience* **71**: 1013-24 [PMID:8684604]
  105. De Mingo Alemany MC, Mifsud Grau L, Moreno Macián F, Ferrer Lorente B and León Cariñena S. (2020) A de novo CACNA1D missense mutation in a patient with congenital hyperinsulinism, primary hyperaldosteronism and hypotonia. *Channels (Austin)* **14**: 175-180 [PMID:32336187]
  106. de Vries B, Stam AH, Beker F, van den Maagdenberg AM, Vanmolkot KR, Laan L, Ginjaar IB, Frants RR, Lauffer H and Haan J *et al.*. (2008) CACNA1A mutation linking hemiplegic migraine and alternating hemiplegia of childhood. *Cephalalgia* **28**: 887-91 [PMID:18498393]
  107. de Weille JR, Schweitz H, Maes P, Tartar A and Lazdunski M. (1991) Calciseptine, a peptide isolated from black mamba venom, is a specific blocker of the L-type calcium channel. *Proc Natl Acad Sci U S A* **88**: 2437-40 [PMID:1848702]
  108. Denier C, Ducros A, Vahedi K, Joutel A, Thierry P, Ritz A, Castelnovo G, Deonna T, Gérard P and Devoise JL *et al.*. (1999) High prevalence of CACNA1A truncations and broader clinical spectrum in episodic ataxia type 2. *Neurology* **52**: 1816-21 [PMID:10371528]
  109. Desnuelle C, Liot D, Serratrice G and Lombet A. (1985) Biochemical characterization of plasma membrane isolated from human skeletal muscle. *FEBS Lett* **188**: 222-6 [PMID:2411596]
  110. Dick IE, Tadross MR, Liang H, Tay LH, Yang W and Yue DT. (2008) A modular switch for spatial Ca<sup>2+</sup> selectivity in the calmodulin regulation of CaV channels. *Nature* **451**: 830-4 [PMID:18235447]
  111. Dirksen RT and Beam KG. (1995) Single calcium channel behavior in native skeletal muscle. *J Gen Physiol* **105**: 227-47 [PMID:7539048]
  112. Dirksen RT, Nakai J, Gonzalez A, Imoto K and Beam KG. (1997) The S5-S6 linker of repeat I is a critical determinant of L-type Ca<sup>2+</sup> channel conductance. *Biophys J* **73**: 1402-9 [PMID:9284307]
  113. Doering CJ, Hamid J, Simms B, McRory JE and Zamponi GW. (2005) Cav1.4 encodes a calcium channel with low open probability and unitary conductance. *Biophys J* **89**: 3042-8 [PMID:16085774]
  114. Doering CJ, Rehak R, Bonfield S, Peloquin JB, Stell WK, Mema SC, Sauvé Y and McRory JE. (2008) Modified Cav(v)1.4 expression in the Cacna1f(nob2) mouse due to alternative splicing of an ETn inserted in exon 2. *PLoS ONE* **3**: e2538 [PMID:18596967]
  115. Dogrul A, Gardell LR, Ossipov MH, Tulunay FC, Lai J and Porreca F. (2003) Reversal of experimental neuropathic pain by T-type calcium channel blockers. *Pain* **105**: 159-68 [PMID:14499432]
  116. Domes K, Ding J, Lemke T, Blaich A, Wegener JW, Brandmayr J, Moosmang S and Hofmann F. (2011) Truncation of murine CaV1.2 at Asp-1904 results in heart failure after birth. *J Biol Chem* **286**: 33863-71 [PMID:21832054]
  117. Dos Santos RG, Van Renterghem C, Martin-Moutot N, Mansuelle P, Cordeiro MN, Diniz CR, Mori Y, De Lima ME and Seagar M. (2002) Phoneutria nigriventer omega-phonetoxin IIA blocks the Cav2 family of calcium channels and interacts with omega-conotoxin-binding sites. *J Biol Chem* **277**: 13856-62 [PMID:11827974]
  118. Dove LS, Abbott LC and Griffith WH. (1998) Whole-cell and single-channel analysis of P-type calcium currents in cerebellar Purkinje cells of leaner mutant mice. *J Neurosci* **18**: 7687-99 [PMID:9742139]
  119. Drouet B, Garcia L, Simon-Chazottes D, Mattei MG, Guénet JL, Schwartz A, Varadi G and Pinçon-Raymond M. (1993) The gene coding for the alpha 1 subunit of the skeletal dihydropyridine receptor (Cchl1a3 = mdg) maps to mouse chromosome 1 and human 1q32. *Mamm Genome* **4**: 499-503 [PMID:8118099]
  120. Dubel SJ, Starr TV, Hell J, Ahlijanian MK, Enyeart JJ, Catterall WA and Snutch TP. (1992) Molecular cloning of the alpha-1 subunit of an omega-conotoxin-sensitive calcium channel. *Proc Natl Acad Sci USA* **89**: 5058-62 [PMID:1317580]

121. Ducros A, Denier C, Joutel A, Cecillon M, Lescoat C, Vahedi K, Darcel F, Vicaut E, Bousser MG and Tournier-Lasserre E. (2001) The clinical spectrum of familial hemiplegic migraine associated with mutations in a neuronal calcium channel. *N Engl J Med* **345**: 17-24 [PMID:11439943]
122. Ducros A, Denier C, Joutel A, Vahedi K, Michel A, Darcel F, Madigand M, Guerouaou D, Tison F and Julien J *et al.*. (1999) Recurrence of the T666M calcium channel CACNA1A gene mutation in familial hemiplegic migraine with progressive cerebellar ataxia. *Am J Hum Genet* **64**: 89-98 [PMID:9915947]
123. Ellis SB, Williams ME, Ways NR, Brenner R, Sharp AH, Leung AT, Campbell KP, McKenna E, Koch WJ and Hui A. (1988) Sequence and expression of mRNAs encoding the alpha 1 and alpha 2 subunits of a DHP-sensitive calcium channel. *Science* **241**: 1661-4 [PMID:2458626]
124. Emerick MC, Stein R, Kunze R, McNulty MM, Regan MR, Hanck DA and Agnew WS. (2006) Profiling the array of Ca(v)3.1 variants from the human T-type calcium channel gene CACNA1G: alternative structures, developmental expression, and biophysical variations. *Proteins* **64**: 320-42 [PMID:16671074]
125. Epi4K Consortium. (2016) De Novo Mutations in SLC1A2 and CACNA1A Are Important Causes of Epileptic Encephalopathies. *Am J Hum Genet* **99**: 287-98 [PMID:27476654]
126. Epi4K Consortium, Epilepsy Phenome/Genome Project, Allen AS, Berkovic SF, Cossette P, Delanty N, Dlugos D, Eichler EE, Epstein MP and Glauser T *et al.*. (2013) De novo mutations in epileptic encephalopathies. *Nature* **501**: 217-21 [PMID:23934111]
127. Ertel EA, Campbell KP, Harpold MM, Hofmann F, Mori Y, Perez-Reyes E, Schwartz A, Snutch TP, Tanabe T, Birnbaumer L, Tsien RW and Catterall WA. (2000) Nomenclature of voltage-gated calcium channels. *Neuron* **25**: 533-5 [PMID:10774722]
128. Fan C, Lehmann-Horn F, Weber MA, Bednarz M, Groome JR, Jonsson MK and Jurkat-Rott K. (2013) Transient compartment-like syndrome and normokalaemic periodic paralysis due to a Cav1.1 mutation. *Brain* **136**: 3775-86 [PMID:24240197]
129. Feng ZP, Hamid J, Doering C, Jarvis SE, Bosey GM, Bourinet E, Snutch TP and Zamponi GW. (2001) Amino acid residues outside of the pore region contribute to N-type calcium channel permeation. *J Biol Chem* **276**: 5726-30 [PMID:11120735]
130. Ferron L, Kadurin I and Dolphin AC. (2018) Proteolytic maturation of  $\alpha_2\delta$  controls the probability of synaptic vesicular release. *Elife* **7** [PMID:29916807]
131. Flanagan SE, Vairo F, Johnson MB, Caswell R, Laver TW, Lango Allen H, Hussain K and Ellard S. (2017) A CACNA1D mutation in a patient with persistent hyperinsulinaemic hypoglycaemia, heart defects, and severe hypotonia. *Pediatr Diabetes* **18**: 320-323 [PMID:28318089]
132. Flucher BE. (2020) Skeletal muscle Ca<sub>v</sub>1.1 channelopathies. *Pflugers Arch* **472**: 739-754 [PMID:32222817]
133. Flucher BE, Andrews SB, Fleischer S, Marks AR, Caswell A and Powell JA. (1993) Triad formation: organization and function of the sarcoplasmic reticulum calcium release channel and triadin in normal and dysgenic muscle in vitro. *J Cell Biol* **123**: 1161-74 [PMID:8245124]
134. Flucher BE and Campiglio M. (2019) STAC proteins: The missing link in skeletal muscle EC coupling and new regulators of calcium channel function. *Biochim Biophys Acta Mol Cell Res* **1866**: 1101-1110 [PMID:30543836]
135. Flucher BE and Tuluc P. (2011) A new L-type calcium channel isoform required for normal patterning of the developing neuromuscular junction. *Channels (Austin)* **5**: 518-24 [PMID:21993196]
136. Foell JD, Balijepalli RC, Delisle BP, Yunker AM, Robia SL, Walker JW, McEnery MW, January CT and Kamp TJ. (2004) Molecular heterogeneity of calcium channel beta-subunits in canine and human heart: evidence for differential subcellular localization. *Physiol Genomics* **17**: 183-200 [PMID:14762176]
137. Forti L, Tottene A, Moretti A and Pietrobon D. (1994) Three novel types of voltage-dependent calcium channels in rat cerebellar neurons. *J Neurosci* **14**: 5243-56 [PMID:8083734]
138. Fouad G, Dalakas M, Servidei S, Mendell JR, Van den Bergh P, Angelini C, Alderson K, Griggs RC, Tawil R and Gregg R *et al.*. (1997) Genotype-phenotype correlations of DHP receptor alpha 1-subunit gene mutations causing hypokalemic periodic paralysis. *Neuromuscul Disord* **7**: 33-8 [PMID:9132138]
139. Fowler MR, Colotti G, Chiancone E, Smith GL and Fearon IM. (2008) Sorcin modulates cardiac L-type Ca<sup>2+</sup> current by functional interaction with the alpha1C subunit in rabbits. *Exp Physiol* **93**: 1233-8 [PMID:18603601]
140. Francois A, Kerckhove N, Meleine M, Alloui A, Barrere C, Gelot A, Uebele VN, Renger JJ, Eschalier A and Ardid D *et al.*. (2013) State-dependent properties of a new T-type calcium channel blocker enhance Ca(V)3.2 selectivity and support analgesic effects. *Pain* **154**: 283-93 [PMID:23257507]
141. Freise D, Held B, Wissenbach U, Pfeifer A, Trost C, Himmerkus N, Schweig U, Freichel M, Biel M and Hofmann F *et al.*. (2000) Absence of the gamma subunit of the skeletal muscle dihydropyridine receptor increases L-type Ca<sup>2+</sup> currents and alters channel inactivation



- properties. *J Biol Chem* **275**: 14476-81 [PMID:10799530]
142. Friend KL, Crimmins D, Phan TG, Sue CM, Colley A, Fung VS, Morris JG, Sutherland GR and Richards RI. (1999) Detection of a novel missense mutation and second recurrent mutation in the CACNA1A gene in individuals with EA-2 and FHM. *Hum Genet* **105**: 261-5 [PMID:10987655]
  143. Fu Y, Westenbroek RE, Scheuer T and Catterall WA. (2013) Phosphorylation sites required for regulation of cardiac calcium channels in the fight-or-flight response. *Proc Natl Acad Sci USA* **110**: 19621-6 [PMID:24218620]
  144. Fu Y, Westenbroek RE, Yu FH, Clark 3rd JP, Marshall MR, Scheuer T and Catterall WA. (2011) Deletion of the distal C terminus of CaV1.2 channels leads to loss of beta-adrenergic regulation and heart failure in vivo. *J Biol Chem* **286**: 12617-26 [PMID:21216955]
  145. Fujii S, Kameyama K, Hosono M, Hayashi Y and Kitamura K. (1997) Effect of cilnidipine, a novel dihydropyridine Ca<sup>++</sup>-channel antagonist, on N-type Ca<sup>++</sup> channel in rat dorsal root ganglion neurons. *J Pharmacol Exp Ther* **280**: 1184-91 [PMID:9067302]
  146. Fukuyama M, Ohno S, Wang Q, Kimura H, Makiyama T, Itoh H, Ito M and Horie M. (2013) L-type calcium channel mutations in Japanese patients with inherited arrhythmias. *Circ J* **77**: 1799-806 [PMID:23575362]
  147. Furukawa T, Miura R, Honda M, Kamiya N, Mori Y, Takeshita S, Isshiki T and Nukada T. (2004) Identification of R(-)-isomer of efonidipine as a selective blocker of T-type Ca<sup>2+</sup> channels. *Br J Pharmacol* **143**: 1050-7 [PMID:15545287]
  148. Gardner K, Bernal O, Keegan M, Badger J, Gerber O, Lowry N and Hoffman EP. (1999) A new mutation in the Chr19p calcium channel gene CACNLIA4 causing hemiplegic migraine with ataxia. *Neurology* **52**: A115
  149. Gebhart M, Juhasz-Vedres G, Zuccotti A, Brandt N, Engel J, Trockenbacher A, Kaur G, Obermair GJ, Knipper M and Koschak A *et al.*. (2010) Modulation of Cav1.3 Ca<sup>2+</sup> channel gating by Rab3 interacting molecule. *Mol Cell Neurosci* **44**: 246-59 [PMID:20363327]
  150. Ghaleb YE, Schneeberger PE, Polstra AM, van Hagen JM, Campiglio M, Denecke J, Fernandez-Quintero M, Liedl KR, Kutsche K and Flucher BE. (2020) Two CaV3.3 (CACNA1I) Gain-of-Function Mutations Linked to Epilepsy and Intellectual Disability Affect Gating Properties and the Window Current *Biophysical Journal* **118**: 106a
  151. Ghasemzadeh MB, Pierce RC and Kalivas PW. (1999) The monoamine neurons of the rat brain preferentially express a splice variant of alpha1B subunit of the N-type calcium channel. *J Neurochem* **73**: 1718-23 [PMID:10501220]
  152. Giffin NJ, Benton S and Goadsby PJ. (2002) Benign paroxysmal torticollis of infancy: four new cases and linkage to CACNA1A mutation. *Dev Med Child Neurol* **44**: 490-3 [PMID:12162387]
  153. Gillis J, Burashnikov E, Antzelevitch C, Blaser S, Gross G, Turner L, Babul-Hirji R and Chitayat D. (2012) Long QT, syndactyly, joint contractures, stroke and novel CACNA1C mutation: expanding the spectrum of Timothy syndrome. *Am J Med Genet A* **158A**: 182-7 [PMID:22106044]
  154. Giordanetto F, Knerr L and Wällberg A. (2011) T-type calcium channels inhibitors: a patent review. *Expert Opin Ther Pat* **21**: 85-101 [PMID:21087200]
  155. Giordano TP, Tropea TF, Satpute SS, Sinnegger-Brauns MJ, Striessnig J, Kosofsky BE and Rajadhyaksha AM. (2010) Molecular switch from L-type Ca<sup>v</sup> 1.3 to Ca<sup>v</sup> 1.2 Ca<sup>2+</sup> channel signaling underlies long-term psychostimulant-induced behavioral and molecular plasticity. *J Neurosci* **30**: 17051-62 [PMID:21159975]
  156. Glossmann H and Striessnig J. (1990) Molecular properties of calcium channels. *Rev Physiol Biochem Pharmacol* **114**: 1-105 [PMID:2155469]
  157. Goll A, Ferry DR, Striessnig J, Schober M and Glossmann H. (1984) (-)-[3H]Desmethoxyverapamil, a novel Ca<sup>2+</sup> channel probe. Binding characteristics and target size analysis of its receptor in skeletal muscle. *FEBS Lett* **176**: 371-7 [PMID:6092142]
  158. Gomora JC, Daud AN, Weiergräber M and Perez-Reyes E. (2001) Block of cloned human T-type calcium channels by succinimide antiepileptic drugs. *Mol Pharmacol* **60**: 1121-32 [PMID:11641441]
  159. Gomora JC, Murbartián J, Arias JM, Lee JH and Perez-Reyes E. (2002) Cloning and expression of the human T-type channel Ca(v)3.3: insights into prepulse facilitation. *Biophys J* **83**: 229-41 [PMID:12080115]
  160. Goonasekera SA, Hammer K, Auger-Messier M, Bodi I, Chen X, Zhang H, Reiken S, Elrod JW, Correll RN and York AJ *et al.*. (2012) Decreased cardiac L-type Ca<sup>2+</sup> channel activity induces hypertrophy and heart failure in mice. *J Clin Invest* **122**: 280-90 [PMID:22133878]
  161. Gorman KM, Meyer E, Grozeva D, Spinelli E, McTague A, Sanchis-Juan A, Carss KJ, Bryant E, Reich A and Schneider AL *et al.*. (2019) Bi-allelic Loss-of-Function CACNA1B Mutations in Progressive Epilepsy-Dyskinesia. *Am J Hum Genet* **104**: 948-956 [PMID:30982612]
  162. Grant L and Fuchs P. (2008) Calcium- and calmodulin-dependent inactivation of calcium channels in inner hair cells of the rat cochlea. *J Neurophysiol* **99**: 2183-93 [PMID:18322004]
  163. Graves TD, Imbrici P, Kors EE, Terwindt GM, Eunson LH, Frants RR, Haan J, Ferrari MD, Goadsby PJ and Hanna MG *et al.*. (2008) Premature stop codons in a facilitating EF-hand splice

- variant of CaV2.1 cause episodic ataxia type 2. *Neurobiol Dis* **32**: 10-5 [PMID:18606230]
164. Gregory FD, Bryan KE, Pangršič T, Calin-Jageman IE, Moser T and Lee A. (2011) Harmonin inhibits presynaptic Cav1.3 Ca<sup>2+</sup> channels in mouse inner hair cells. *Nat Neurosci* **14**: 1109-11 [PMID:21822269]
  165. Gregory FD, Pangrsic T, Calin-Jageman IE, Moser T and Lee A. (2013) Harmonin enhances voltage-dependent facilitation of Cav1.3 channels and synchronous exocytosis in mouse inner hair cells. *J Physiol (Lond.)* **591**: 3253-69 [PMID:23613530]
  166. Griessmeier K, Cuny H, Rötzer K, Griesbeck O, Harz H, Biel M and Wahl-Schott C. (2009) Calmodulin is a functional regulator of Cav1.4 L-type Ca<sup>2+</sup> channels. *J Biol Chem* **284**: 29809-16 [PMID:19717559]
  167. Guida S, Trettel F, Pagnutti S, Mantuano E, Tottene A, Veneziano L, Fellin T, Spadaro M, Stauderman K and Williams M *et al.*. (2001) Complete loss of P/Q calcium channel activity caused by a CACNA1A missense mutation carried by patients with episodic ataxia type 2. *Am J Hum Genet* **68**: 759-64 [PMID:11179022]
  168. Gundlfinger A, Bischofberger J, Johenning FW, Torvinen M, Schmitz D and Breustedt J. (2007) Adenosine modulates transmission at the hippocampal mossy fibre synapse via direct inhibition of presynaptic calcium channels. *J Physiol (Lond.)* **582**: 263-77 [PMID:17478533]
  169. Gómez AM, Valdivia HH, Cheng H, Lederer MR, Santana LF, Cannell MB, McCune SA, Altschuld RA and Lederer WJ. (1997) Defective excitation-contraction coupling in experimental cardiac hypertrophy and heart failure. *Science* **276**: 800-6 [PMID:9115206]
  170. Haase H, Kresse A, Hohaus A, Schulte HD, Maier M, Osterziel KJ, Lange PE and Morano I. (1996) Expression of calcium channel subunits in the normal and diseased human myocardium. *J Mol Med* **74**: 99-104 [PMID:8820405]
  171. Haeseleer F, Imanishi Y, Maeda T, Possin DE, Maeda A, Lee A, Rieke F and Palczewski K. (2004) Essential role of Ca<sup>2+</sup>-binding protein 4, a Cav1.4 channel regulator, in photoreceptor synaptic function. *Nat Neurosci* **7**: 1079-87 [PMID:15452577]
  172. Hagiwara M, Adachi-Akahane S and Nagao T. (1997) High-affinity binding of DTZ323, a novel derivative of diltiazem, to rabbit skeletal muscle L-type Ca<sup>++</sup> channels. *J Pharmacol Exp Ther* **281**: 173-9 [PMID:9103495]
  173. Hall DD, Dai S, Tseng PY, Malik Z, Nguyen M, Matt L, Schnizler K, Shephard A, Mohapatra DP and Tsuruta F *et al.*. (2013) Competition between  $\alpha$ -actinin and Ca<sup>2+</sup>-calmodulin controls surface retention of the L-type Ca<sup>2+</sup> channel Ca(V)1.2. *Neuron* **78**: 483-97 [PMID:23664615]
  174. Hall DD, Feekes JA, Arachchige Don AS, Shi M, Hamid J, Chen L, Strack S, Zamponi GW, Horne MC and Hell JW. (2006) Binding of protein phosphatase 2A to the L-type calcium channel Cav1.2 next to Ser1928, its main PKA site, is critical for Ser1928 dephosphorylation. *Biochemistry* **45**: 3448-59 [PMID:16519540]
  175. Han W, Saegusa H, Zong S and Tanabe T. (2002) Altered cocaine effects in mice lacking Ca(v)2.3 (alpha(1E)) calcium channel. *Biochem Biophys Res Commun* **299**: 299-304 [PMID:12437986]
  176. Han Y, Kaeser PS, Südhof TC and Schneggenburger R. (2011) RIM determines Ca<sup>2+</sup> channel density and vesicle docking at the presynaptic active zone. *Neuron* **69**: 304-16 [PMID:21262468]
  177. Hans M, Luvisetto S, Williams ME, Spagnolo M, Urrutia A, Tottene A, Brust PF, Johnson EC, Harpold MM and Stauderman KA *et al.*. (1999) Functional consequences of mutations in the human alpha1A calcium channel subunit linked to familial hemiplegic migraine. *J Neurosci* **19**: 1610-9 [PMID:10024348]
  178. Hans M, Urrutia A, Deal C, Brust PF, Stauderman K, Ellis SB, Harpold MM, Johnson EC and Williams ME. (1999) Structural elements in domain IV that influence biophysical and pharmacological properties of human alpha1A-containing high-voltage-activated calcium channels. *Biophys J* **76**: 1384-400 [PMID:10049321]
  179. Hansen PB, Jensen BL, Andreassen D, Friis UG and Skøtt O. (2000) Vascular smooth muscle cells express the alpha(1A) subunit of a P-/Q-type voltage-dependent Ca(2+)Channel, and It is functionally important in renal afferent arterioles. *Circ Res* **87**: 896-902 [PMID:11073885]
  180. Hauke J, Schild A, Neugebauer A, Lappa A, Fricke J, Fauser S, Rösler S, Pannes A, Zarrinnam D and Altmüller J *et al.*. (2013) A novel large in-frame deletion within the CACNA1F gene associates with a cone-rod dystrophy 3-like phenotype. *PLoS ONE* **8**: e76414 [PMID:24124559]
  181. Hawrylycz MJ, Lein ES, Guillozet-Bongaarts AL, Shen EH, Ng L, Miller JA, van de Lagemaat LN, Smith KA, Ebbert A and Riley ZL *et al.*. (2012) An anatomically comprehensive atlas of the adult human brain transcriptome. *Nature* **489**: 391-9 [PMID:22996553]
  182. Heady TN, Gomora JC, Macdonald TL and Perez-Reyes E. (2001) Molecular pharmacology of T-type Ca<sup>2+</sup> channels. *Jpn J Pharmacol* **85**: 339-50 [PMID:11388636]
  183. Heinemann SH, Terlau H, Stühmer W, Imoto K and Numa S. (1992) Calcium channel characteristics conferred on the sodium channel by single mutations. *Nature* **356**: 441-3 [PMID:1313551]
  184. Helbig KL, Lauerer RJ, Bahr JC, Souza IA, Myers CT, Uysal B, Schwarz N, Gandini MA, Huang S and Keren B *et al.*. (2018) De Novo Pathogenic Variants in CACNA1E Cause Developmental and

- Epileptic Encephalopathy with Contractures, Macrocephaly, and Dyskinesias. *Am J Hum Genet* **103**: 666-678 [PMID:30343943]
185. Helton TD, Xu W and Lipscombe D. (2005) Neuronal L-type calcium channels open quickly and are inhibited slowly. *J Neurosci* **25**: 10247-51 [PMID:16267232]
  186. Hemara-Wahanui A, Berjukow S, Hope CI, Dearden PK, Wu SB, Wilson-Wheeler J, Sharp DM, Lundon-Treweek P, Clover GM and Hoda JC *et al.*. (2005) A CACNA1F mutation identified in an X-linked retinal disorder shifts the voltage dependence of Cav1.4 channel activation. *Proc Natl Acad Sci USA* **102**: 7553-8 [PMID:15897456]
  187. Herlitze S, Garcia DE, Mackie K, Hille B, Scheuer T and Catterall WA. (1996) Modulation of Ca<sup>2+</sup> channels by G-protein beta gamma subunits. *Nature* **380**: 258-62 [PMID:8637576]
  188. Heron SE, Phillips HA, Mulley JC, Mazarib A, Neufeld MY, Berkovic SF and Scheffer IE. (2004) Genetic variation of CACNA1H in idiopathic generalized epilepsy. *Ann Neurol* **55**: 595-6 [PMID:15048902]
  189. Hess P, Lansman JB and Tsien RW. (1986) Calcium channel selectivity for divalent and monovalent cations. Voltage and concentration dependence of single channel current in ventricular heart cells. *J Gen Physiol* **88**: 293-319 [PMID:2428919]
  190. Hibino H, Pironkova R, Onwumere O, Rousset M, Charnet P, Hudspeth AJ and Lesage F. (2003) Direct interaction with a nuclear protein and regulation of gene silencing by a variant of the Ca<sup>2+</sup>-channel beta 4 subunit. *Proc Natl Acad Sci USA* **100**: 307-12 [PMID:12518067]
  191. Hillyard DR, Monje VD, Mintz IM, Bean BP, Nadasdi L, Ramachandran J, Miljanich G, Azimi-Zoonooz A, McIntosh JM and Cruz LJ. (1992) A new Conus peptide ligand for mammalian presynaptic Ca<sup>2+</sup> channels. *Neuron* **9**: 69-77 [PMID:1352986]
  192. Hirano M, Kokunai Y, Nagai A, Nakamura Y, Saigoh K, Kusunoki S and Takahashi MP. (2011) A novel mutation in the calcium channel gene in a family with hypokalemic periodic paralysis. *J Neurol Sci* **309**: 9-11 [PMID:21855088]
  193. Hirtz JJ, Braun N, Griesemer D, Hannes C, Janz K, Löhrike S, Müller B and Friauf E. (2012) Synaptic refinement of an inhibitory topographic map in the auditory brainstem requires functional Cav1.3 calcium channels. *J Neurosci* **32**: 14602-16 [PMID:23077046]
  194. Hobai IA, Bates JA, Howarth FC and Levi AJ. (1997) Inhibition by external Cd<sup>2+</sup> of Na/Ca exchange and L-type Ca channel in rabbit ventricular myocytes. *Am J Physiol* **272**: H2164-72 [PMID:9176282]
  195. Hockerman GH, Johnson BD, Scheuer T and Catterall WA. (1995) Molecular determinants of high affinity phenylalkylamine block of L-type calcium channels. *J Biol Chem* **270**: 22119-22 [PMID:7673189]
  196. Hockerman GH, Peterson BZ, Johnson BD and Catterall WA. (1997) Molecular determinants of drug binding and action on L-type calcium channels. *Annu Rev Pharmacol Toxicol* **37**: 361-96 [PMID:9131258]
  197. Hoda JC, Zaghetto F, Koschak A and Striessnig J. (2005) Congenital stationary night blindness type 2 mutations S229P, G369D, L1068P, and W1440X alter channel gating or functional expression of Ca(v)1.4 L-type Ca<sup>2+</sup> channels. *J Neurosci* **25**: 252-9 [PMID:15634789]
  198. Hoda JC, Zaghetto F, Singh A, Koschak A and Striessnig J. (2006) Effects of congenital stationary night blindness type 2 mutations R508Q and L1364H on Cav1.4 L-type Ca<sup>2+</sup> channel function and expression. *J Neurochem* **96**: 1648-58 [PMID:16476079]
  199. Hofer NT, Tuluc P, Ortner NJ, Nikonishyna YV, Fernández-Quintero ML, Liedl KR, Flucher BE, Cox H and Striessnig J. (2020) Biophysical classification of a CACNA1D de novo mutation as a high-risk mutation for a severe neurodevelopmental disorder. *Mol Autism* **11**: 4 [PMID:31921405]
  200. Hofmann F, Lacinová L and Klugbauer N. (1999) Voltage-dependent calcium channels: from structure to function. *Rev Physiol Biochem Pharmacol* **139**: 33-87 [PMID:10453692]
  201. Holmkvist J, Tojjar D, Almgren P, Lyssenko V, Lindgren CM, Isomaa B, Tuomi T, Berglund G, Renström E and Groop L. (2007) Polymorphisms in the gene encoding the voltage-dependent Ca(2+) channel Ca (V)2.3 (CACNA1E) are associated with type 2 diabetes and impaired insulin secretion. *Diabetologia* **50**: 2467-75 [PMID:17934712]
  202. Hong TT, Smyth JW, Gao D, Chu KY, Vogan JM, Fong TS, Jensen BC, Colecraft HM and Shaw RM. (2010) BIN1 localizes the L-type calcium channel to cardiac T-tubules. *PLoS Biol* **8**: e1000312 [PMID:20169111]
  203. Horstick EJ, Linsley JW, Dowling JJ, Hauser MA, McDonald KK, Ashley-Koch A, Saint-Amant L, Satish A, Cui WW and Zhou W *et al.*. (2013) Stac3 is a component of the excitation-contraction coupling machinery and mutated in Native American myopathy. *Nat Commun* **4**: 1952 [PMID:23736855]
  204. Huang H, Yu D and Soong TW. (2013) C-terminal alternative splicing of CaV1.3 channels distinctively modulates their dihydropyridine sensitivity. *Mol Pharmacol* **84**: 643-53 [PMID:23924992]
  205. Hughes AD and Wijetunge S. (1993) The action of amlodipine on voltage-operated calcium channels in vascular smooth muscle. *Br J Pharmacol* **109**: 120-5 [PMID:8388295]



206. Huguenard JR, Gutnick MJ and Prince DA. (1993) Transient Ca<sup>2+</sup> currents in neurons isolated from rat lateral habenula. *J Neurophysiol* **70**: 158-66 [PMID:8395572]
207. Hulme JT, Ahn M, Hauschka SD, Scheuer T and Catterall WA. (2002) A novel leucine zipper targets AKAP15 and cyclic AMP-dependent protein kinase to the C terminus of the skeletal muscle Ca<sup>2+</sup> channel and modulates its function. *J Biol Chem* **277**: 4079-87 [PMID:11733497]
208. Ihara Y, Yamada Y, Fujii Y, Gono T, Yano H, Yasuda K, Inagaki N, Seino Y and Seino S. (1995) Molecular diversity and functional characterization of voltage-dependent calcium channels (CACN4) expressed in pancreatic beta-cells. *Mol Endocrinol* **9**: 121-30 [PMID:7760845]
209. Ikeda SR. (1996) Voltage-dependent modulation of N-type calcium channels by G-protein beta gamma subunits. *Nature* **380**: 255-8 [PMID:8637575]
210. Imbrici P, Jaffe SL, Eunson LH, Davies NP, Herd C, Robertson R, Kullmann DM and Hanna MG. (2004) Dysfunction of the brain calcium channel CaV2.1 in absence epilepsy and episodic ataxia. *Brain* **127**: 2682-92 [PMID:15483044]
211. Ino M, Yoshinaga T, Wakamori M, Miyamoto N, Takahashi E, Sonoda J, Kagaya T, Oki T, Nagasu T and Nishizawa Y *et al.*. (2001) Functional disorders of the sympathetic nervous system in mice lacking the alpha 1B subunit (Cav 2.2) of N-type calcium channels. *Proc Natl Acad Sci USA* **98**: 5323-8 [PMID:11296258]
212. Ishikawa K, Fujigasaki H, Saegusa H, Ohwada K, Fujita T, Iwamoto H, Komatsuzaki Y, Toru S, Toriyama H and Watanabe M *et al.*. (1999) Abundant expression and cytoplasmic aggregations of [alpha]1A voltage-dependent calcium channel protein associated with neurodegeneration in spinocerebellar ataxia type 6. *Hum Mol Genet* **8**: 1185-93 [PMID:10369863]
213. Jalkanen R, Bech-Hansen NT, Tobias R, Sankila EM, Mäntyjärvi M, Forsius H, de la Chapelle A and Alitalo T. (2007) A novel CACNA1F gene mutation causes Aland Island eye disease. *Invest Ophthalmol Vis Sci* **48**: 2498-502 [PMID:17525176]
214. Jalkanen R, Mäntyjärvi M, Tobias R, Isosomppi J, Sankila EM, Alitalo T and Bech-Hansen NT. (2006) X linked cone-rod dystrophy, CORDX3, is caused by a mutation in the CACNA1F gene. *J Med Genet* **43**: 699-704 [PMID:16505158]
215. Jarvis MF, Scott VE, McGaraughty S, Chu KL, Xu J, Niforatos W, Milicic I, Joshi S, Zhang Q and Xia Z. (2014) A peripherally acting, selective T-type calcium channel blocker, ABT-639, effectively reduces nociceptive and neuropathic pain in rats. *Biochem Pharmacol* **89**: 536-44 [PMID:24726441]
216. Jay SD, Ellis SB, McCue AF, Williams ME, Vedvick TS, Harpold MM and Campbell KP. (1990) Primary structure of the gamma subunit of the DHP-sensitive calcium channel from skeletal muscle. *Science* **248**: 490-2 [PMID:2158672]
217. Jen J, Kim GW and Baloh RW. (2004) Clinical spectrum of episodic ataxia type 2. *Neurology* **62**: 17-22 [PMID:14718690]
218. Jen J, Wan J, Graves M, Yu H, Mock AF, Coulin CJ, Kim G, Yue Q, Papazian DM and Baloh RW. (2001) Loss-of-function EA2 mutations are associated with impaired neuromuscular transmission. *Neurology* **57**: 1843-8 [PMID:11723274]
219. Jen J, Yue Q, Nelson SF, Yu H, Litt M, Nutt J and Baloh RW. (1999) A novel nonsense mutation in CACNA1A causes episodic ataxia and hemiplegia. *Neurology* **53**: 34-7 [PMID:10408533]
220. Jeng CJ, Chen YT, Chen YW and Tang CY. (2006) Dominant-negative effects of human P/Q-type Ca<sup>2+</sup> channel mutations associated with episodic ataxia type 2. *Am J Physiol, Cell Physiol* **290**: C1209-20 [PMID:16306128]
221. Jenkins MA, Christel CJ, Jiao Y, Abiria S, Kim KY, Usachev YM, Obermair GJ, Colbran RJ and Lee A. (2010) Ca<sup>2+</sup>-dependent facilitation of Cav1.3 Ca<sup>2+</sup> channels by densin and Ca<sup>2+</sup>/calmodulin-dependent protein kinase II. *J Neurosci* **30**: 5125-35 [PMID:20392935]
222. Jeon D, Kim C, Yang YM, Rhim H, Yim E, Oh U and Shin HS. (2007) Impaired long-term memory and long-term potentiation in N-type Ca<sup>2+</sup> channel-deficient mice. *Genes Brain Behav* **6**: 375-88 [PMID:16939638]
223. Jeon D, Kim S, Chetana M, Jo D, Ruley HE, Lin SY, Rabah D, Kinet JP and Shin HS. (2010) Observational fear learning involves affective pain system and Cav1.2 Ca<sup>2+</sup> channels in ACC. *Nat Neurosci* **13**: 482-8 [PMID:20190743]
224. Jiménez C, Bourinet E, Leuranguer V, Richard S, Snutch TP and Nargeot J. (2000) Determinants of voltage-dependent inactivation affect Mibefradil block of calcium channels. *Neuropharmacology* **39**: 1-10 [PMID:10665814]
225. Jing X, Li DQ, Olofsson CS, Salehi A, Surve VV, Caballero J, Ivarsson R, Lundquist I, Pereverzev A and Schneider T *et al.*. (2005) CaV2.3 calcium channels control second-phase insulin release. *J Clin Invest* **115**: 146-54 [PMID:15630454]
226. Johnson BD, Hockerman GH, Scheuer T and Catterall WA. (1996) Distinct effects of mutations in transmembrane segment IVS6 on block of L-type calcium channels by structurally similar phenylalkylamines. *Mol Pharmacol* **50**: 1388-400 [PMID:8913371]
227. Jouvenceau A, Eunson LH, Spauschus A, Ramesh V, Zuberi SM, Kullmann DM and Hanna MG. (2001) Human epilepsy associated with dysfunction of the brain P/Q-type calcium channel. *Lancet* **358**: 801-7 [PMID:11564488]



228. Jurkat-Rott K, Lehmann-Horn F, Elbaz A, Heine R, Gregg RG, Hogan K, Powers PA, Lapie P, Vale-Santos JE and Weissenbach J *et al.*. (1994) A calcium channel mutation causing hypokalemic periodic paralysis. *Hum Mol Genet* **3**: 1415-9 [PMID:7987325]
229. Jurkat-Rott K, Lerche H and Lehmann-Horn F. (2002) Skeletal muscle channelopathies. *J Neurol* **249**: 1493-502 [PMID:12420087]
230. Jurkat-Rott K, Weber MA, Fauler M, Guo XH, Holzherr BD, Paczulla A, Nordsborg N, Joechle W and Lehmann-Horn F. (2009) K<sup>+</sup>-dependent paradoxical membrane depolarization and Na<sup>+</sup> overload, major and reversible contributors to weakness by ion channel leaks. *Proc Natl Acad Sci USA* **106**: 4036-41 [PMID:19225109]
231. Kaeser PS, Deng L, Wang Y, Dulubova I, Liu X, Rizo J and Südhof TC. (2011) RIM proteins tether Ca<sup>2+</sup> channels to presynaptic active zones via a direct PDZ-domain interaction. *Cell* **144**: 282-95 [PMID:21241895]
232. Kaja S, van de Ven RC, Broos LA, Veldman H, van Dijk JG, Verschuuren JJ, Frants RR, Ferrari MD, van den Maagdenberg AM and Plomp JJ. (2005) Gene dosage-dependent transmitter release changes at neuromuscular synapses of CACNA1A R192Q knockin mice are non-progressive and do not lead to morphological changes or muscle weakness. *Neuroscience* **135**: 81-95 [PMID:16111830]
233. Kanaya S and Katzung BG. (1984) Effects of diltiazem on transmembrane potential and current of right ventricular papillary muscle of ferrets. *J Pharmacol Exp Ther* **228**: 245-51 [PMID:6694106]
234. Kaneko S, Cooper CB, Nishioka N, Yamasaki H, Suzuki A, Jarvis SE, Akaike A, Satoh M and Zamponi GW. (2002) Identification and characterization of novel human Ca(v)2.2 (alpha 1B) calcium channel variants lacking the synaptic protein interaction site. *J Neurosci* **22**: 82-92 [PMID:11756491]
235. Kang J, Chen XL, Ji J, Lei Q and Rampe D. (2012) Ca<sup>2+</sup> channel activators reveal differential L-type Ca<sup>2+</sup> channel pharmacology between native and stem cell-derived cardiomyocytes. *J Pharmacol Exp Ther* **341**: 510-7 [PMID:22353878]
236. Kawabata M, Ogawa T, Han WH and Takabatake T. (1999) Renal effects of efonidipine hydrochloride, a new calcium antagonist, in spontaneously hypertensive rats with glomerular injury. *Clin Exp Pharmacol Physiol* **26**: 674-9 [PMID:10499155]
237. Ke T, Gomez CR, Mateus HE, Castano JA and Wang QK. (2009) Novel CACNA1S mutation causes autosomal dominant hypokalemic periodic paralysis in a South American family. *J Hum Genet* **54**: 660-4 [PMID:19779499]
238. Kersten FF, van Wijk E, van Reeuwijk J, van der Zwaag B, Märker T, Peters TA, Katsanis N, Wolfrum U, Keunen JE and Roepman R *et al.*. (2010) Association of whirlin with Cav1.3 (alpha1D) channels in photoreceptors, defining a novel member of the usher protein network. *Invest Ophthalmol Vis Sci* **51**: 2338-46 [PMID:19959638]
239. Khosravani H, Bladen C, Parker DB, Snutch TP, McRory JE and Zamponi GW. (2005) Effects of Cav3.2 channel mutations linked to idiopathic generalized epilepsy. *Ann Neurol* **57**: 745-9 [PMID:15852375]
240. Kim C, Jun K, Lee T, Kim SS, McEnery MW, Chin H, Kim HL, Park JM, Kim DK and Jung SJ *et al.*. (2001) Altered nociceptive response in mice deficient in the alpha(1B) subunit of the voltage-dependent calcium channel. *Mol Cell Neurosci* **18**: 235-45 [PMID:11520183]
241. Kim D, Song I, Keum S, Lee T, Jeong MJ, Kim SS, McEnery MW and Shin HS. (2001) Lack of the burst firing of thalamocortical relay neurons and resistance to absence seizures in mice lacking alpha(1G) T-type Ca(2+) channels. *Neuron* **31**: 35-45 [PMID:11498049]
242. Kim S, Yun HM, Baik JH, Chung KC, Nah SY and Rhim H. (2007) Functional interaction of neuronal Cav1.3 L-type calcium channel with ryanodine receptor type 2 in the rat hippocampus. *J Biol Chem* **282**: 32877-89 [PMID:17823125]
243. Kimm T and Bean BP. (2014) Inhibition of A-type potassium current by the peptide toxin SNX-482. *J Neurosci* **34**: 9182-9 [PMID:25009251]
244. Kipfer S, Jung S, Lemke JR, Kipfer-Kauer A, Howell JP, Kaelin-Lang A, Nyffeler T, Gutbrod K, Abicht A and Müri RM. (2013) Novel CACNA1A mutation(s) associated with slow saccade velocities. *J Neurol* **260**: 3010-4 [PMID:24046065]
245. Kiyonaka S, Wakamori M, Miki T, Uriu Y, Nonaka M, Bito H, Beedle AM, Mori E, Hara Y and De Waard M *et al.*. (2007) RIM1 confers sustained activity and neurotransmitter vesicle anchoring to presynaptic Ca<sup>2+</sup> channels. *Nat Neurosci* **10**: 691-701 [PMID:17496890]
246. Klassen T, Davis C, Goldman A, Burgess D, Chen T, Wheeler D, McPherson J, Bourquin T, Lewis L and Villasana D *et al.*. (2011) Exome sequencing of ion channel genes reveals complex profiles confounding personal risk assessment in epilepsy. *Cell* **145**: 1036-48 [PMID:21703448]
247. Klugbauer N, Marais E and Hofmann F. (2003) Calcium channel alpha2delta subunits: differential expression, function, and drug binding. *J Bioenerg Biomembr* **35**: 639-47 [PMID:15000524]
248. Klugbauer N, Marais E, Lacinová L and Hofmann F. (1999) A T-type calcium channel from mouse brain. *Pflugers Arch* **437**: 710-5 [PMID:10087148]

249. Komuro H and Rakic P. (1992) Selective role of N-type calcium channels in neuronal migration. *Science* **257**: 806-9 [PMID:1323145]
250. Kordasiewicz HB, Thompson RM, Clark HB and Gomez CM. (2006) C-termini of P/Q-type Ca<sup>2+</sup> channel alpha1A subunits translocate to nuclei and promote polyglutamine-mediated toxicity. *Hum Mol Genet* **15**: 1587-99 [PMID:16595610]
251. Kors EE, Haan J, Giffin NJ, Pazdera L, Schnittger C, Lennox GG, Terwindt GM, Vermeulen FL, Van den Maagdenberg AM and Frants RR *et al.*. (2003) Expanding the phenotypic spectrum of the CACNA1A gene T666M mutation: a description of 5 families with familial hemiplegic migraine. *Arch Neurol* **60**: 684-8 [PMID:12756131]
252. Kors EE, Melberg A, Vanmolkot KR, Kumlien E, Haan J, Raininko R, Flink R, Ginjaar HB, Frants RR and Ferrari MD *et al.*. (2004) Childhood epilepsy, familial hemiplegic migraine, cerebellar ataxia, and a new CACNA1A mutation. *Neurology* **63**: 1136-7 [PMID:15452324]
253. Kors EE, Terwindt GM, Vermeulen FL, Fitzsimons RB, Jardine PE, Heywood P, Love S, van den Maagdenberg AM, Haan J and Frants RR *et al.*. (2001) Delayed cerebral edema and fatal coma after minor head trauma: role of the CACNA1A calcium channel subunit gene and relationship with familial hemiplegic migraine. *Ann Neurol* **49**: 753-60 [PMID:11409427]
254. Koschak A, Reimer D, Huber I, Grabner M, Glossmann H, Engel J and Striessnig J. (2001) alpha 1D (Cav1.3) subunits can form l-type Ca<sup>2+</sup> channels activating at negative voltages. *J Biol Chem* **276**: 22100-6 [PMID:11285265]
255. Koschak A, Reimer D, Walter D, Hoda JC, Heinzle T, Grabner M and Striessnig J. (2003) Cav1.4alpha1 subunits can form slowly inactivating dihydropyridine-sensitive L-type Ca<sup>2+</sup> channels lacking Ca<sup>2+</sup>-dependent inactivation. *J Neurosci* **23**: 6041-9 [PMID:12853422]
256. Kotturi MF and Jefferies WA. (2005) Molecular characterization of L-type calcium channel splice variants expressed in human T lymphocytes. *Mol Immunol* **42**: 1461-74 [PMID:15899519]
257. Kozlov AS, McKenna F, Lee JH, Cribbs LL, Perez-Reyes E, Feltz A and Lambert RC. (1999) Distinct kinetics of cloned T-type Ca<sup>2+</sup> channels lead to differential Ca<sup>2+</sup> entry and frequency-dependence during mock action potentials. *Eur J Neurosci* **11**: 4149-58 [PMID:10594640]
258. Kraus RL, Sinnegger MJ, Glossmann H, Hering S and Striessnig J. (1998) Familial hemiplegic migraine mutations change alpha1A Ca<sup>2+</sup> channel kinetics. *J Biol Chem* **273**: 5586-90 [PMID:9488686]
259. Kraus RL, Sinnegger MJ, Koschak A, Glossmann H, Stenirri S, Carrera P and Striessnig J. (2000) Three new familial hemiplegic migraine mutants affect P/Q-type Ca(2+) channel kinetics. *J Biol Chem* **275**: 9239-43 [PMID:10734061]
260. Kubota M, Murakoshi T, Saegusa H, Kazuno A, Zong S, Hu Q, Noda T and Tanabe T. (2001) Intact LTP and fear memory but impaired spatial memory in mice lacking Ca(v)2.3 (alpha(IE)) channel. *Biochem Biophys Res Commun* **282**: 242-8 [PMID:11263998]
261. Lalevée N, Rebsamen MC, Barrère-Lemaire S, Perrier E, Nargeot J, Bénitah JP and Rossier MF. (2005) Aldosterone increases T-type calcium channel expression and in vitro beating frequency in neonatal rat cardiomyocytes. *Cardiovasc Res* **67**: 216-24 [PMID:15919070]
262. Lamb GD and Walsh T. (1987) Calcium currents, charge movement and dihydropyridine binding in fast- and slow-twitch muscles of rat and rabbit. *J Physiol (Lond.)* **393**: 595-617 [PMID:2451745]
263. Lampe RA, Defeo PA, Davison MD, Young J, Herman JL, Spreen RC, Horn MB, Mangano TJ and Keith RA. (1993) Isolation and pharmacological characterization of omega-gammatoxin SIA, a novel peptide inhibitor of neuronal voltage-sensitive calcium channel responses. *Mol Pharmacol* **44**: 451-60 [PMID:8394998]
264. Langwieser N, Christel CJ, Kleppisch T, Hofmann F, Wotjak CT and Moosmang S. (2010) Homeostatic switch in hebbian plasticity and fear learning after sustained loss of Cav1.2 calcium channels. *J Neurosci* **30**: 8367-75 [PMID:20573883]
265. Latour I, Hamid J, Beedle AM, Zamponi GW and Macvicar BA. (2003) Expression of voltage-gated Ca<sup>2+</sup> channel subtypes in cultured astrocytes. *Glia* **41**: 347-53 [PMID:12555202]
266. Lee A, Westenbroek RE, Haeseleer F, Palczewski K, Scheuer T and Catterall WA. (2002) Differential modulation of Ca(v)2.1 channels by calmodulin and Ca<sup>2+</sup>-binding protein 1. *Nat Neurosci* **5**: 210-7 [PMID:11865310]
267. Lee A, Wong ST, Gallagher D, Li B, Storm DR, Scheuer T and Catterall WA. (1999) Ca<sup>2+</sup>/calmodulin binds to and modulates P/Q-type calcium channels. *Nature* **399**: 155-9 [PMID:10335845]
268. Lee AS, Ra S, Rajadhyaksha AM, Britt JK, De Jesus-Cortes H, Gonzales KL, Lee A, Moosmang S, Hofmann F and Pieper AA *et al.*. (2012) Forebrain elimination of cacna1c mediates anxiety-like behavior in mice. *Mol Psychiatry* **17**: 1054-5 [PMID:22665262]
269. Lee JH, Daud AN, Cribbs LL, Lacerda AE, Pereverzev A, Klöckner U, Schneider T and Perez-Reyes E. (1999) Cloning and expression of a novel member of the low voltage-activated T-type calcium channel family. *J Neurosci* **19**: 1912-21 [PMID:10066244]
270. Lee JH, Gomora JC, Cribbs LL and Perez-Reyes E. (1999) Nickel block of three cloned T-type calcium channels: low concentrations selectively block alpha1H. *Biophys J* **77**: 3034-42

- [PMID:10585925]
271. Lee TS, Karl R, Moosmang S, Lenhardt P, Klugbauer N, Hofmann F, Kleppisch T and Welling A. (2006) Calmodulin kinase II is involved in voltage-dependent facilitation of the L-type Cav1.2 calcium channel: Identification of the phosphorylation sites. *J Biol Chem* **281**: 25560-7 [PMID:16820363]
272. Lein ES, Hawrylycz MJ, Ao N, Ayres M, Bensinger A, Bernard A, Boe AF, Boguski MS, Brockway KS and Byrnes EJ *et al.*. (2007) Genome-wide atlas of gene expression in the adult mouse brain. *Nature* **445**: 168-76 [PMID:17151600]
273. Leroy J, Richter W, Mika D, Castro LR, Abi-Gerges A, Xie M, Scheitrum C, Lefebvre F, Schittl J and Mateo P *et al.*. (2011) Phosphodiesterase 4B in the cardiac L-type Ca<sup>2+</sup> channel complex regulates Ca<sup>2+</sup> current and protects against ventricular arrhythmias in mice. *J Clin Invest* **121**: 2651-61 [PMID:21670503]
274. Lewis RJ, Nielsen KJ, Craik DJ, Loughnan ML, Adams DA, Sharpe IA, Luchian T, Adams DJ, Bond T and Thomas L *et al.*. (2000) Novel omega-conotoxins from *Conus catus* discriminate among neuronal calcium channel subtypes. *J Biol Chem* **275**: 35335-44 [PMID:10938268]
275. Leão RM, Cruz JS, Diniz CR, Cordeiro MN and Beirão PS. (2000) Inhibition of neuronal high-voltage activated calcium channels by the omega-phoneutria nigriventer Tx3-3 peptide toxin. *Neuropharmacology* **39**: 1756-67 [PMID:10884557]
276. Li FF, Li QQ, Tan ZX, Zhang SY, Liu J, Zhao EY, Yu GC, Zhou J, Zhang LM and Liu SL. (2012) A novel mutation in CACNA1S gene associated with hypokalemic periodic paralysis which has a gender difference in the penetrance. *J Mol Neurosci* **46**: 378-83 [PMID:21845430]
277. Li GR, Yang B, Feng J, Bosch RF, Carrier M and Nattel S. (1999) Transmembrane ICa contributes to rate-dependent changes of action potentials in human ventricular myocytes. *Am J Physiol* **276**: H98-H106 [PMID:9887022]
278. Li L, Bischofberger J and Jonas P. (2007) Differential gating and recruitment of P/Q-, N-, and R-type Ca<sup>2+</sup> channels in hippocampal mossy fiber boutons. *J Neurosci* **27**: 13420-9 [PMID:18057200]
279. Liao P, Yu D, Li G, Yong TF, Soon JL, Chua YL and Soong TW. (2007) A smooth muscle Cav1.2 calcium channel splice variant underlies hyperpolarized window current and enhanced state-dependent inhibition by nifedipine. *J Biol Chem* **282**: 35133-42 [PMID:17916557]
280. Lieb A, Scharinger A, Sartori S, Sinnegger-Brauns MJ and Striessnig J. (2012) Structural determinants of Cav1.3 L-type calcium channel gating. *Channels (Austin)* **6**: 197-205 [PMID:22760075]
281. Limpitikul WB, Dick IE, Ben-Johny M and Yue DT. (2016) An autism-associated mutation in Cav1.3 channels has opposing effects on voltage- and Ca(2+)-dependent regulation. *Sci Rep* **6**: 27235 [PMID:27255217]
282. Lin Z, Lin Y, Schorge S, Pan JQ, Beierlein M and Lipscombe D. (1999) Alternative splicing of a short cassette exon in alpha1B generates functionally distinct N-type calcium channels in central and peripheral neurons. *J Neurosci* **19**: 5322-31 [PMID:10377343]
283. Liu G, Papa A, Katchman AN, Zakharov SI, Roybal D, Hennessey JA, Kushner J, Yang L, Chen BX and Kushnir A *et al.*. (2020) Mechanism of adrenergic Cav1.2 stimulation revealed by proximity proteomics. *Nature* **577**: 695-700 [PMID:31969708]
284. Liu H, De Waard M, Scott VE, Gurnett CA, Lennon VA and Campbell KP. (1996) Identification of three subunits of the high affinity omega-conotoxin MVIIC-sensitive Ca<sup>2+</sup> channel. *J Biol Chem* **271**: 13804-10 [PMID:8662888]
285. Liu L, Gonzalez PK, Barrett CF and Rittenhouse AR. (2003) The calcium channel ligand FPL 64176 enhances L-type but inhibits N-type neuronal calcium currents. *Neuropharmacology* **45**: 281-92 [PMID:12842134]
286. Liu X, Yang PS, Yang W and Yue DT. (2010) Enzyme-inhibitor-like tuning of Ca(2+) channel connectivity with calmodulin. *Nature* **463**: 968-72 [PMID:20139964]
287. Llinás R, Sugimori M, Hillman DE and Cherksey B. (1992) Distribution and functional significance of the P-type, voltage-dependent Ca<sup>2+</sup> channels in the mammalian central nervous system. *Trends Neurosci* **15**: 351-5 [PMID:1382335]
288. Lu ZJ, Pereverzev A, Liu HL, Weiergräber M, Henry M, Krieger A, Smyth N, Hescheler J and Schneider T. (2004) Arrhythmia in isolated prenatal hearts after ablation of the Cav2.3 (alpha1E) subunit of voltage-gated Ca<sup>2+</sup> channels. *Cell Physiol Biochem* **14**: 11-22 [PMID:14976402]
289. Ludwig A, Flockerzi V and Hofmann F. (1997) Regional expression and cellular localization of the alpha1 and beta subunit of high voltage-activated calcium channels in rat brain. *J Neurosci* **17**: 1339-49 [PMID:9006977]
290. Luebke JI, Dunlap K and Turner TJ. (1993) Multiple calcium channel types control glutamatergic synaptic transmission in the hippocampus. *Neuron* **11**: 895-902 [PMID:7902110]
291. Maciel IS, Azevedo VM, Pereira TC, Bogo MR, Souza AH, Gomez MV and Campos MM. (2014) The spinal inhibition of N-type voltage-gated calcium channels selectively prevents scratching behavior in mice. *Neuroscience* **277**: 794-805 [PMID:25108164]



292. Magupalli VG, Mochida S, Yan J, Jiang X, Westenbroek RE, Nairn AC, Scheuer T and Catterall WA. (2013) Ca<sup>2+</sup>-independent activation of Ca<sup>2+</sup>/calmodulin-dependent protein kinase II bound to the C-terminal domain of Cav2.1 calcium channels. *J Biol Chem* **288**: 4637-48 [PMID:23255606]
293. Magyar J, Iost N, Körtvély A, Bányász T, Virág L, Szigligeti P, Varró A, Opincariu M, Szécsi J and Papp JG *et al.*. (2000) Effects of endothelin-1 on calcium and potassium currents in undiseased human ventricular myocytes. *Pflugers Arch* **441**: 144-9 [PMID:11205054]
294. Malmberg AB and Yaksh TL. (1994) Voltage-sensitive calcium channels in spinal nociceptive processing: blockade of N- and P-type channels inhibits formalin-induced nociception. *J Neurosci* **14**: 4882-90 [PMID:8046458]
295. Mangoni ME, Couette B, Bourinet E, Platzer J, Reimer D, Striessnig J and Nargeot J. (2003) Functional role of L-type Cav1.3 Ca<sup>2+</sup> channels in cardiac pacemaker activity. *Proc Natl Acad Sci USA* **100**: 5543-8 [PMID:12700358]
296. Mangoni ME, Traboulsie A, Leoni AL, Couette B, Marger L, Le Quang K, Kupfer E, Cohen-Solal A, Vilar J and Shin HS *et al.*. (2006) Bradycardia and slowing of the atrioventricular conduction in mice lacking Cav3.1/alpha1G T-type calcium channels. *Circ Res* **98**: 1422-30 [PMID:16690884]
297. Mansergh F, Orton NC, Vessey JP, Lalonde MR, Stell WK, Tremblay F, Barnes S, Rancourt DE and Bech-Hansen NT. (2005) Mutation of the calcium channel gene *Cacna1f* disrupts calcium signaling, synaptic transmission and cellular organization in mouse retina. *Hum Mol Genet* **14**: 3035-46 [PMID:16155113]
298. Mantuano E, Romano S, Veneziano L, Gellera C, Castellotti B, Caimi S, Testa D, Estienne M, Zorzi G and Bugiani M *et al.*. (2010) Identification of novel and recurrent CACNA1A gene mutations in fifteen patients with episodic ataxia type 2. *J Neurol Sci* **291**: 30-6 [PMID:20129625]
299. Mantuano E, Veneziano L, Spadaro M, Giunti P, Guida S, Leggio MG, Verriello L, Wood N, Jodice C and Frontali M. (2004) Clusters of non-truncating mutations of P/Q type Ca<sup>2+</sup> channel subunit Ca(v)2.1 causing episodic ataxia 2. *J Med Genet* **41**: e82 [PMID:15173248]
300. Marcantoni A, Caloric A, Hidisoglu E, Chiantia G and Carbone E. (2020) Cav1.2 channelopathies causing autism: new hallmarks on Timothy syndrome. *Pflugers Arch* **472**: 775-789 [PMID:32621084]
301. Marcantoni A, Vandael DH, Mahapatra S, Carabelli V, Sinnegger-Brauns MJ, Striessnig J and Carbone E. (2010) Loss of Cav1.3 channels reveals the critical role of L-type and BK channel coupling in pacemaking mouse adrenal chromaffin cells. *J Neurosci* **30**: 491-504 [PMID:20071512]
302. Marionneau C, Couette B, Liu J, Li H, Mangoni ME, Nargeot J, Lei M, Escande D and Demolombe S. (2005) Specific pattern of ionic channel gene expression associated with pacemaker activity in the mouse heart. *J Physiol* **562**: 223-34 [PMID:15498808]
303. Marshall MR, Clark 3rd JP, Westenbroek R, Yu FH, Scheuer T and Catterall WA. (2011) Functional roles of a C-terminal signaling complex of Cav1 channels and A-kinase anchoring protein 15 in brain neurons. *J Biol Chem* **286**: 12627-39 [PMID:21224388]
304. Martin RL, Lee JH, Cribbs LL, Perez-Reyes E and Hanck DA. (2000) Mibefradil block of cloned T-type calcium channels. *J Pharmacol Exp Ther* **295**: 302-8 [PMID:10991994]
305. Mathur VS. (2000) A new pharmacological class of drug for the management of pain. *Seminars in Anesthesia, Perioperative Medicine and Pain* **19**: 67-75
306. Matsuda Y, Saegusa H, Zong S, Noda T and Tanabe T. (2001) Mice lacking Ca(v)2.3 (alpha1E) calcium channel exhibit hyperglycemia. *Biochem Biophys Res Commun* **289**: 791-5 [PMID:11735114]
307. Matsuyama Z, Wakamori M, Mori Y, Kawakami H, Nakamura S and Imoto K. (1999) Direct alteration of the P/Q-type Ca<sup>2+</sup> channel property by polyglutamine expansion in spinocerebellar ataxia 6. *J Neurosci* **19**: RC14 [PMID:10366652]
308. Matthews E, Labrum R, Sweeney MG, Sud R, Haworth A, Chinnery PF, Meola G, Schorge S, Kullmann DM and Davis MB *et al.*. (2009) Voltage sensor charge loss accounts for most cases of hypokalemic periodic paralysis. *Neurology* **72**: 1544-7 [PMID:19118277]
309. Matthews EA, Bee LA, Stephens GJ and Dickenson AH. (2007) The Cav2.3 calcium channel antagonist SNX-482 reduces dorsal horn neuronal responses in a rat model of chronic neuropathic pain. *Eur J Neurosci* **25**: 3561-9 [PMID:17610575]
310. Matza D, Badou A, Kobayashi KS, Goldsmith-Pestana K, Masuda Y, Komuro A, McMahon-Pratt D, Marchesi VT and Flavell RA. (2008) A scaffold protein, AHNAK1, is required for calcium signaling during T cell activation. *Immunity* **28**: 64-74 [PMID:18191595]
311. McDonough SI, Boland LM, Mintz IM and Bean BP. (2002) Interactions among toxins that inhibit N-type and P-type calcium channels. *J Gen Physiol* **119**: 313-28 [PMID:11929883]
312. McDonough SI, Lampe RA, Keith RA and Bean BP. (1997) Voltage-dependent inhibition of N- and P-type calcium channels by the peptide toxin omega-grammotoxin-SIA. *Mol Pharmacol* **52**: 1095-104 [PMID:9415720]



313. McDonough SI, Swartz KJ, Mintz IM, Boland LM and Bean BP. (1996) Inhibition of calcium channels in rat central and peripheral neurons by omega-conotoxin MVIIC. *J Neurosci* **16**: 2612-23 [PMID:8786437]
314. McGivern JG. (2006) Pharmacology and drug discovery for T-type calcium channels. *CNS Neurol Disord Drug Targets* **5**: 587-603 [PMID:17168744]
315. McGuire D, Bowersox S, Fellmann JD and Luther RR. (1997) Sympatholysis after neuron-specific, N-type, voltage-sensitive calcium channel blockade: first demonstration of N-channel function in humans. *J Cardiovasc Pharmacol* **30**: 400-3 [PMID:9300326]
316. McKay BE, McRory JE, Molineux ML, Hamid J, Snutch TP, Zamponi GW and Turner RW. (2006) Ca(V)3 T-type calcium channel isoforms differentially distribute to somatic and dendritic compartments in rat central neurons. *Eur J Neurosci* **24**: 2581-94 [PMID:17100846]
317. McKinney BC and Murphy GG. (2006) The L-Type voltage-gated calcium channel Cav1.3 mediates consolidation, but not extinction, of contextually conditioned fear in mice. *Learn Mem* **13**: 584-9 [PMID:17015855]
318. McKinney BC, Sze W, Lee B and Murphy GG. (2009) Impaired long-term potentiation and enhanced neuronal excitability in the amygdala of Ca(V)1.3 knockout mice. *Neurobiol Learn Mem* **92**: 519-28 [PMID:19595780]
319. McNaughton NC and Randall AD. (1997) Electrophysiological properties of the human N-type Ca<sup>2+</sup> channel: I. Channel gating in Ca<sup>2+</sup>, Ba<sup>2+</sup> and Sr<sup>2+</sup> containing solutions. *Neuropharmacology* **36**: 895-915 [PMID:9257935]
320. McRory JE, Hamid J, Doering CJ, Garcia E, Parker R, Hamming K, Chen L, Hildebrand M, Beedle AM and Feldcamp L *et al.*. (2004) The CACNA1F gene encodes an L-type calcium channel with unique biophysical properties and tissue distribution. *J Neurosci* **24**: 1707-18 [PMID:14973233]
321. McRory JE, Santi CM, Hamming KS, Mezeyova J, Sutton KG, Baillie DL, Stea A and Snutch TP. (2001) Molecular and functional characterization of a family of rat brain T-type calcium channels. *J Biol Chem* **276**: 3999-4011 [PMID:11073957]
322. Melliti K, Grabner M and Seabrook GR. (2003) The familial hemiplegic migraine mutation R192Q reduces G-protein-mediated inhibition of P/Q-type (Ca(V)2.1) calcium channels expressed in human embryonic kidney cells. *J Physiol (Lond.)* **546**: 337-47 [PMID:12527722]
323. Mermelstein PG, Foehring RC, Tkatch T, Song WJ, Baranauskas G and Surmeier DJ. (1999) Properties of Q-type calcium channels in neostriatal and cortical neurons are correlated with beta subunit expression. *J Neurosci* **19**: 7268-77 [PMID:10460233]
324. Mewes T and Ravens U. (1994) L-type calcium currents of human myocytes from ventricle of non-failing and failing hearts and from atrium. *J Mol Cell Cardiol* **26**: 1307-20 [PMID:7869391]
325. Michna M, Knirsch M, Hoda JC, Muenkner S, Langer P, Platzer J, Striessnig J and Engel J. (2003) Cav1.3 (alpha1D) Ca<sup>2+</sup> currents in neonatal outer hair cells of mice. *J Physiol (Lond.)* **553**: 747-58 [PMID:14514878]
326. Mintz IM. (1994) Block of Ca channels in rat central neurons by the spider toxin omega-Aga-IIIa. *J Neurosci* **14**: 2844-53 [PMID:8182443]
327. Mintz IM, Adams ME and Bean BP. (1992) P-type calcium channels in rat central and peripheral neurons. *Neuron* **9**: 85-95 [PMID:1321648]
328. Mintz IM, Sabatini BL and Regehr WG. (1995) Calcium control of transmitter release at a cerebellar synapse. *Neuron* **15**: 675-88 [PMID:7546746]
329. Mintz IM, Venema VJ, Swiderek KM, Lee TD, Bean BP and Adams ME. (1992) P-type calcium channels blocked by the spider toxin omega-Aga-IVA. *Nature* **355**: 827-9 [PMID:1311418]
330. Mitchell JW, Larsen JK and Best PM. (2002) Identification of the calcium channel alpha 1E (Ca(v)2.3) isoform expressed in atrial myocytes. *Biochim Biophys Acta* **1577**: 17-26 [PMID:12151091]
331. Mochida S, Few AP, Scheuer T and Catterall WA. (2008) Regulation of presynaptic Ca(V)2.1 channels by Ca<sup>2+</sup> sensor proteins mediates short-term synaptic plasticity. *Neuron* **57**: 210-6 [PMID:18215619]
332. Monnier N, Procaccio V, Stieglitz P and Lunardi J. (1997) Malignant-hyperthermia susceptibility is associated with a mutation of the alpha 1-subunit of the human dihydropyridine-sensitive L-type voltage-dependent calcium-channel receptor in skeletal muscle. *Am J Hum Genet* **60**: 1316-25 [PMID:9199552]
333. Monteil A, Chemin J, Bourinet E, Mennessier G, Lory P and Nargeot J. (2000) Molecular and functional properties of the human alpha(1G) subunit that forms T-type calcium channels. *J Biol Chem* **275**: 6090-100 [PMID:10692398]
334. Monteil A, Chemin J, Leuranguer V, Altier C, Mennessier G, Bourinet E, Lory P and Nargeot J. (2000) Specific properties of T-type calcium channels generated by the human alpha 1I subunit. *J Biol Chem* **275**: 16530-5 [PMID:10749850]
335. Moosmang S, Haider N, Klugbauer N, Adelsberger H, Langwieser N, Müller J, Stieess M, Marais E, Schulla V and Lacinova L *et al.*. (2005) Role of hippocampal Cav1.2 Ca<sup>2+</sup> channels in NMDA receptor-independent synaptic plasticity and spatial memory. *J Neurosci* **25**: 9883-92 [PMID:16251435]

336. Moosmang S, Schulla V, Welling A, Feil R, Feil S, Wegener JW, Hofmann F and Klugbauer N. (2003) Dominant role of smooth muscle L-type calcium channel Cav1.2 for blood pressure regulation. *EMBO J* **22**: 6027-34 [PMID:14609949]
337. Morgans CW, Gaughwin P and Maleszka R. (2001) Expression of the alpha1F calcium channel subunit by photoreceptors in the rat retina. *Mol Vis* **7**: 202-9 [PMID:11526344]
338. Morino H, Matsuda Y, Muguruma K, Miyamoto R, Ohsawa R, Ohtake T, Otake R, Watanabe M, Maruyama H and Hashimoto K *et al.*. (2015) A mutation in the low voltage-gated calcium channel CACNA1G alters the physiological properties of the channel, causing spinocerebellar ataxia. *Mol Brain* **8**: 89 [PMID:26715324]
339. Muller YL, Hanson RL, Zimmerman C, Harper I, Sutherland J, Kobes S, International Type 2 Diabetes 1q Consortium, Knowler WC, Bogardus C and Baier LJ. (2007) Variants in the Ca V 2.3 (alpha 1E) subunit of voltage-activated Ca<sup>2+</sup> channels are associated with insulin resistance and type 2 diabetes in Pima Indians. *Diabetes* **56**: 3089-94 [PMID:17720895]
340. Murakami M, Nakagawasai O, Fujii S, Kameyama K, Murakami S, Hozumi S, Esashi A, Taniguchi R, Yanagisawa T and Tan-no K *et al.*. (2001) Antinociceptive action of amlodipine blocking N-type Ca<sup>2+</sup> channels at the primary afferent neurons in mice. *Eur J Pharmacol* **419**: 175-81 [PMID:11426839]
341. Murakami M, Nakagawasai O, Yanai K, Nunoki K, Tan-No K, Tadano T and Iijima T. (2007) Modified behavioral characteristics following ablation of the voltage-dependent calcium channel beta3 subunit. *Brain Res* **1160**: 102-12 [PMID:17588550]
342. Murakami M, Ohba T, Wu TW, Fujisawa S, Suzuki T, Takahashi Y, Takahashi E, Watanabe H, Miyoshi I and Ono K *et al.*. (2007) Modified sympathetic regulation in N-type calcium channel null-mouse. *Biochem Biophys Res Commun* **354**: 1016-20 [PMID:17275790]
343. Murbartián J, Arias JM and Perez-Reyes E. (2004) Functional impact of alternative splicing of human T-type Cav3.3 calcium channels. *J Neurophysiol* **92**: 3399-407 [PMID:15254077]
344. Myoga MH and Regehr WG. (2011) Calcium microdomains near R-type calcium channels control the induction of presynaptic long-term potentiation at parallel fiber to purkinje cell synapses. *J Neurosci* **31**: 5235-43 [PMID:21471358]
345. Müller R, Struck H, Ho MS, Brockhaus-Dumke A, Klosterkötter J, Broich K, Hescheler J, Schneider T and Weiergräber M. (2012) Atropine-sensitive hippocampal  $\theta$  oscillations are mediated by Cav2.3 R-type Ca<sup>2+</sup> channels. *Neuroscience* **205**: 125-39 [PMID:22240250]
346. Müllner C, Broos LA, van den Maagdenberg AM and Striessnig J. (2004) Familial hemiplegic migraine type 1 mutations K1336E, W1684R, and V1696I alter Cav2.1 Ca<sup>2+</sup> channel gating: evidence for beta-subunit isoform-specific effects. *J Biol Chem* **279**: 51844-50 [PMID:15448138]
347. N'gouemo P, Faingold CL and Morad M. (2009) Calcium channel dysfunction in inferior colliculus neurons of the genetically epilepsy-prone rat. *Neuropharmacology* **56**: 665-75 [PMID:19084544]
348. Nakamura M, Ito S, Piao CH, Terasaki H and Miyake Y. (2003) Retinal and optic disc atrophy associated with a CACNA1F mutation in a Japanese family. *Arch Ophthalmol* **121**: 1028-33 [PMID:12860808]
349. Nakamura M, Ito S, Terasaki H and Miyake Y. (2001) Novel CACNA1F mutations in Japanese patients with incomplete congenital stationary night blindness. *Invest Ophthalmol Vis Sci* **42**: 1610-6 [PMID:11381068]
350. Nanba K, Blinder AR, Rege J, Hattangady NG, Else T, Liu CJ, Tomlins SA, Vats P, Kumar-Sinha C and Giordano TJ *et al.*. (2020) Somatic CACNA1H Mutation As a Cause of Aldosterone-Producing Adenoma. *Hypertension* **75**: 645-649 [PMID:31983310]
351. Nanou E and Catterall WA. (2018) Calcium Channels, Synaptic Plasticity, and Neuropsychiatric Disease. *Neuron* **98**: 466-481 [PMID:29723500]
352. Naylor MJ, Rancourt DE and Bech-Hansen NT. (2000) Isolation and characterization of a calcium channel gene, Cacna1f, the murine orthologue of the gene for incomplete X-linked congenital stationary night blindness. *Genomics* **66**: 324-7 [PMID:10873387]
353. Nelson MT, Joksovic PM, Perez-Reyes E and Todorovic SM. (2005) The endogenous redox agent L-cysteine induces T-type Ca<sup>2+</sup> channel-dependent sensitization of a novel subpopulation of rat peripheral nociceptors. *J Neurosci* **25**: 8766-75 [PMID:16177046]
354. Newcomb R, Szoke B, Palma A, Wang G, Chen Xh, Hopkins W, Cong R, Miller J, Urge L and Tarczy-Hornoch K *et al.*. (1998) Selective peptide antagonist of the class E calcium channel from the venom of the tarantula *Hysterocrates gigas*. *Biochemistry* **37**: 15353-62 [PMID:9799496]
355. Newton PM, Orr CJ, Wallace MJ, Kim C, Shin HS and Messing RO. (2004) Deletion of N-type calcium channels alters ethanol reward and reduces ethanol consumption in mice. *J Neurosci* **24**: 9862-9 [PMID:15525770]
356. Nimmrich V and Gross G. (2012) P/Q-type calcium channel modulators. *Br J Pharmacol* **167**: 741-59 [PMID:22670568]
357. Nokin P, Clinet M, Beaufort P, Meysmans L, Laruel R and Chatelain P. (1990) SR 33557, a novel calcium entry blocker. II. Interactions with 1,4-dihydropyridine, phenylalkylamine and benzothiazepine binding sites in rat heart sarcolemmal membranes. *J Pharmacol Exp Ther* **255**:

- 600-7 [PMID:2147036]
358. Nowycky MC, Fox AP and Tsien RW. (1985) Three types of neuronal calcium channel with different calcium agonist sensitivity. *Nature* **316**: 440-3 [PMID:2410796]
359. O'Roak BJ, Vives L, Girirajan S, Karakoc E, Krumm N, Coe BP, Levy R, Ko A, Lee C and Smith JD *et al.*. (2012) Sporadic autism exomes reveal a highly interconnected protein network of de novo mutations. *Nature* **485**: 246-50 [PMID:22495309]
360. Obermair GJ, Kugler G, Baumgartner S, Tuluc P, Grabner M and Flucher BE. (2005) The Ca<sup>2+</sup> channel alpha2delta-1 subunit determines Ca<sup>2+</sup> current kinetics in skeletal muscle but not targeting of alpha1S or excitation-contraction coupling. *J Biol Chem* **280**: 2229-37 [PMID:15536090]
361. Ogawa T, Kashiwagi A, Kikkawa R and Shigeta Y. (1995) Increase of voltage-sensitive calcium channels and calcium accumulation in skeletal muscles of streptozocin-induced diabetic rats. *Metab Clin Exp* **44**: 1455-61 [PMID:7476334]
362. Okayama S, Imagawa K, Naya N, Iwama H, Somekawa S, Kawata H, Horii M, Nakajima T, Uemura S and Saito Y. (2006) Blocking T-type Ca<sup>2+</sup> channels with efonidipine decreased plasma aldosterone concentration in healthy volunteers. *Hypertens Res* **29**: 493-7 [PMID:17044661]
363. Olivera BM, Miljanich GP, Ramachandran J and Adams ME. (1994) Calcium channel diversity and neurotransmitter release: the omega-conotoxins and omega-agatoxins. *Annu Rev Biochem* **63**: 823-67 [PMID:7979255]
364. Oliveria SF, Dittmer PJ, Youn DH, Dell'Acqua ML and Sather WA. (2012) Localized calcineurin confers Ca<sup>2+</sup>-dependent inactivation on neuronal L-type Ca<sup>2+</sup> channels. *J Neurosci* **32**: 15328-37 [PMID:23115171]
365. Olson PA, Tkatch T, Hernandez-Lopez S, Ulrich S, Ilijic E, Mugnaini E, Zhang H, Bezprozvanny I and Surmeier DJ. (2005) G-protein-coupled receptor modulation of striatal CaV1.3 L-type Ca<sup>2+</sup> channels is dependent on a Shank-binding domain. *J Neurosci* **25**: 1050-62 [PMID:15689540]
366. Omilusik K, Priatel JJ, Chen X, Wang YT, Xu H, Choi KB, Gopaul R, McIntyre-Smith A, Teh HS and Tan R *et al.*. (2011) The Ca(v)1.4 calcium channel is a critical regulator of T cell receptor signaling and naive T cell homeostasis. *Immunity* **35**: 349-60 [PMID:21835646]
367. Ophoff RA, Terwindt GM, Vergouwe MN, van Eijk R, Oefner PJ, Hoffman SM, Lamerdin JE, Mohrenweiser HW, Bulman DE and Ferrari M *et al.*. (1996) Familial hemiplegic migraine and episodic ataxia type-2 are caused by mutations in the Ca<sup>2+</sup> channel gene CACNL1A4. *Cell* **87**: 543-52 [PMID:8898206]
368. Ortner NJ, Bock G, Dougalis A, Kharitonova M, Duda J, Hess S, Tuluc P, Pomberger T, Stefanova N and Pitterl F *et al.*. (2017) Lower Affinity of Isradipine for L-Type Ca<sup>2+</sup> Channels during Substantia Nigra Dopamine Neuron-Like Activity: Implications for Neuroprotection in Parkinson's Disease. *J Neurosci* **37**: 6761-6777 [PMID:28592699]
369. Ortner NJ, Kaserer T, Copeland JN and Striessnig J. (2020) De novo CACNA1D Ca<sup>2+</sup> channelopathies: clinical phenotypes and molecular mechanism. *Pflugers Arch* **472**: 755-773 [PMID:32583268]
370. Ortner NJ, Pinggera A, Hofer NT, Siller A, Brandt N, Raffener A, Vilusic K, Lang I, Blum K and Obermair GJ *et al.*. (2020) RBP2 stabilizes slow Cav1.3 Ca<sup>2+</sup> channel inactivation properties of cochlear inner hair cells. *Pflugers Arch* **472**: 3-25 [PMID:31848688]
371. Osanai M, Saegusa H, Kazuno AA, Nagayama S, Hu Q, Zong S, Murakoshi T and Tanabe T. (2006) Altered cerebellar function in mice lacking CaV2.3 Ca<sup>2+</sup> channel. *Biochem Biophys Res Commun* **344**: 920-5 [PMID:16631598]
372. Pan JQ and Lipscombe D. (2000) Alternative splicing in the cytoplasmic II-III loop of the N-type Ca channel alpha 1B subunit: functional differences are beta subunit-specific. *J Neurosci* **20**: 4769-75 [PMID:10864934]
373. Pang C, Crump SM, Jin L, Correll RN, Finlin BS, Satin J and Andres DA. (2010) Rem GTPase interacts with the proximal CaV1.2 C-terminus and modulates calcium-dependent channel inactivation. *Channels (Austin)* **4**: 192-202 [PMID:20458179]
374. Papanayotou C, De Almeida I, Liao P, Oliveira NM, Lu SQ, Kougioumtzidou E, Zhu L, Shaw A, Sheng G and Streit A *et al.*. (2013) Calfacilitin is a calcium channel modulator essential for initiation of neural plate development. *Nat Commun* **4**: 1837 [PMID:23673622]
375. Parent L, Schneider T, Moore CP and Talwar D. (1997) Subunit regulation of the human brain alpha 1E calcium channel. *J Membr Biol* **160**: 127-40 [PMID:9354705]
376. Park CY, Shcheglovitov A and Dolmetsch R. (2010) The CRAC channel activator STIM1 binds and inhibits L-type voltage-gated calcium channels. *Science* **330**: 101-5 [PMID:20929812]
377. Park JH, Choi JK, Lee E, Lee JK, Rhim H, Seo SH, Kim Y, Doddareddy MR, Pae AN, Kang J and Roh EJ. (2007) Lead discovery and optimization of T-type calcium channel blockers. *Bioorg Med Chem* **15**: 1409-19 [PMID:17150365]
378. Patten M, Maas R, Bauer P, Lüderitz B, Sonntag F, Dluzniewski M, Hatala R, Opolski G, Müller HW and Meinertz T *et al.*. (2004) Suppression of paroxysmal atrial tachyarrhythmias--results of the SOPAT trial. *Eur Heart J* **25**: 1395-404 [PMID:15321697]



379. Pelzmann B, Schaffer P, Bernhart E, Lang P, Mächler H, Rigler B and Koidl B. (1998) L-type calcium current in human ventricular myocytes at a physiological temperature from children with tetralogy of Fallot. *Cardiovasc Res* **38**: 424-32 [PMID:9709403]
380. Peng S, Hajela RK and Atchison WD. (2002) Characteristics of block by Pb<sup>2+</sup> of function of human neuronal L-, N-, and R-type Ca<sup>2+</sup> channels transiently expressed in human embryonic kidney 293 cells. *Mol Pharmacol* **62**: 1418-30 [PMID:12435810]
381. Penn RD and Paice JA. (2000) Adverse effects associated with the intrathecal administration of ziconotide. *Pain* **85**: 291-6 [PMID:10692631]
382. Pereverzev A, Klöckner U, Henry M, Grabsch H, Vajna R, Olyschläger S, Viatchenko-Karpinski S, Schröder R, Hescheler J and Schneider T. (1998) Structural diversity of the voltage-dependent Ca<sup>2+</sup> channel alpha1E-subunit. *Eur J Neurosci* **10**: 916-25 [PMID:9753159]
383. Pereverzev A, Mikhna M, Vajna R, Gissel C, Henry M, Weiergräber M, Hescheler J, Smyth N and Schneider T. (2002) Disturbances in glucose-tolerance, insulin-release, and stress-induced hyperglycemia upon disruption of the Ca(v)2.3 (alpha 1E) subunit of voltage-gated Ca(2+) channels. *Mol Endocrinol* **16**: 884-95 [PMID:11923483]
384. Perez-Reyes E. (2003) Molecular physiology of low-voltage-activated t-type calcium channels. *Physiol Rev* **83**: 117-61 [PMID:12506128]
385. Perez-Reyes E, Cribbs LL, Daud A, Lacerda AE, Barclay J, Williamson MP, Fox M, Rees M and Lee JH. (1998) Molecular characterization of a neuronal low-voltage-activated T-type calcium channel. *Nature* **391**: 896-900 [PMID:9495342]
386. Peterson BZ, DeMaria CD, Adelman JP and Yue DT. (1999) Calmodulin is the Ca<sup>2+</sup> sensor for Ca<sup>2+</sup>-dependent inactivation of L-type calcium channels. *Neuron* **22**: 549-58 [PMID:10197534]
387. Pietrobon D and Striessnig J. (2003) Neurobiology of migraine. *Nat Rev Neurosci* **4**: 386-98 [PMID:12728266]
388. Pignier C and Potreau D. (2000) Characterization of nifedipine-resistant calcium current in neonatal rat ventricular cardiomyocytes. *Am J Physiol Heart Circ Physiol* **279**: H2259-68 [PMID:11045961]
389. Pirone A, Schredelseker J, Tuluc P, Gravino E, Fortunato G, Flucher BE, Carsana A, Salvatore F and Grabner M. (2010) Identification and functional characterization of malignant hyperthermia mutation T1354S in the outer pore of the Cavalpha1S-subunit. *Am J Physiol, Cell Physiol* **299**: C1345-54 [PMID:20861472]
390. Pitt GS. (2007) Calmodulin and CaMKII as molecular switches for cardiac ion channels. *Cardiovasc Res* **73**: 641-7 [PMID:17137569]
391. Pizarro G, Fitts R, Uribe I and Ríos E. (1989) The voltage sensor of excitation-contraction coupling in skeletal muscle. Ion dependence and selectivity. *J Gen Physiol* **94**: 405-28 [PMID:2481710]
392. Platzer J, Engel J, Schrott-Fischer A, Stephan K, Bova S, Chen H, Zheng H and Striessnig J. (2000) Congenital deafness and sinoatrial node dysfunction in mice lacking class D L-type Ca<sup>2+</sup> channels. *Cell* **102**: 89-97 [PMID:10929716]
393. Plummer MR, Logothetis DE and Hess P. (1989) Elementary properties and pharmacological sensitivities of calcium channels in mammalian peripheral neurons. *Neuron* **2**: 1453-63 [PMID:2560643]
394. Polster A, Dittmer PJ, Perni S, Bichraoui H, Sather WA and Beam KG. (2018) Stac Proteins Suppress Ca<sup>2+</sup>-Dependent Inactivation of Neuronal L-type Ca<sup>2+</sup> Channels. *J Neurosci* **38**: 9215-9227 [PMID:30201773]
395. Polster A, Perni S, Bichraoui H and Beam KG. (2015) Stac adaptor proteins regulate trafficking and function of muscle and neuronal L-type Ca<sup>2+</sup> channels. *Proc Natl Acad Sci U S A* **112**: 602-6 [PMID:25548159]
396. Poole-Wilson PA, Lubsen J, Kirwan BA, van Dalen FJ, Wagener G, Danchin N, Just H, Fox KA, Pocock SJ and Clayton TC *et al.*. (2004) Effect of long-acting nifedipine on mortality and cardiovascular morbidity in patients with stable angina requiring treatment (ACTION trial): randomised controlled trial. *Lancet* **364**: 849-57 [PMID:15351192]
397. Prinz H and Striessnig J. (1993) Ligand-induced accelerated dissociation of (+)-cis-diltiazem from L-type Ca<sup>2+</sup> channels is simply explained by competition for individual attachment points. *J Biol Chem* **268**: 18580-5 [PMID:8395510]
398. Ptáček LJ, Tawil R, Griggs RC, Engel AG, Layzer RB, Kwieciński H, McManis PG, Santiago L, Moore M and Fouad G *et al.*. (1994) Dihydropyridine receptor mutations cause hypokalemic periodic paralysis. *Cell* **77**: 863-8 [PMID:8004673]
399. Pérez-Alvarez A, Hernández-Vivanco A, Caba-González JC and Albillos A. (2011) Different roles attributed to Cav1 channel subtypes in spontaneous action potential firing and fine tuning of exocytosis in mouse chromaffin cells. *J Neurochem* **116**: 105-21 [PMID:21054386]
400. Pérez-Vizcaíno F, Tamargo J, Hof RP and Rüegg UT. (1993) Vascular selectivity of seven prototype calcium antagonists: a study at the single cell level. *J Cardiovasc Pharmacol* **22**: 768-75 [PMID:7506331]
401. Qin N, Yagel S, Momplaisir ML, Codd EE and D'Andrea MR. (2002) Molecular cloning and



- characterization of the human voltage-gated calcium channel  $\alpha(2)\delta$ -4 subunit. *Mol Pharmacol* **62**: 485-96 [PMID:12181424]
402. Qu Y, Baroudi G, Yue Y and Boutjdir M. (2005) Novel molecular mechanism involving  $\alpha$ 1D (Cav1.3) L-type calcium channel in autoimmune-associated sinus bradycardia. *Circulation* **111**: 3034-41 [PMID:15939813]
403. Qu Y, Baroudi G, Yue Y, El-Sherif N and Boutjdir M. (2005) Localization and modulation of  $\alpha$ 1D (Cav1.3) L-type Ca channel by protein kinase A. *Am J Physiol Heart Circ Physiol* **288**: H2123-30 [PMID:15615842]
404. Ramachandran KV, Hennessey JA, Barnett AS, Yin X, Stadt HA, Foster E, Shah RA, Yazawa M, Dolmetsch RE and Kirby ML *et al.*. (2013) Calcium influx through L-type CaV1.2 Ca<sup>2+</sup> channels regulates mandibular development. *J Clin Invest* **123**: 1638-46 [PMID:23549079]
405. Ramakrishnan NA, Drescher MJ and Drescher DG. (2009) Direct interaction of otoferlin with syntaxin 1A, SNAP-25, and the L-type voltage-gated calcium channel Cav1.3. *J Biol Chem* **284**: 1364-72 [PMID:19004828]
406. Randall A and Tsien RW. (1995) Pharmacological dissection of multiple types of Ca<sup>2+</sup> channel currents in rat cerebellar granule neurons. *J Neurosci* **15**: 2995-3012 [PMID:7722641]
407. Randall AD and Tsien RW. (1997) Contrasting biophysical and pharmacological properties of T-type and R-type calcium channels. *Neuropharmacology* **36**: 879-93 [PMID:9257934]
408. Regan LJ, Sah DW and Bean BP. (1991) Ca<sup>2+</sup> channels in rat central and peripheral neurons: high-threshold current resistant to dihydropyridine blockers and omega-conotoxin. *Neuron* **6**: 269-80 [PMID:1847065]
409. Regehr WG and Mintz IM. (1994) Participation of multiple calcium channel types in transmission at single climbing fiber to Purkinje cell synapses. *Neuron* **12**: 605-13 [PMID:8155322]
410. Restituito S, Thompson RM, Eliet J, Raike RS, Riedl M, Charnet P and Gomez CM. (2000) The polyglutamine expansion in spinocerebellar ataxia type 6 causes a beta subunit-specific enhanced activation of P/Q-type calcium channels in *Xenopus* oocytes. *J Neurosci* **20**: 6394-403 [PMID:10964945]
411. Rettig J, Sheng ZH, Kim DK, Hodson CD, Snutch TP and Catterall WA. (1996) Isoform-specific interaction of the  $\alpha$ 1A subunits of brain Ca<sup>2+</sup> channels with the presynaptic proteins syntaxin and SNAP-25. *Proc Natl Acad Sci U S A* **93**: 7363-8 [PMID:8692999]
412. Reuter H. (1979) Properties of two inward membrane currents in the heart. *Annu Rev Physiol* **41**: 413-24 [PMID:373598]
413. Reuter H. (1983) Calcium channel modulation by neurotransmitters, enzymes and drugs. *Nature* **301**: 569-74 [PMID:6131381]
414. Richards KS, Swensen AM, Lipscombe D and Bommert K. (2007) Novel CaV2.1 clone replicates many properties of Purkinje cell CaV2.1 current. *Eur J Neurosci* **26**: 2950-61 [PMID:18001290]
415. Ridgeway B, Wallace M and Gerayli A. (2000) Ziconotide for the treatment of severe spasticity after spinal cord injury. *Pain* **85**: 287-9 [PMID:10692630]
416. Rijkers K, Mescheriakova J, Majoie M, Lemmens E, van Wijk X, Philippens M, Van Kranen-Mastenbroek V, Schijns O, Vles J and Hoogland G. (2010) Polymorphisms in CACNA1E and Camk2d are associated with seizure susceptibility of Sprague-Dawley rats. *Epilepsy Res* **91**: 28-34 [PMID:20638246]
417. Robert V, Triffaux E, Paulet PE, Guéry JC, Pelletier L and Savignac M. (2014) Protein kinase C-dependent activation of CaV1.2 channels selectively controls human TH2-lymphocyte functions. *J Allergy Clin Immunol* **133**: 1175-83 [PMID:24365142]
418. Romaniello R, Zucca C, Tonelli A, Bonato S, Baschiroto C, Zanotta N, Epifanio R, Righini A, Bresolin N and Bassi MT *et al.*. (2010) A wide spectrum of clinical, neurophysiological and neuroradiological abnormalities in a family with a novel CACNA1A mutation. *J Neurol Neurosurg Psychiatr* **81**: 840-3 [PMID:20682717]
419. Rosa N, Triffaux E, Robert V, Mars M, Klein M, Bouchaud G, Canivet A, Magnan A, Guéry JC and Pelletier L *et al.*. (2018) The  $\beta$  and  $\alpha$ 2 $\delta$  auxiliary subunits of voltage-gated calcium channel 1 (Ca<sub>v</sub>1) are required for T<sub>H</sub>2 lymphocyte function and acute allergic airway inflammation. *J Allergy Clin Immunol* **142**: 892-903.e8 [PMID:29129580]
420. Roubertie A, Echenne B, Leydet J, Soete S, Krams B, Rivier F, Riant F and Tournier-Lasserre E. (2008) Benign paroxysmal tonic upgaze, benign paroxysmal torticollis, episodic ataxia and CACNA1A mutation in a family. *J Neurol* **255**: 1600-2 [PMID:18758887]
421. Ruth P, Röhrkasten A, Biel M, Bosse E, Regulla S, Meyer HE, Flockerzi V and Hofmann F. (1989) Primary structure of the beta subunit of the DHP-sensitive calcium channel from skeletal muscle. *Science* **245**: 1115-8 [PMID:2549640]
422. Ríos E, Pizarro G and Stefani E. (1992) Charge movement and the nature of signal transduction in skeletal muscle excitation-contraction coupling. *Annu Rev Physiol* **54**: 109-33 [PMID:1562172]
423. Saegusa H, Kurihara T, Zong S, Kazuno A, Matsuda Y, Nonaka T, Han W, Toriyama H and Tanabe T. (2001) Suppression of inflammatory and neuropathic pain symptoms in mice lacking the N-type Ca<sup>2+</sup> channel. *EMBO J* **20**: 2349-56 [PMID:11350923]

424. Saegusa H, Kurihara T, Zong S, Minowa O, Kazuno A, Han W, Matsuda Y, Yamanaka H, Osanai M and Noda T *et al.*. (2000) Altered pain responses in mice lacking alpha 1E subunit of the voltage-dependent Ca<sup>2+</sup> channel. *Proc Natl Acad Sci USA* **97**: 6132-7 [PMID:10801976]
425. Safa P, Boulter J and Hales TG. (2001) Functional properties of Cav1.3 (alpha1D) L-type Ca<sup>2+</sup> channel splice variants expressed by rat brain and neuroendocrine GH3 cells. *J Biol Chem* **276**: 38727-37 [PMID:11514547]
426. Santi CM, Cayabyab FS, Sutton KG, McRory JE, Mezeyova J, Hamming KS, Parker D, Stea A and Snutch TP. (2002) Differential inhibition of T-type calcium channels by neuroleptics. *J Neurosci* **22**: 396-403 [PMID:11784784]
427. Schierberl K, Giordano T, Satpute S, Hao J, Kaur G, Hofmann F, Moosmang S, Striessnig J and Rajadhyaksha A. (2012) Cav 1.3 L-type Ca ( 2+) channels mediate long-term adaptation in dopamine D2L-mediated GluA1 trafficking in the dorsal striatum following cocaine exposure. *Channels (Austin)* **6**: 11-7 [PMID:22419037]
428. Schneider T, Wei X, Olcese R, Costantin JL, Neely A, Palade P, Perez-Reyes E, Qin N, Zhou J and Crawford GD. (1994) Molecular analysis and functional expression of the human type E neuronal Ca<sup>2+</sup> channel alpha 1 subunit. *Recept Channels* **2**: 255-70 [PMID:7536609]
429. Scholl UI, Goh G, Stölting G, de Oliveira RC, Choi M, Overton JD, Fonseca AL, Korah R, Starker LF and Kunstman JW *et al.*. (2013) Somatic and germline CACNA1D calcium channel mutations in aldosterone-producing adenomas and primary aldosteronism. *Nat Genet* **45**: 1050-4 [PMID:23913001]
430. Scholl UI, Stölting G, Nelson-Williams C, Vichot AA, Choi M, Loring E, Prasad ML, Goh G, Carling T and Juhlin CC *et al.*. (2015) Recurrent gain of function mutation in calcium channel CACNA1H causes early-onset hypertension with primary aldosteronism. *Elife* **4**: e06315 [PMID:25907736]
431. Scholze A, Plant TD, Dolphin AC and Nürnberg B. (2001) Functional expression and characterization of a voltage-gated CaV1.3 (alpha1D) calcium channel subunit from an insulin-secreting cell line. *Mol Endocrinol* **15**: 1211-21 [PMID:11435619]
432. Schrauwen I, Helfmann S, Inagaki A, Predoehl F, Tabatabaiefar MA, Picher MM, Sommen M, Seco CZ, Oostrik J and Kremer H *et al.*. (2012) A mutation in CABP2, expressed in cochlear hair cells, causes autosomal-recessive hearing impairment. *Am J Hum Genet* **91**: 636-45 [PMID:22981119]
433. Schrier AD, Wang H, Talley EM, Perez-Reyes E and Barrett PQ. (2001) alpha1H T-type Ca<sup>2+</sup> channel is the predominant subtype expressed in bovine and rat zona glomerulosa. *Am J Physiol, Cell Physiol* **280**: C265-72 [PMID:11208520]
434. Schulla V, Renström E, Feil R, Feil S, Franklin I, Gjinovci A, Jing XJ, Laux D, Lundquist I and Magnuson MA *et al.*. (2003) Impaired insulin secretion and glucose tolerance in beta cell-selective Ca(v)1.2 Ca<sup>2+</sup> channel null mice. *EMBO J* **22**: 3844-54 [PMID:12881419]
435. Schultz D, Mikala G, Yatani A, Engle DB, Iles DE, Segers B, Sinke RJ, Weghuis DO, Klöckner U and Wakamori M *et al.*. (1993) Cloning, chromosomal localization, and functional expression of the alpha 1 subunit of the L-type voltage-dependent calcium channel from normal human heart. *Proc Natl Acad Sci USA* **90**: 6228-32 [PMID:8392192]
436. Schwinger RH, Hoischen S, Reuter H and Hullin R. (1999) Regional expression and functional characterization of the L-type Ca<sup>2+</sup>-channel in myocardium from patients with end-stage heart failure and in non-failing human hearts. *J Mol Cell Cardiol* **31**: 283-96 [PMID:10072735]
437. Scott VE, De Waard M, Liu H, Gurnett CA, Venzke DP, Lennon VA and Campbell KP. (1996) Beta subunit heterogeneity in N-type Ca<sup>2+</sup> channels. *J Biol Chem* **271**: 3207-12 [PMID:8621722]
438. Seino S, Chen L, Seino M, Blondel O, Takeda J, Johnson JH and Bell GI. (1992) Cloning of the alpha 1 subunit of a voltage-dependent calcium channel expressed in pancreatic beta cells. *Proc Natl Acad Sci USA* **89**: 584-8 [PMID:1309948]
439. Seisenberger C, Specht V, Welling A, Platzer J, Pfeifer A, Kühbandner S, Striessnig J, Klugbauer N, Feil R and Hofmann F. (2000) Functional embryonic cardiomyocytes after disruption of the L-type alpha1C (Cav1.2) calcium channel gene in the mouse. *J Biol Chem* **275**: 39193-9 [PMID:10973973]
440. Semenova NA, Ryzhkova OR, Strokova TV and Taran NN. (2018) [The third case report a patient with primary aldosteronism, seizures, and neurologic abnormalities (PASNA) syndrome de novo variant mutations in the CACNA1D gene]. *Zh Nevrol Psikhiatr Im S S Korsakova* **118**: 49-52 [PMID:30698561]
441. Shaltiel L, Pappazios C, Fenske S, Hassan S, Gruner C, Rötzer K, Biel M and Wahl-Schott CA. (2012) Complex regulation of voltage-dependent activation and inactivation properties of retinal voltage-gated Cav1.4 L-type Ca<sup>2+</sup> channels by Ca<sup>2+</sup>-binding protein 4 (CaBP4). *J Biol Chem* **287**: 36312-21 [PMID:22936811]
442. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
443. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286

444. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
445. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
446. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
447. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
448. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
449. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
450. Shcheglovitov AK, Boldyrev AI, Lyubanova OP, Shuba YM and . (2005) Peculiarities of selectivity of three subtypes of low-threshold T-type calcium channels. *Neurophysiology* **37**: 277-286
451. Shen Y, Yu D, Hiel H, Liao P, Yue DT, Fuchs PA and Soong TW. (2006) Alternative splicing of the Ca(v)1.3 channel IQ domain, a molecular switch for Ca<sup>2+</sup>-dependent inactivation within auditory hair cells. *J Neurosci* **26**: 10690-9 [PMID:17050708]
452. Shi L, Jian K, Ko ML, Trump D and Ko GY. (2009) Retinoschisin, a new binding partner for L-type voltage-gated calcium channels in the retina. *J Biol Chem* **284**: 3966-75 [PMID:19074145]
453. Shimizu M, Ogawa K, Sasaki H, Uehara Y, Otsuka Y, Okumura H, Kusaka M, Hasuda T, Yamada T and Mochizuki S. (2003) Effects of efonidipine, an L- and T-Type dual calcium channel blocker, on heart rate and blood pressure in patients with mild to severe hypertension: an uncontrolled, open-label pilot study. *Curr Ther Res Clin Exp* **64**: 707-14 [PMID:24944418]
454. Sidach SS and Mintz IM. (2002) Kurtoxin, a gating modifier of neuronal high- and low-threshold Ca channels. *J Neurosci* **22**: 2023-34 [PMID:11896142]
455. Singh A, Gebhart M, Fritsch R, Sinnegger-Brauns MJ, Poggiani C, Hoda JC, Engel J, Romanin C, Striessnig J and Koschak A. (2008) Modulation of voltage- and Ca<sup>2+</sup>-dependent gating of CaV1.3 L-type calcium channels by alternative splicing of a C-terminal regulatory domain. *J Biol Chem* **283**: 20733-44 [PMID:18482979]
456. Singh A, Hamedinger D, Hoda JC, Gebhart M, Koschak A, Romanin C and Striessnig J. (2006) C-terminal modulator controls Ca<sup>2+</sup>-dependent gating of Ca(v)1.4 L-type Ca<sup>2+</sup> channels. *Nat Neurosci* **9**: 1108-16 [PMID:16921373]
457. Sinnegger-Brauns MJ, Hetzenauer A, Huber IG, Renström E, Wietzorrek G, Berjukov S, Cavalli M, Walter D, Koschak A and Waldschütz R *et al.*. (2004) Isoform-specific regulation of mood behavior and pancreatic beta cell and cardiovascular function by L-type Ca<sup>2+</sup> channels. *J Clin Invest* **113**: 1430-9 [PMID:15146240]
458. Sinnegger-Brauns MJ, Huber IG, Koschak A, Wild C, Obermair GJ, Einzinger U, Hoda JC, Sartori SB and Striessnig J. (2009) Expression and 1,4-dihydropyridine-binding properties of brain L-type calcium channel isoforms. *Mol Pharmacol* **75**: 407-14 [PMID:19029287]
459. Siwek ME, Müller R, Henseler C, Broich K, Papazoglou A and Weiergräber M. (2014) The CaV2.3 R-type voltage-gated Ca<sup>2+</sup> channel in mouse sleep architecture. *Sleep* **37**: 881-92 [PMID:24790266]
460. Sluka KA. (1997) Blockade of calcium channels can prevent the onset of secondary hyperalgesia and allodynia induced by intradermal injection of capsaicin in rats. *Pain* **71**: 157-64 [PMID:9211477]
461. Sluka KA. (1998) Blockade of N- and P/Q-type calcium channels reduces the secondary heat hyperalgesia induced by acute inflammation. *J Pharmacol Exp Ther* **287**: 232-7 [PMID:9765342]
462. Smith MT, Cabot PJ, Ross FB, Robertson AD and Lewis RJ. (2002) The novel N-type calcium channel blocker, AM336, produces potent dose-dependent antinociception after intrathecal dosing in rats and inhibits substance P release in rat spinal cord slices. *Pain* **96**: 119-27 [PMID:11932068]
463. Snutch TP, Leonard JP, Gilbert MM, Lester HA and Davidson N. (1990) Rat brain expresses a heterogeneous family of calcium channels. *Proc Natl Acad Sci USA* **87**: 3391-3395 [PMID:1692134]
464. Sochivko D, Pereverzev A, Smyth N, Gissel C, Schneider T and Beck H. (2002) The Ca(V)2.3 Ca(2+) channel subunit contributes to R-type Ca(2+) currents in murine hippocampal and neocortical neurones. *J Physiol (Lond.)* **542**: 699-710 [PMID:12154172]
465. Soldatov NM, Zühlke RD, Bouron A and Reuter H. (1997) Molecular structures involved in L-type calcium channel inactivation. Role of the carboxyl-terminal region encoded by exons 40-42 in alpha1C subunit in the kinetics and Ca<sup>2+</sup> dependence of inactivation. *J Biol Chem* **272**: 3560-6 [PMID:9013606]
466. Song H, Nie L, Rodriguez-Contreras A, Sheng ZH and Yamoah EN. (2003) Functional interaction of auxiliary subunits and synaptic proteins with Ca(v)1.3 may impart hair cell Ca<sup>2+</sup> current properties. *J Neurophysiol* **89**: 1143-9 [PMID:12574487]
467. Soong TW, DeMaria CD, Alvania RS, Zweifel LS, Liang MC, Mittman S, Agnew WS and Yue DT.



- (2002) Systematic identification of splice variants in human P/Q-type channel  $\alpha 1(2.1)$  subunits: implications for current density and  $\text{Ca}^{2+}$ -dependent inactivation. *J Neurosci* **22**: 10142-52 [PMID:12451115]
468. Soong TW, Stea A, Hodson CD, Dubel SJ, Vincent SR and Snutch TP. (1993) Structure and functional expression of a member of the low voltage-activated calcium channel family. *Science* **260**: 1133-6 [PMID:8388125]
469. Spacey SD, Hildebrand ME, Materek LA, Bird TD and Snutch TP. (2004) Functional implications of a novel EA2 mutation in the P/Q-type calcium channel. *Ann Neurol* **56**: 213-20 [PMID:15293273]
470. Spacey SD, Materek LA, Szczygielski BI and Bird TD. (2005) Two novel CACNA1A gene mutations associated with episodic ataxia type 2 and interictal dystonia. *Arch Neurol* **62**: 314-6 [PMID:15710862]
471. Splawski I, Timothy KW, Decher N, Kumar P, Sachse FB, Beggs AH, Sanguinetti MC and Keating MT. (2005) Severe arrhythmia disorder caused by cardiac L-type calcium channel mutations. *Proc Natl Acad Sci USA* **102**: 8089-8096; discussion 8086-8088 [PMID:15863612]
472. Splawski I, Timothy KW, Sharpe LM, Decher N, Kumar P, Bloise R, Napolitano C, Schwartz PJ, Joseph RM and Condouris K *et al.*. (2004)  $\text{Ca}(V)1.2$  calcium channel dysfunction causes a multisystem disorder including arrhythmia and autism. *Cell* **119**: 19-31 [PMID:15454078]
473. Splawski I, Yoo DS, Stotz SC, Cherry A, Clapham DE and Keating MT. (2006) CACNA1H mutations in autism spectrum disorders. *J Biol Chem* **281**: 22085-91 [PMID:16754686]
474. Staats PS, Yearwood T, Charapata SG, Presley RW, Wallace MS, Byas-Smith M, Fisher R, Bryce DA, Mangieri EA and Luther RR *et al.*. (2004) Intrathecal ziconotide in the treatment of refractory pain in patients with cancer or AIDS: a randomized controlled trial. *JAMA* **291**: 63-70 [PMID:14709577]
475. Stam AH, Vanmolkot KR, Kremer HP, Gärtner J, Brown J, Leshinsky-Silver E, Gilad R, Kors EE, Frankhuizen WS and Ginjaar HB *et al.*. (2008) CACNA1A R1347Q: a frequent recurrent mutation in hemiplegic migraine. *Clin Genet* **74**: 481-5 [PMID:18400034]
476. Starr TV, Prystay W and Snutch TP. (1991) Primary structure of a calcium channel that is highly expressed in the rat cerebellum. *Proc Natl Acad Sci USA* **88**: 5621-5 [PMID:1648226]
477. Stea A, Dubel SJ and Snutch TP. (1999)  $\alpha 1B$  N-type calcium channel isoforms with distinct biophysical properties. *Ann N Y Acad Sci* **868**: 118-30 [PMID:10414290]
478. Stea A, Tomlinson WJ, Soong TW, Bourinet E, Dubel SJ, Vincent SR and Snutch TP. (1994) Localization and functional properties of a rat brain  $\alpha 1A$  calcium channel reflect similarities to neuronal Q- and P-type channels. *Proc Natl Acad Sci USA* **91**: 10576-80 [PMID:7524096]
479. Stockner T and Koschak A. (2013) What can naturally occurring mutations tell us about  $\text{Ca}(v)1.x$  channel function? *Biochim Biophys Acta* **1828**: 1598-607 [PMID:23219801]
480. Stokes L, Gordon J and Grafton G. (2004) Non-voltage-gated L-type  $\text{Ca}^{2+}$  channels in human T cells: pharmacology and molecular characterization of the major  $\alpha$  pore-forming and auxiliary  $\beta$ -subunits. *J Biol Chem* **279**: 19566-73 [PMID:14981074]
481. Strauss O, Buss F, Rosenthal R, Fischer D, Mergler S, Stumpff F and Thieme H. (2000) Activation of neuroendocrine L-type channels ( $\alpha 1D$  subunits) in retinal pigment epithelial cells and brain neurons by pp60(c-src). *Biochem Biophys Res Commun* **270**: 806-10 [PMID:10772906]
482. Striessnig J. (1999) Pharmacology, structure and function of cardiac L-type  $\text{Ca}(2+)$  channels. *Cell Physiol Biochem* **9**: 242-69 [PMID:10575201]
483. Striessnig J, Bolz HJ and Koschak A. (2010) Channelopathies in Cav1.1, Cav1.3, and Cav1.4 voltage-gated L-type  $\text{Ca}^{2+}$  channels. *Pflugers Arch* **460**: 361-74 [PMID:20213496]
484. Striessnig J, Hoda JC, Koschak A, Zaghetto F, Müllner C, Sinnegger-Brauns MJ, Wild C, Watschinger K, Trockenbacher A and Pelster G. (2004) L-type  $\text{Ca}^{2+}$  channels in  $\text{Ca}^{2+}$  channelopathies. *Biochem Biophys Res Commun* **322**: 1341-6 [PMID:15336981]
485. Strom TM, Nyakatura G, Apfelstedt-Sylla E, Hellebrand H, Lorenz B, Weber BH, Wutz K, Gutwillinger N, Rüther K and Drescher B *et al.*. (1998) An L-type calcium-channel gene mutated in incomplete X-linked congenital stationary night blindness. *Nat Genet* **19**: 260-3 [PMID:9662399]
486. Sutton KG, Siok C, Stea A, Zamponi GW, Heck SD, Volkmann RA, Ahlijanian MK and Snutch TP. (1998) Inhibition of neuronal calcium channels by a novel peptide spider toxin, DW13.3. *Mol Pharmacol* **54**: 407-18 [PMID:9687583]
487. Swensen AM, Herrington J, Bugianesi RM, Dai G, Haedo RJ, Ratliff KS, Smith MM, Warren VA, Arneric SP and Eduljee C *et al.*. (2012) Characterization of the substituted N-triazole oxindole TROX-1, a small-molecule, state-dependent inhibitor of  $\text{Ca}(V)2$  calcium channels. *Mol Pharmacol* **81**: 488-97 [PMID:22188924]
488. Takahara A. (2009) Cilnidipine: a new generation  $\text{Ca}$  channel blocker with inhibitory action on sympathetic neurotransmitter release. *Cardiovasc Ther* **27**: 124-39 [PMID:19426250]
489. Takahashi M, Seagar MJ, Jones JF, Reber BF and Catterall WA. (1987) Subunit structure of dihydropyridine-sensitive calcium channels from skeletal muscle. *Proc Natl Acad Sci U S A* **84**:



- 5478-5482 [PMID:2440051]
490. Takahashi T and Momiyama A. (1993) Different types of calcium channels mediate central synaptic transmission. *Nature* **366**: 156-8 [PMID:7901765]
491. Takahashi Y, Jeong SY, Ogata K, Goto J, Hashida H, Isahara K, Uchiyama Y and Kanazawa I. (2003) Human skeletal muscle calcium channel alpha1S is expressed in the basal ganglia: distinctive expression pattern among L-type Ca<sup>2+</sup> channels. *Neurosci Res* **45**: 129-37 [PMID:12507731]
492. Talley EM, Cribbs LL, Lee JH, Daud A, Perez-Reyes E and Bayliss DA. (1999) Differential distribution of three members of a gene family encoding low voltage-activated (T-type) calcium channels. *J Neurosci* **19**: 1895-911 [PMID:10066243]
493. Talley EM, Solórzano G, Depaulis A, Perez-Reyes E and Bayliss DA. (2000) Low-voltage-activated calcium channel subunit expression in a genetic model of absence epilepsy in the rat. *Brain Res Mol Brain Res* **75**: 159-65 [PMID:10648900]
494. Tan BZ, Jiang F, Tan MY, Yu D, Huang H, Shen Y and Soong TW. (2011) Functional characterization of alternative splicing in the C terminus of L-type CaV1.3 channels. *J Biol Chem* **286**: 42725-35 [PMID:21998309]
495. Tanabe T, Beam KG, Powell JA and Numa S. (1988) Restoration of excitation-contraction coupling and slow calcium current in dysgenic muscle by dihydropyridine receptor complementary DNA. *Nature* **336**: 134-9 [PMID:2903448]
496. Tang L, Gamal El-Din TM, Lenaeus MJ, Zheng N and Catterall WA. (2019) Structural Basis for Diltiazem Block of a Voltage-Gated Ca<sup>2+</sup> Channel. *Mol Pharmacol* **96**: 485-492 [PMID:31391290]
497. Tang L, Gamal El-Din TM, Payandeh J, Martinez GQ, Heard TM, Scheuer T, Zheng N and Catterall WA. (2014) Structural basis for Ca<sup>2+</sup> selectivity of a voltage-gated calcium channel. *Nature* **505**: 56-61 [PMID:24270805]
498. Tang L, Gamal El-Din TM, Swanson TM, Pryde DC, Scheuer T, Zheng N and Catterall WA. (2016) Structural basis for inhibition of a voltage-gated Ca<sup>2+</sup> channel by Ca<sup>2+</sup> antagonist drugs. *Nature* **537**: 117-121 [PMID:27556947]
499. Tang ZZ, Yarotsky V, Wei L, Sobczak K, Nakamori M, Eichinger K, Moxley RT, Dirksen RT and Thornton CA. (2012) Muscle weakness in myotonic dystrophy associated with misregulated splicing and altered gating of Ca(V)1.1 calcium channel. *Hum Mol Genet* **21**: 1312-24 [PMID:22140091]
500. Tarabova B, Lacinova L and Engel J. (2007) Effects of phenylalkylamines and benzothiazepines on Ca(v)1.3-mediated Ca<sup>2+</sup> currents in neonatal mouse inner hair cells. *Eur J Pharmacol* **573**: 39-48 [PMID:17651721]
501. Thomsen MB, Wang C, Ozgen N, Wang HG, Rosen MR and Pitt GS. (2009) Accessory subunit KChIP2 modulates the cardiac L-type calcium current. *Circ Res* **104**: 1382-9 [PMID:19461043]
502. Tippens AL and Lee A. (2007) Caldendrin, a neuron-specific modulator of Cav/1.2 (L-type) Ca<sup>2+</sup> channels. *J Biol Chem* **282**: 8464-73 [PMID:17224447]
503. Tiwari S, Zhang Y, Heller J, Abernethy DR and Soldatov NM. (2006) Atherosclerosis-related molecular alteration of the human CaV1.2 calcium channel alpha1C subunit. *Proc Natl Acad Sci USA* **103**: 17024-9 [PMID:17071743]
504. Tonelli A, D'Angelo MG, Salati R, Villa L, Germinasi C, Frattini T, Meola G, Turconi AC, Bresolin N and Bassi MT. (2006) Early onset, non fluctuating spinocerebellar ataxia and a novel missense mutation in CACNA1A gene. *J Neurol Sci* **241**: 13-7 [PMID:16325861]
505. Toppin PJ, Chandu TT, Ghanekar A, Kraeva N, Beattie WS and Riaz S. (2010) A report of fulminant malignant hyperthermia in a patient with a novel mutation of the CACNA1S gene. *Can J Anaesth* **57**: 689-93 [PMID:20431982]
506. Toru S, Murakoshi T, Ishikawa K, Saegusa H, Fujigasaki H, Uchihara T, Nagayama S, Osanai M, Mizusawa H and Tanabe T. (2000) Spinocerebellar ataxia type 6 mutation alters P-type calcium channel function. *J Biol Chem* **275**: 10893-8 [PMID:10753886]
507. Tottene A, Fellin T, Pagnutti S, Luvisetto S, Striessnig J, Fletcher C and Pietrobon D. (2002) Familial hemiplegic migraine mutations increase Ca(2+) influx through single human CaV2.1 channels and decrease maximal CaV2.1 current density in neurons. *Proc Natl Acad Sci USA* **99**: 13284-9 [PMID:12235360]
508. Tottene A, Pivotto F, Fellin T, Cesetti T, van den Maagdenberg AM and Pietrobon D. (2005) Specific kinetic alterations of human CaV2.1 calcium channels produced by mutation S218L causing familial hemiplegic migraine and delayed cerebral edema and coma after minor head trauma. *J Biol Chem* **280**: 17678-86 [PMID:15743764]
509. Tottene A, Volsen S and Pietrobon D. (2000) alpha(1E) subunits form the pore of three cerebellar R-type calcium channels with different pharmacological and permeation properties. *J Neurosci* **20**: 171-8 [PMID:10627594]
510. Treinys R, Kaselis A, Jover E, Bagnard D and Šatkauskas S. (2014) R-type calcium channels are crucial for semaphorin 3A-induced DRG axon growth cone collapse. *PLoS ONE* **9**: e102357 [PMID:25032951]

511. Tringham E, Powell KL, Cain SM, Kuplast K, Mezeyova J, Weerapura M, Eduljee C, Jiang X, Smith P and Morrison JL *et al.*. (2012) T-type calcium channel blockers that attenuate thalamic burst firing and suppress absence seizures. *Sci Transl Med* **4**: 121ra19 [PMID:22344687]
512. Trombetta M, Bonetti S, Boselli M, Turrini F, Malerba G, Trabetti E, Pignatti P, Bonora E and Bonadonna RC. (2012) CACNA1E variants affect beta cell function in patients with newly diagnosed type 2 diabetes. the Verona newly diagnosed type 2 diabetes study (VNDS) 3. *PLoS ONE* **7**: e32755 [PMID:22427875]
513. Tsakiridou E, Bertollini L, de Curtis M, Avanzini G and Pape HC. (1995) Selective increase in T-type calcium conductance of reticular thalamic neurons in a rat model of absence epilepsy. *J Neurosci* **15**: 3110-7 [PMID:7722649]
514. Tsien RW, Lipscombe D, Madison D, Bley K and Fox A. (1995) Reflections on Ca(2+)-channel diversity, 1988-1994. *Trends Neurosci* **18**: 52-4 [PMID:7537405]
515. Tsunemi T, Saegusa H, Ishikawa K, Nagayama S, Murakoshi T, Mizusawa H and Tanabe T. (2002) Novel Cav2.1 splice variants isolated from Purkinje cells do not generate P-type Ca<sup>2+</sup> current. *J Biol Chem* **277**: 7214-21 [PMID:11756409]
516. Tuluc P, Molenda N, Schlick B, Obermair GJ, Flucher BE and Jurkat-Rott K. (2009) A CaV1.1 Ca<sup>2+</sup> channel splice variant with high conductance and voltage-sensitivity alters EC coupling in developing skeletal muscle. *Biophys J* **96**: 35-44 [PMID:19134469]
517. Turner TJ, Adams ME and Dunlap K. (1992) Calcium channels coupled to glutamate release identified by omega-Aga-IVA. *Science* **258**: 310-3 [PMID:1357749]
518. Turner TJ, Adams ME and Dunlap K. (1993) Multiple Ca<sup>2+</sup> channel types coexist to regulate synaptosomal neurotransmitter release. *Proc Natl Acad Sci USA* **90**: 9518-22 [PMID:8415733]
519. Tzour A, Sosial E, Meir T, Canello T, Naveh-Manly T, Gabizon R and Nussinovitch I. (2013) Multiple pathways for high voltage-activated Ca(2+) influx in anterior pituitary lactotrophs and somatotrophs. *J Neuroendocrinol* **25**: 76-86 [PMID:22882461]
520. Uchitel OD, Protti DA, Sanchez V, Cherksey BD, Sugimori M and Llinás R. (1992) P-type voltage-dependent calcium channel mediates presynaptic calcium influx and transmitter release in mammalian synapses. *Proc Natl Acad Sci USA* **89**: 3330-3 [PMID:1348859]
521. Uebele VN, Nuss CE, Renger JJ and Connolly TM. (2004) Role of voltage-gated calcium channels in potassium-stimulated aldosterone secretion from rat adrenal zona glomerulosa cells. *J Steroid Biochem Mol Biol* **92**: 209-18 [PMID:15555914]
522. Vaeth M and Feske S. (2018) Ion channelopathies of the immune system. *Curr Opin Immunol* **52**: 39-50 [PMID:29635109]
523. Vahedi K, Denier C, Ducros A, Bousson V, Levy C, Chabriat H, Haguenau M, Tournier-Lasserre E and Boussier MG. (2000) CACNA1A gene de novo mutation causing hemiplegic migraine, coma, and cerebellar atrophy. *Neurology* **55**: 1040-2 [PMID:11061267]
524. Vajna R, Schramm M, Pereverzev A, Arnhold S, Grabsch H, Klöckner U, Perez-Reyes E, Hescheler J and Schneider T. (1998) New isoform of the neuronal Ca<sup>2+</sup> channel alpha1E subunit in islets of Langerhans and kidney--distribution of voltage-gated Ca<sup>2+</sup> channel alpha1 subunits in cell lines and tissues. *Eur J Biochem* **257**: 274-85 [PMID:9799129]
525. Valence S, Cochet E, Rougeot C, Garel C, Chantot-Bastarud S, Lainey E, Afenjar A, Barthez MA, Bednarek N and Doummar D *et al.*. (2019) Exome sequencing in congenital ataxia identifies two new candidate genes and highlights a pathophysiological link between some congenital ataxias and early infantile epileptic encephalopathies. *Genet Med* **21**: 553-563 [PMID:29997391]
526. van den Maagdenberg AM, Kors EE, Brunt ER, van Paesschen W, Pascual J, Ravine D, Keeling S, Vanmolkot KR, Vermeulen FL and Terwindt GM *et al.*. (2002) Episodic ataxia type 2. Three novel truncating mutations and one novel missense mutation in the CACNA1A gene. *J Neurol* **249**: 1515-9 [PMID:12420090]
527. van den Maagdenberg AM, Pietrobon D, Pizzorusso T, Kaja S, Broos LA, Cesetti T, van de Ven RC, Tottene A, van der Kaa J and Plomp JJ *et al.*. (2004) A Cacna1a knockin migraine mouse model with increased susceptibility to cortical spreading depression. *Neuron* **41**: 701-10 [PMID:15003170]
528. Vandael DH, Zuccotti A, Striessnig J and Carbone E. (2012) Ca(V)1.3-driven SK channel activation regulates pacemaking and spike frequency adaptation in mouse chromaffin cells. *J Neurosci* **32**: 16345-59 [PMID:23152617]
529. Venance SL, Cannon SC, Fialho D, Fontaine B, Hanna MG, Ptacek LJ, Tristani-Firouzi M, Tawil R, Griggs RC and CINCH investigators. (2006) The primary periodic paralyses: diagnosis, pathogenesis and treatment. *Brain* **129**: 8-17 [PMID:16195244]
530. Vieira LB, Kushmerick C, Hildebrand ME, Garcia E, Stea A, Cordeiro MN, Richardson M, Gomez MV and Snutch TP. (2005) Inhibition of high voltage-activated calcium channels by spider toxin PnTx3-6. *J Pharmacol Exp Ther* **314**: 1370-7 [PMID:15933156]
531. Vignali S, Leiss V, Karl R, Hofmann F and Welling A. (2006) Characterization of voltage-dependent sodium and calcium channels in mouse pancreatic A- and B-cells. *J Physiol (Lond.)* **572**: 691-706 [PMID:16513675]
532. Vila-Pueyo M, Gené GG, Flotats-Bastardes M, Elorza X, Sintas C, Valverde MA, Cormand B,

- Fernández-Fernández JM and Macaya A. (2014) A loss-of-function CACNA1A mutation causing benign paroxysmal torticollis of infancy. *Eur J Paediatr Neurol* **18**: 430-3 [PMID:24445160]
533. Vitko I, Chen Y, Arias JM, Shen Y, Wu XR and Perez-Reyes E. (2005) Functional characterization and neuronal modeling of the effects of childhood absence epilepsy variants of CACNA1H, a T-type calcium channel. *J Neurosci* **25**: 4844-55 [PMID:15888660]
534. Wahl-Schott C, Baumann L, Cuny H, Eckert C, Griessmeier K and Biel M. (2006) Switching off calcium-dependent inactivation in L-type calcium channels by an autoinhibitory domain. *Proc Natl Acad Sci USA* **103**: 15657-62 [PMID:17028172]
535. Wallace SJ. (1986) Use of ethosuximide and valproate in the treatment of epilepsy. *Neurologic clinics* **4**: 601-16 [PMID:3092003]
536. Walsh KB, Bryant SH and Schwartz A. (1986) Effect of calcium antagonist drugs on calcium currents in mammalian skeletal muscle fibers. *J Pharmacol Exp Ther* **236**: 403-7 [PMID:2418195]
537. Wan J, Khanna R, Sandusky M, Papazian DM, Jen JC and Baloh RW. (2005) CACNA1A mutations causing episodic and progressive ataxia alter channel trafficking and kinetics. *Neurology* **64**: 2090-7 [PMID:15985579]
538. Wang G, Dayanithi G, Newcomb R and Lemos JR. (1999) An R-type Ca(2+) current in neurohypophysial terminals preferentially regulates oxytocin secretion. *J Neurosci* **19**: 9235-41 [PMID:10531427]
539. Wang H, Zhang X, Xue L, Xing J, Jouvin MH, Putney JW, Anderson MP, Trebak M and Kinet JP. (2016) Low-Voltage-Activated CaV3.1 Calcium Channels Shape T Helper Cell Cytokine Profiles. *Immunity* **44**: 782-94 [PMID:27037192]
540. Wang HG, George MS, Kim J, Wang C and Pitt GS. (2007) Ca<sup>2+</sup>/calmodulin regulates trafficking of Ca(V)<sub>1</sub>.2 Ca<sup>2+</sup> channels in cultured hippocampal neurons. *J Neurosci* **27**: 9086-93 [PMID:17715345]
541. Wang Q, Gao Y, Li S, Guo X and Zhang Q. (2012) Mutation screening of TRPM1, GRM6, NYX and CACNA1F genes in patients with congenital stationary night blindness. *Int J Mol Med* **30**: 521-6 [PMID:22735794]
542. Wang S and Cortes CJ. (2021) Interactions with PDZ proteins diversify voltage-gated calcium channel signaling. *J Neurosci Res* **99**: 332-348 [PMID:32476168]
543. Wang X, Gao G, Guo K, Yarotsky V, Huang C, Elmslie KS and Peterson BZ. (2010) Phospholemman modulates the gating of cardiac L-type calcium channels. *Biophys J* **98**: 1149-59 [PMID:20371314]
544. Wang Y, Deng X, Mancarella S, Hendron E, Eguchi S, Soboloff J, Tang XD and Gill DL. (2010) The calcium store sensor, STIM1, reciprocally controls Orai and CaV1.2 channels. *Science* **330**: 105-9 [PMID:20929813]
545. Wang YX, Pettus M, Gao D, Phillips C and Scott Bowersox S. (2000) Effects of intrathecal administration of ziconotide, a selective neuronal N-type calcium channel blocker, on mechanical allodynia and heat hyperalgesia in a rat model of postoperative pain. *Pain* **84**: 151-8 [PMID:10666519]
546. Wappl E, Koschak A, Poteser M, Sinnegger MJ, Walter D, Eberhart A, Groschner K, Glossmann H, Kraus RL and Grabner M *et al.*. (2002) Functional consequences of P/Q-type Ca<sup>2+</sup> channel Cav2.1 missense mutations associated with episodic ataxia type 2 and progressive ataxia. *J Biol Chem* **277**: 6960-6 [PMID:11742003]
547. Watanabe M, Sakuma Y and Kato M. (2004) High expression of the R-type voltage-gated Ca<sup>2+</sup> channel and its involvement in Ca<sup>2+</sup>-dependent gonadotropin-releasing hormone release in GT1-7 cells. *Endocrinology* **145**: 2375-83 [PMID:14736732]
548. Watanabe TX, Itahara Y, Kuroda H, Chen YN, Kimura T and Sakakibara S. (1995) Smooth muscle relaxing and hypotensive activities of synthetic calciseptine and the homologous snake venom peptide FS2. *Jpn J Pharmacol* **68**: 305-13 [PMID:7474554]
549. Wegener JW, Schulla V, Koller A, Klugbauer N, Feil R and Hofmann F. (2006) Control of intestinal motility by the Ca(v)<sub>1</sub>.2 L-type calcium channel in mice. *FASEB J* **20**: 1260-2 [PMID:16636102]
550. Wegener JW, Schulla V, Lee TS, Koller A, Feil S, Feil R, Kleppisch T, Klugbauer N, Moosmang S and Welling A *et al.*. (2004) An essential role of Cav1.2 L-type calcium channel for urinary bladder function. *FASEB J* **18**: 1159-61 [PMID:15132976]
551. Weick JP, Groth RD, Isaksen AL and Mermelstein PG. (2003) Interactions with PDZ proteins are required for L-type calcium channels to activate cAMP response element-binding protein-dependent gene expression. *J Neurosci* **23**: 3446-56 [PMID:12716953]
552. Weiergräber M, Henry M, Radhakrishnan K, Hescheler J and Schneider T. (2007) Hippocampal seizure resistance and reduced neuronal excitotoxicity in mice lacking the Cav2.3 E/R-type voltage-gated calcium channel. *J Neurophysiol* **97**: 3660-9 [PMID:17376845]
553. Weleber RG. (2002) Infantile and childhood retinal blindness: a molecular perspective (The Franceschetti Lecture). *Ophthalmic Genet* **23**: 71-97 [PMID:12187427]
554. Wennemuth G, Westenbroek RE, Xu T, Hille B and Babcock DF. (2000) CaV2.2 and CaV2.3 (N-



- and R-type) Ca<sup>2+</sup> channels in depolarization-evoked entry of Ca<sup>2+</sup> into mouse sperm. *J Biol Chem* **275**: 21210-7 [PMID:10791962]
555. Westenbroek RE and Babcock DF. (1999) Discrete regional distributions suggest diverse functional roles of calcium channel alpha1 subunits in sperm. *Dev Biol* **207**: 457-69 [PMID:10068476]
556. Westenbroek RE, Bausch SB, Lin RC, Franck JE, Noebels JL and Catterall WA. (1998) Upregulation of L-type Ca<sup>2+</sup> channels in reactive astrocytes after brain injury, hypomyelination, and ischemia. *J Neurosci* **18**: 2321-34 [PMID:9502793]
557. Westenbroek RE, Hell JW, Warner C, Dubel SJ, Snutch TP and Catterall WA. (1992) Biochemical properties and subcellular distribution of an N-type calcium channel alpha 1 subunit. *Neuron* **9**: 1099-115 [PMID:1334419]
558. Westenbroek RE, Hoskins L and Catterall WA. (1998) Localization of Ca<sup>2+</sup> channel subtypes on rat spinal motor neurons, interneurons, and nerve terminals. *J Neurosci* **18**: 6319-30 [PMID:9698323]
559. Westenbroek RE, Sakurai T, Elliott EM, Hell JW, Starr TV, Snutch TP and Catterall WA. (1995) Immunohistochemical identification and subcellular distribution of the alpha 1A subunits of brain calcium channels. *J Neurosci* **15**: 6403-18 [PMID:7472404]
560. White JA, McKinney BC, John MC, Powers PA, Kamp TJ and Murphy GG. (2008) Conditional forebrain deletion of the L-type calcium channel Ca<sub>v</sub> 1.2 disrupts remote spatial memories in mice. *Learn Mem* **15**: 1-5 [PMID:18174367]
561. Williams JA, Day M and Heavner JE. (2008) Ziconotide: an update and review. *Expert Opin Pharmacother* **9**: 1575-83 [PMID:18518786]
562. Williams ME, Brust PF, Feldman DH, Patthi S, Simerson S, Maroufi A, McCue AF, Veliçelebi G, Ellis SB and Harpold MM. (1992) Structure and functional expression of an omega-conotoxin-sensitive human N-type calcium channel. *Science* **257**: 389-95 [PMID:1321501]
563. Williams ME, Marubio LM, Deal CR, Hans M, Brust PF, Philipson LH, Miller RJ, Johnson EC, Harpold MM and Ellis SB. (1994) Structure and functional characterization of neuronal alpha 1E calcium channel subtypes. *J Biol Chem* **269**: 22347-57 [PMID:8071363]
564. Williams ME, Washburn MS, Hans M, Urrutia A, Brust PF, Prodanovich P, Harpold MM and Stauderman KA. (1999) Structure and functional characterization of a novel human low-voltage activated calcium channel. *J Neurochem* **72**: 791-9 [PMID:9930755]
565. Willis M, Kaufmann WA, Wietzorrek G, Hutter-Paier B, Moosmang S, Humpel C, Hofmann F, Windisch M, Knaus HG and Marksteiner J. (2010) L-type calcium channel Ca<sub>v</sub> 1.2 in transgenic mice overexpressing human AβetaPP751 with the London (V717I) and Swedish (K670M/N671L) mutations. *J Alzheimers Dis* **20**: 1167-80 [PMID:20413896]
566. Witcher DR, De Waard M and Campbell KP. (1993) Characterization of the purified N-type Ca<sup>2+</sup> channel and the cation sensitivity of omega-conotoxin GVIA binding. *Neuropharmacology* **32**: 1127-39 [PMID:8107967]
567. Wiśniowska B, Mendyk A, Fijorek K, Glinka A and Polak S. (2012) Predictive model for L-type channel inhibition: multichannel block in QT prolongation risk assessment. *J Appl Toxicol* **32**: 858-66 [PMID:22761000]
568. Wu F, Mi W, Hernández-Ochoa EO, Burns DK, Fu Y, Gray HF, Struyk AF, Schneider MF and Cannon SC. (2012) A calcium channel mutant mouse model of hypokalemic periodic paralysis. *J Clin Invest* **122**: 4580-91 [PMID:23187123]
569. Wu J, Yan Z, Li Z, Qian X, Lu S, Dong M, Zhou Q and Yan N. (2016) Structure of the voltage-gated calcium channel Ca<sub>v</sub>(v)1.1 at 3.6 Å resolution. *Nature* **537**: 191-196 [PMID:27580036]
570. Wu J, Yan Z, Li Z, Yan C, Lu S, Dong M and Yan N. (2015) Structure of the voltage-gated calcium channel Cav1.1 complex. *Science* **350**: aad2395 [PMID:26680202]
571. Wu LG, Borst JG and Sakmann B. (1998) R-type Ca<sup>2+</sup> currents evoke transmitter release at a rat central synapse. *Proc Natl Acad Sci USA* **95**: 4720-5 [PMID:9539805]
572. Wu LG and Saggau P. (1995) Block of multiple presynaptic calcium channel types by omega-conotoxin-MV1C at hippocampal CA3 to CA1 synapses. *J Neurophysiol* **73**: 1965-72 [PMID:7623094]
573. Wutz K, Sauer C, Zrenner E, Lorenz B, Alitalo T, Broghammer M, Hergersberg M, de la Chapelle A, Weber BH and Wissinger B *et al.*. (2002) Thirty distinct CACNA1F mutations in 33 families with incomplete type of XLCSNB and Cacna1f expression profiling in mouse retina. *Eur J Hum Genet* **10**: 449-56 [PMID:12111638]
574. Xiang Z, Thompson AD, Brogan JT, Schulte ML, Melancon BJ, Mi D, Lewis LM, Zou B, Yang L and Morrison R *et al.*. (2011) The Discovery and Characterization of ML218: A Novel, Centrally Active T-Type Calcium Channel Inhibitor with Robust Effects in STN Neurons and in a Rodent Model of Parkinson's Disease. *ACS Chem Neurosci* **2**: 730-742 [PMID:22368764]
575. Xie X, Van Deusen AL, Vitko I, Babu DA, Davies LA, Huynh N, Cheng H, Yang N, Barrett PQ and Perez-Reyes E. (2007) Validation of high throughput screening assays against three subtypes of Ca<sub>v</sub>3 T-type channels using molecular and pharmacologic approaches. *Assay Drug Dev Technol* **5**: 191-203 [PMID:17477828]



576. Xu G, Wu H, Du B and Qin L. (2012) The efficacy and safety of cilnidipine on mild to moderate essential hypertension: a systematic review and meta-analysis of randomized controlled trials in Chinese patients. *Cardiovasc Hematol Disord Drug Targets* **12**: 56-62 [PMID:22746347]
577. Xu H, Ginsburg KS, Hall DD, Zimmermann M, Stein IS, Zhang M, Tandan S, Hill JA, Horne MC and Bers D *et al.*. (2010) Targeting of protein phosphatases PP2A and PP2B to the C-terminus of the L-type calcium channel Ca v1.2. *Biochemistry* **49**: 10298-307 [PMID:21053940]
578. Xu M, Welling A, Papparisto S, Hofmann F and Klugbauer N. (2003) Enhanced expression of L-type Cav1.3 calcium channels in murine embryonic hearts from Cav1.2-deficient mice. *J Biol Chem* **278**: 40837-41 [PMID:12900400]
579. Xu W and Lipscombe D. (2001) Neuronal Ca(V)1.3 $\alpha$ (1) L-type channels activate at relatively hyperpolarized membrane potentials and are incompletely inhibited by dihydropyridines. *J Neurosci* **21**: 5944-51 [PMID:11487617]
580. Yang L, Dai DF, Yuan C, Westenbroek RE, Yu H, West N, de la Iglesia HO and Catterall WA. (2016) Loss of  $\beta$ -adrenergic-stimulated phosphorylation of CaV1.2 channels on Ser1700 leads to heart failure. *Proc Natl Acad Sci U S A* **113**: E7976-E7985 [PMID:27864509]
581. Yang T, Puckerin A and Colecraft HM. (2012) Distinct RGK GTPases differentially use  $\alpha$ 1- and auxiliary  $\beta$ -binding-dependent mechanisms to inhibit CaV1.2/CaV2.2 channels. *PLoS ONE* **7**: e37079 [PMID:22590648]
582. Yokoyama K, Kurihara T, Saegusa H, Zong S, Makita K and Tanabe T. (2004) Blocking the R-type (Cav2.3) Ca<sup>2+</sup> channel enhanced morphine analgesia and reduced morphine tolerance. *Eur J Neurosci* **20**: 3516-9 [PMID:15610184]
583. Yu FH and Catterall WA. (2004) The VGL-chanome: a protein superfamily specialized for electrical signaling and ionic homeostasis. *Sci STKE* **2004**: re15 [PMID:15467096]
584. Yu K, Xiao Q, Cui G, Lee A and Hartzell HC. (2008) The best disease-linked Cl<sup>-</sup> channel hBest1 regulates Ca V 1 (L-type) Ca<sup>2+</sup> channels via src-homology-binding domains. *J Neurosci* **28**: 5660-70 [PMID:18509027]
585. Yue Q, Jen JC, Nelson SF and Baloh RW. (1997) Progressive ataxia due to a missense mutation in a calcium-channel gene. *Am J Hum Genet* **61**: 1078-87 [PMID:9345107]
586. Zamponi GW. (2003) Calmodulin lobotomized: novel insights into calcium regulation of voltage-gated calcium channels. *Neuron* **39**: 879-81 [PMID:12971887]
587. Zamponi GW. (2016) Targeting voltage-gated calcium channels in neurological and psychiatric diseases. *Nat Rev Drug Discov* **15**: 19-34 [PMID:26542451]
588. Zamponi GW, Bourinet E and Snutch TP. (1996) Nickel block of a family of neuronal calcium channels: subtype- and subunit-dependent action at multiple sites. *J Membr Biol* **151**: 77-90 [PMID:8661496]
589. Zamponi GW, Feng ZP, Zhang L, Pajouhesh H, Ding Y, Belardetti F, Pajouhesh H, Dolphin D, Mitscher LA and Snutch TP. (2009) Scaffold-based design and synthesis of potent N-type calcium channel blockers. *Bioorg Med Chem Lett* **19**: 6467-72 [PMID:19815411]
590. Zamponi GW and Snutch TP. (1998) Decay of prepulse facilitation of N type calcium channels during G protein inhibition is consistent with binding of a single G $\beta$  subunit. *Proc Natl Acad Sci U S A* **95**: 4035-9 [PMID:9520488]
591. Zamponi GW, Striessnig J, Koschak A and Dolphin AC. (2015) The Physiology, Pathology, and Pharmacology of Voltage-Gated Calcium Channels and Their Future Therapeutic Potential. *Pharmacol Rev* **67**: 821-70 [PMID:26362469]
592. Zeitz C, Labs S, Lorenz B, Forster U, Uksti J, Kroes HY, De Baere E, Leroy BP, Cremers FP and Wittmer M *et al.*. (2009) Genotyping microarray for CSNB-associated genes. *Invest Ophthalmol Vis Sci* **50**: 5919-26 [PMID:19578023]
593. Zeitz C, Minotti R, Feil S, Mátyás G, Cremers FP, Hoyng CB and Berger W. (2005) Novel mutations in CACNA1F and NYX in Dutch families with X-linked congenital stationary night blindness. *Mol Vis* **11**: 179-83 [PMID:15761389]
594. Zhang H, Maximov A, Fu Y, Xu F, Tang TS, Tkatch T, Surmeier DJ and Bezprozvanny I. (2005) Association of CaV1.3 L-type calcium channels with Shank. *J Neurosci* **25**: 1037-49 [PMID:15689539]
595. Zhang J, Berra-Romani R, Sinnegger-Brauns MJ, Striessnig J, Blaustein MP and Matteson DR. (2007) Role of Cav1.2 L-type Ca<sup>2+</sup> channels in vascular tone: effects of nifedipine and Mg<sup>2+</sup>. *Am J Physiol Heart Circ Physiol* **292**: H415-25 [PMID:16980345]
596. Zhang Q, Bengtsson M, Partridge C, Salehi A, Braun M, Cox R, Eliasson L, Johnson PR, Renström E and Schneider T *et al.*. (2007) R-type Ca(2+)-channel-evoked CICR regulates glucose-induced somatostatin secretion. *Nat Cell Biol* **9**: 453-60 [PMID:17369816]
597. Zhang Y, Chen K, Sloan SA, Bennett ML, Scholze AR, O'Keeffe S, Phatnani HP, Guarnieri P, Caneda C and Ruderisch N *et al.*. (2014) An RNA-Sequencing Transcriptome and Splicing Database of Glia, Neurons, and Vascular Cells of the Cerebral Cortex. *J Neurosci* **34**: 11929-47 [PMID:25186741]
598. Zhang Y, Mori M, Burgess DL and Noebels JL. (2002) Mutations in high-voltage-activated calcium channel genes stimulate low-voltage-activated currents in mouse thalamic relay

- neurons. *J Neurosci* **22**: 6362-71 [PMID:12151514]
599. Zhang Z, Xu Y, Song H, Rodriguez J, Tuteja D, Namkung Y, Shin HS and Chiamvimonvat N. (2002) Functional Roles of Ca(v)1.3 (alpha(1D)) calcium channel in sinoatrial nodes: insight gained using gene-targeted null mutant mice. *Circ Res* **90**: 981-7 [PMID:12016264]
600. Zhao Y, Huang G, Wu J, Wu Q, Gao S, Yan Z, Lei J and Yan N. (2019) Molecular Basis for Ligand Modulation of a Mammalian Voltage-Gated Ca<sup>2+</sup> Channel. *Cell* **177**: 1495-1506.e12 [PMID:31150622]
601. Zhao Y, Huang G, Wu Q, Wu K, Li R, Lei J, Pan X and Yan N. (2019) Cryo-EM structures of apo and antagonist-bound human Ca<sub>v</sub>3.1. *Nature* **576**: 492-497 [PMID:31766050]
602. Zheng W, Rampe D and Triggle DJ. (1991) Pharmacological, radioligand binding, and electrophysiological characteristics of FPL 64176, a novel nondihydropyridine Ca<sup>2+</sup> channel activator, in cardiac and vascular preparations. *Mol Pharmacol* **40**: 734-41 [PMID:1719369]
603. Zhong X, Liu JR, Kyle JW, Hanck DA and Agnew WS. (2006) A profile of alternative RNA splicing and transcript variation of CACNA1H, a human T-channel gene candidate for idiopathic generalized epilepsies. *Hum Mol Genet* **15**: 1497-512 [PMID:16565161]
604. Zhuchenko O, Bailey J, Bonnen P, Ashizawa T, Stockton DW, Amos C, Dobyns WB, Subramony SH, Zoghbi HY and Lee CC. (1997) Autosomal dominant cerebellar ataxia (SCA6) associated with small polyglutamine expansions in the alpha 1A-voltage-dependent calcium channel. *Nat Genet* **15**: 62-9 [PMID:8988170]
605. Zito I, Allen LE, Patel RJ, Meindl A, Bradshaw K, Yates JR, Bird AC, Erskine L, Cheetham ME and Webster AR *et al.*. (2003) Mutations in the CACNA1F and NYX genes in British CSNBX families. *Hum Mutat* **21**: 169 [PMID:12552565]
606. Zühlke RD, Pitt GS, Deisseroth K, Tsien RW and Reuter H. (1999) Calmodulin supports both inactivation and facilitation of L-type calcium channels. *Nature* **399**: 159-62 [PMID:10335846]