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## Characterization of CIC transporter proteins

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# References

## References

- Accardi, A. and Miller, C.** (2004) Secondary active transport mediated by a prokaryotic homologue of ClC Cl<sup>-</sup> channels. *Nature.*, **427**, 803-807.
- Accardi, A., Kolmakova-Partensky, L., Williams, C. and Miller, C.** (2004) Ionic currents mediated by a prokaryotic homologue of ClC Cl<sup>-</sup> channels. *Journal Gen. Physiology.*, **123**, 109-119.
- Adler, P.R. and Wilcox, C.E** (1995) Ammonium increases the net rate of sodium influx and partitioning to the leaf of muskmelon. *Journal of Plant Nutrition.* **18**, 1951-1962
- Allaway, W.G.** (1973) Accumulation of malat in guard cells of *Vicia faba* during stomatal opening. *Planta.*, **110**, 63-70.
- Allen, G.J, Kutchisu, K, Chu, S.P, Murata, Y. and Schroeder, J.I.** (1999) *Arabidopsis* abi-1 and abi-2 phosphatase mutations reduce abscisic acid-induced cytoplasmic calcium rises in guard cells. *Plant Cell*, **11**, 1785-1798.
- Ames, B, Shigenaga, M. and Hagen, T.** (1993) Oxidants, antioxidants, and the degenerative diseases of ageing. *Proceedings of the National Academy of Sciences, USA.* **90**, 7915-7922.
- Amtmann, A. and Sanders, D.** (1999) Mechanisms of Na uptake by plant cells. *Advances in Botanical Research.*, **29**, 75-112.
- Arduini, I, Godbold, D.L. and Onnis, A.** (1996) Influence of copper on root growth and morphology of *pinus pinea* L. and *Pinus Pinaster Ait.* Seedling. *Tree physiology*, **15**, 411-415.
- Aronson, P.S.** (1985) Kinetics properties of the plasma membrane Na<sup>+</sup>/H<sup>+</sup> exchanger. *Annu. Rev. Physiol.* **47**, 545-560.
- Askerlund P, Sommarin M.** (1996) Calcium efflux transporters in higher plants. In: Smallwood M, Knox JP, Bowles DJ, editors. *Membranes: Specialized Functions in Plants.* Oxford: BIOS Scientific Publishers., 281-299.
- Assmann,S.M. and Haubrick, L.L.** (1996) Transport proteins of the plant plasma membrane. *Curr Opin Cell Biol.*, **8**, 458-467.
- Axelsen, K.B. and Palmgren, M.G.** (1998) Evolution of substrate specificities in the P-type ATPases superfamily. *J Mol Evol.*, **46**, 84-101.
- Bar, Y. Apelbaum, A. Kafkafi, U. and Goren, R.** (1997) Relationship between chloride and nitrate and its effect on growth and mineral composition of avocado and citrus plants. *Journal of Plant Nutrition.* **20**, 715-731.
- Bar, Y. Apelbaum, A. Kafkafi, U. and Goren, R.** (1997) Relationship between chloride and nitrate and its effect on growth and mineral composition of avocado and citrus plants. *Journal of Plant Nutrition.* **20**, 715-731.
- Barbier-Brygoo, H, Vinauger, M, Colcombet, J, Ephritikhine, G, Frachisse, J. and Maurel, C.** (2000) Anion channels in higher plants: functional characterization, molecular structure and physiological role. *Biochim. Biophys. Acta*, **1465**, 199-218.
- Barcelo, C. and Poschenrieder.** (1990) Plant water relations as affected by heavy metal stress: a review. *J. Plant Nutr.*, **13**, 1-37.
- Baryla, A., Carrier, P., Franck, F., Coulomb, C., Sahut, C. and Havaux, M.** (2002) Leaf chlorosis in oilseed rape plants (*Brassica napus*) grown on cadmium-polluted soil: causes and consequences for photosynthesis and growth. *Planta*, **212**, 696-709.
- Beffagna, N., Romai, G., Meraviglia, G. and Pallini, S.** (1997) Effects of abscisic acid and cytoplasmic pH on potassium and chloride efflux in *Arabidopsis thaliana* seedlings. *Plant Cell Physiol.*, **38**, 503-510.
- Benfey, N.B., Linstead, P.J., Roberts, K., Schiefelbein, J.W., Hauser, M.T. and Aeschbacher, R.A.** (1993) Root development in *Arabidopsis*: four mutants with dramatically altered root morphogenesis. *Development.* **119**, 57-70
- Bergsdorf, E.Y., Zdebik, A.A and Jentsch., T.J** (2009). Residues important for nitrate/proton coupling in plant and mammalian CLC transporters. *J. Biol. Chem.* **284**, 11184-11193
- Besson-Bard, A., Gravot, A., Richaud P., Auroy, P., Duc, C., Gaymard, F., Taconnat, L., Renou, J.P., Pugin, A. and Wandehenne, D.** (2009) Nitric oxide contributes to cadmium toxicity in *Arabidopsis* by promoting cadmium accumulation in roots and by up-regulating genes related to iron uptake. *Plant Physiology*, **149**, 1302-1315.

- Blatt, M.R.** (1999) Reassessing roles for  $\text{Ca}^{2+}$  in guard cell signalling. *J. Exp. Bot.* **50**, 989-999.
- Blazka, M.E. and Shaikh, Z.A.** (1991) Differences in cadmium and mercury uptake by hepatocytes: role of calcium channel. *Toxicol Appl Pharmacol*, **110**, 355-363.
- Blazka, M.E. and Shaikh, Z.A.** (1992) Cadmium and mercury accumulation in rat hepatocytes. *Toxicol Appl Pharmacol*, **113**, 118-125.
- Blumwald, E., Aharon, G.S. and Apse, M.P.** (2000) Sodium transport in plant cell. *Biochim. Biophys. Acta.*, **1465**, 140-151.
- Bowling, D.J.F.** (1976) Malate-switch hypothesis to explain the action of stomata. *Nature.*, **262**, 393-394.
- Brandt, P.C. and Vanaman, T.C.** (1998) Calmodulin and ion flux regulation. In: Van Eldik L, Watterson DM, editors. *Calmodulin and Signal Transduction*. San Diego: Academic Press., 397-471.
- Breckle, S.** (1991) Growth under stress. Heavy metals. In: Plant Poots: The Hidden Half, Eds. Y. Waisel, A. Eshel and U. Kafkafi, M. Dekker, Inc, New York, 351-373.
- Britto, D.T., Ruth, T.J., Lapi, S. and Kronzucker, H.J.** (2004) Cellular and whole-plant chloride dynamics in barley: insights into chloride-nitrogen interaction and salinity responses. *Planta*. **218**, 615-622.
- Buntemeyer, K., Luthen, H. and Bottger, M.** (1998) Auxin-induced changes in cell wall extensibility of maize roots. *Planta.*, **204**, 515-519.
- Carpita, N. and Gibeaut, D.M.** (1993) structural model of primary cell walls in flowering plants: consistency of molecular structure with the physical properties of the walls during growth. *The Plant Journal*. **3**, 1-30.
- Cataldo, D.A., Garland, T.R. and Wildung, R.E.** (1981) Cadmium uptake kinetics in intact soybean plants. *Plant Physiology and Biochemistry*, **73**, 844-848.
- Chang, G., Spencer, R.H., Lee, A.T., Barclay, M.T. and Douglas C. Rees, D.C.** (1998) Structure of the MscL Homolog from *Mycobacterium tuberculosis*: A Gated Mechanosensitive Ion Channel. *Science.*, **282**, 2220 - 2226.
- Chanson, A. and Taiz, L.** (1985) Evidence for an ATP-dependent proton pump on the Golgi of corn coleoptiles. *Plant physiology.*, **78**, 232-240.
- Cho, M.H. and Spalding, E.P.** (1996) An anion channel in *Arabidopsis* hypocotyls activated by blue light. *Proceedings of the National Academy of Sciences.*, **93**, 8134-8138.
- Choi, Y.E., Harada, E., Wada, M., Tsuboi, H., Morita, Y., Kusano, T. and Sano, H.** (2001) Detoxification of cadmium in tobacco plant: formation and active excretion of crystals containing cadmium and calcium through trichomes. *Planta*, **213**, 45-50.
- Clemens, S.** (2006) Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants. *Biochimie*, **88**, 1707-1719.
- Clemens, S., Antosiewicz, D.M., Ward, J.M., Schachtman, D.P. and Schroeder, J.I.** (1998) The plant cDNA LCT1 mediates the uptake of calcium and cadmium in yeast. *Proc. Natl. Acad. Sci USA*, **95**, 12043-12048.
- Cocombet, J., Lelievre, F., Thomine, S. and Barbier-Brygoo, H.** (2005) Distinct pH regulation of slow and rapid anion channels at the plasma membrane of *Arabidopsis thaliana* hypocotyls cells. *J. Exp. Bot.*, **56**, 1897-1903.
- Cohen, J. and Schulten, K.** (2004) Mechanism of anionic conduction across ClC. *Biophysical Journal.*, **86**, 836-845.
- Colcombet, J., Lelievre, F., Thomine, S. and Barbier-Brygoo, H.** (2005) Distinct pH regulation of slow and rapid anion channels at the plasma membrane of *Arabidopsis thaliana* hypocotyl cells. *Journal of Experimental Botany.*, **56**, 1897-1903.
- Cosgrove, D.J.** (1997) Relaxation in a high-stress environment: the molecular bases of extensible cell walls and cell enlargement. *Plant Cell*. **9**, 1031-1041.
- Cosgrove, D.J.** (1999) Enzymes and other agents that enhance cell wall extensibility. *Ann. Rev. Plant Mol. Biol.* **50**, 391-417.
- Cosgrove, D.J.** (2000) Loosening of plant cell walls by expansins. *Nature*. **407**, 321-326.

## References

- Cosson, P., Curtis, I., Pouyssegur, J., Griffiths, G. and Davoust, J.** (1989) Low cytoplasmic pH inhibits endocytosis and transport from the trans-Golgi network to the cell surface. *Journal Cell Biology.*, **108**, 377-387.
- Costa, G. and Morel, J.L.** (1993) Cadmium uptake by *Lupinus albus* (L.): cadmium excretion, a possible mechanism of cadmium tolerance. *J. Plant Nutr.*, **16**, 1921-1929.
- Costa, G. and Morel, J.L.** (1994) Efficiency of H<sup>+</sup> ATPase activity on cadmium uptake by four cultivars of lettuce. *J. Plant Physiology.*, **17**, 627-637.
- De Angeli, A., Monachello, D., Ephritikhine, G., Frachisse, J.M., Thomine, S., Gambale, F. and Barbier-Brygoo, H.** (2006) The nitrate/proton antiporter AtCLCa mediates nitrate accumulation in plant vacuoles. *Nature.* **442**, 939-942.
- De Angeli, A., Thomine, S., Frachisse, J.M., Ephritikhine, G., Gambale, F. and Barbier-Brygoo, H.** (2007) Anion channels and transporters in plant cell membranes. *FEBS Letters*, **581**, 2367-2374.
- De Cnodder, T., Verbelen, J.P. and Vissenberg, K.** (2006) The control of cell size and rate of elongation in the *Arabidopsis* root. *Plant Cell Monogr.* **5**, 249-269.
- De Michelis, M.I. and Spanswick, R.M.** (1986) H<sup>+</sup>-pumping driven by the vanadate-sensitive ATPase in membrane vesicles from corn roots. *Plant Physiology.* **81**, 542-547.
- Dean, R.T., Gieseg, S. and Davies, M.** (1993) Reactive species and their accumulation on radical-damaged proteins. *Trends in Biological Sciences*, **18**, 437-441.
- Deanne-Drummond, C.E.** (1986) A comparison of regulatory effects of chloride on nitrate uptake and nitrate on chloride uptake into *Pisum sativum* seedling. *Physiologia Plantarum.*, **66**, 115-121.
- Demidchik, V., Bowen, H.C., Maathuis, F.J.M., Shabala, S.N., Tester, M.A., White P.J. and Davies J.M.** *Arabidopsis thaliana* root non-selective cation channels mediate calcium uptake and are involved in growth. *The Plant Journal*, **32**, 799-808
- Dettmer, J., Hong-Hermesdorf, A., Stierhof, Y.D. and Schumacher, K.** (2006) Vacuolar H<sup>+</sup>-ATPase activity is required for endocytic and secretory trafficking in *Arabidopsis*. *The Plant Cell.* **18**, 715-730.
- Dettmer, J., Schubert, D., Calvo-Weimar, O., Stierhof, Y.D., Schmidt, R. and Schumacher, K.** (2005) Essential role of the V-ATPase in male gametophyte development. *Plant Journal.*, **41**, 117-124.
- Dietrich, P. and Hedrich, R.** (1998) Anions permeate and gate GCAC1, a voltage-dependent guard cell anion channel. *The Plant Journal.*, **15**, 479-487.
- Dolan, L., Janmaat, K., Willemsen, V., Linstead, P., Poethig, S., Roberts, K. and Scheres, B.** (1993) Cellular organization of the *Arabidopsis thaliana* root. *Development*, **119**, 71-84.
- Donald, P., Briskin and Margaret, C. Cawienowski.** (1996) Role of the plasma Membrane H<sup>+</sup>-ATPase in K<sup>+</sup> transport. *Plant Physiol.* **111** , 1199-1207.
- Downton, W.J.S.** (1977) Influence of rootstocks on the accumulation of chloride, sodium and potassium in grapevines. *Australian Journal of Agricultural Research.* **28**, 879-889.
- Doyle, D.A., Cabral, J. M., Pfuetzer, R.A., Kuo, A., Gulbis, J.M., Cohen, S.L., Chait, B.T. and Mackinnon, R.** (1998) The structure of the potassium channel: molecular basis of K<sup>+</sup> conduction and selectivity. *Science.*, **280**, 69-77.
- Dube, F., Dufresne, L., Coutu, L. and Clotteau, G.** (1991) protein phosphorylation during activation of surf clam oocytes. *Dev Biol.*, **146**, 473-482.
- Duffield, M.D., Rychkov, G.Y., Bretag, A.H. and Roberts, M.L.** (2005) Zinc inhibits human ClC-1 muscle chloride channel by interacting with its common gating mechanism. *J Physiol*, 568, 5-12
- Dutzler, R., Campbell, E. B. & MacKinnon, R.** (2003). Gating the selectivity filter in ClC chloride channels. *Science.*, **300**, 108-12.
- Dutzler, R., Compbell, E.B., Cadene, M., Chait, B.T. and Mackinnon, R.** (2002) X-ray structure of a ClC chloride channel at 3.0 Å reveals the molecular basis of anion selectivity. *Nature.*, **415**, 287-294.

- Edmunds, B.T., Murray, J. and Condeelis, J.** (1995) pH regulation of the F-actin binding properties of *Dictyostelium* elongation factor 1. *Journal Cell Biology.*, **270**, 15222-15230.
- Edwards, K.L. and Scott, T.K.** (1974) Rapid growth responses of corn root segments: Effect of pH on elongation. *Planta.*, **119**, 27-37.
- Elzenga, J.T.M., Prins, H.B.A. and Van Volkenburgh, E.** (1995) Light induced membrane potential changes of epidermal and mesophyll cells in growing leaves of *pisum sativum* arg. *Planta.*, **197**, 127-134.
- Elzenga, J.T.M. and Van Volkenburgh, E.** (1997) Characterization of a light-controlled anion channel in the plasma membrane of mesophyll cells of *Pea*. *Plant Physiology.*, **113**, 1419-1426.
- Evans, D.E.** (1994) Calmodulin-stimulated calcium pumping ATPases located at higher plant intracellular membranes: a significant divergence from other eukaryotes *Physiol Plant.*, **90**, 420-426.
- Evans, D.E. and Williams, L.E.** (1998) P-type calcium ATPases in higher plants: biochemical, molecular and functional properties. *Biochim Biophys Acta.*, **1376**, 1-25.
- Fahlke, C., Yu, H.T., Beck, C.L., Rhodes, T.H. and Georege, A.L.** (1997) Pore-forming segments in voltage-gated chloride channels. *Nature.*, **390**, 529-532.
- Faller, P., Kienzler, K. and Krieger-Liszky, A.** (2005) Mechanism of Cd toxicity: Cd inhibits photoactivation of photosystem II by competitive binding to the essential Ca site. *Biochim, Biophys. Acta*, **1706**, 158-164.
- Fan, L. and Neumann, P.M.** (2004) The spatially variable inhibition by water deficit of maize root growth correlates with altered profiles of proton flux and cell wall pH. *Plant Physiology*, **135**, 2291-2300.
- Fasano, J.M., Swanson, S.J., Blancaflor, E.B., Dowd, P.E., Kao, T.H. and Gilroy, S.** (2001) Changes in root cap pH are required for the gravity response of the Arabidopsis root. *The Plant Cell.*, **13**, 907-921.
- Faundez, V. and Hartzell, H.C.** (2004) Intracellular chloride channels: determinants of function in the endosomal pathway. *Science STKE.*, **2004**, 1-7.
- Fecht-Bartenbach, J.V.D. Bogner, M. Krebs, M. Stierhof, Y.D. Schumacher, K. and Ludwig, U.** (2007) Function of the anion transporter AtCLC-d in the trans-Golgi network. *The Plant Journal.* **50**, 466-474
- Fejjo, J.A., Sainhas, J., Hackett, G.R., Kunkel, J.G. and Hepler, P.K.** (1999) Growing pollen tubes possess a constitutive alkaline band in the clear zone and a growth-dependent acidic tip. *Journal Cell Biology.*, **144**, 483-496.
- Felle, H.** (1994). The H<sup>+</sup>/Cl<sup>-</sup> symporter in root hair cells of *Sinapis alba*. *Plant Physiol.*, **106**, 1131-1136
- Felle, H., Boss, W.F. and Morr , D.J** (1989) pH as a second messenger in plants. Second messengers in plant growth and development. *Alan R. Liss, New York.* 145-166.
- Felle, H.H.** (1994) The H<sup>+</sup>/Cl<sup>-</sup> symporter in root-hair cells of *Sinapsis alba*. *Plant Physiology.*, **106**, 1131-1136.
- Flower, T.J. and Yeo, A.R.** (1995) Breeding for salinity resistance in crop plants. *Aus.J. Plant Physiology.*, **22**, 875-884.
- Folta, K.M. and Spalding, E.P.** (2001) Unexpected roles for cryptochrome 2 and phototropin revealed by high-resolution analysis of blue light-mediated hypocotyl growth inhibition. *Plant Journal.*, **26**, 471-478.
- Foulkes, E.C.** (2000) Transport of toxic heavy metals across cell membranes. *Society for Experimental Biology and Medicine*, 234-240.
- Frachisse, J.M., Colcombet, J., Guern, J. and Barbier-Brygoo, H.** (2000) Characterization of a nitrate-permeable channel able to mediate sustained anion efflux in hypocotyl cells from *Arabidopsis thaliana*. *The Plant Journal.*, **21**, 361-371.
- Fujita, H. and Syono, K.** (1996) Genetic analysis of the effects of polar auxin transport inhibitors on root growth in *Arabidopsis thaliana*. *Plant Cell Physiology.* **37**, 1094-1101.
- Fujita, N., Mori, H., Yura, T. and Ishihama, A.** (1994) Systematic sequencing of the *Escherichia coli* genome: analysis of the 2.4-4.1 min (110, 917-193, 643 bp) region. *Nucleic Acids Res.*, **22**, 1637-1639.

## References

- Fukuda, A., Nakamura, A., Tagiri, A., Tanaka, H., Miyao, A., Hirochika, H. and Tanaka, Y.** (2004) Function, intracellular localization and the importance in salt tolerance of a vacuolar Na<sup>+</sup>/H<sup>+</sup> antiporter from rice. *Plant Cell Physiology*, **45**, 146-159.
- Gairola, C.G., Wagner, G.J. and Diana, J.N.** (1992) Tobacco, Cd and health. *J. Smoking Rel. Dis.*, **3**, 3-6.
- Garnett, T.P., Shabala, S.N., Smethurst, P.J. and Newman, I.A.** (2003) Kinetics of ammonium and nitrate uptake by eucalypt root and associated proton fluxes measured using ion selective microelectrodes. *Functional Plant Biology*, **30**, 1165-1176.
- Gaxiola R.A., Yuan, D.S., Klausner, R.D. and Fink, G.R.** (1998) The yeast CLC chloride channel functions in cation homeostasis. *Proc. Natl. Acad. Sci. USA*
- Geelen, D., Lurin, C., Bouchez, D., Frachisse, J.M., Lelievre, F., Courtial, B., Barbier-Brygoo, H., Guern, J. and Maurel, C.** (2000) Disruption of putative anion channel gene AtCLC-a in *Arabidopsis* suggests a role in the regulation of nitrate content. *The Plant Journal*, **21**, 259-269.
- Geisler, M., Axelsen, K., Harper, J.F. and Palmgren, M.G.** (2000) Molecular aspects of higher plant P-type Ca<sup>2+</sup>-ATPases. *Biochim Biophys Acta*, **1465**, 52-78.
- Gilliham, M. and Tester, M.** (2005) The regulation of anion loading to the maize root xylem. *Plant Physiology*, **137**, 819-828.
- Godbold, D.L.** (1991) Cadmium uptake in Norway spruce. *Tree physiology*, **9**, 349-357.
- Graves, A.R., Curran, P.K., Smith, C.L. and Mindell, J.A.** (2008) The Cl<sup>-</sup>/H<sup>+</sup> antiporter ClC-7 is the primary chloride permeation pathway in lysosomes. *Nature*, **453**, 788-792.
- Green, J.R., Brown, N.H., DiDomenico, B.J., Kaplan, J. and Eide, D.J.** (1993) The GEF1 gene of *Ascharyomyces cerevisiae* encode an integral membrane protein: mutation in which have effects on respiration and iron-limited growth. *Molecular Genetic*, **241**, 542-553.
- Greger, M. and Bertell, G.** (1992) Effect of Ca<sup>2+</sup> and Cd<sup>2+</sup> on the carbohydrate metabolism in sugar beet (*Beta vulgaris*). *J. Exp. Bot.*, **43**, 167-173.
- Greger, M. and Ogren, E.** (1991) Direct and indirect effects of Cd on the photosynthesis and CO<sub>2</sub>-assimilation in sugar beet (*Beta Vulgaris*). *Physio. Pant*, **83**, 129-135.
- Gue, F.Q., Young, J. and Crawford, N.M.** (2003) The nitrate transporter AtNRT1.1 (CHL1) functions in stomatal opening and contributes to drought susceptibility in *Arabidopsis*. *Plant Cell*, **15**, 107-117.
- Guern, J.** (1991) Regulation of intracellular pH in plant cells. *International Review of Cytology*, **127**, 111-173.
- Guern, J., Mathieu, Y., Thomine, S., Jouanneau, J.P. and Beloeil, J.C.** (1992) Plant cells counteract cytoplasmic pH changes but likely use these pH changes as secondary messengers in signal perception. *Curr Top Plant Biochem Physiology*, **11**, 249-269.
- Guo, F.Q., Young, J. and Crawford, N.M.** (2003) The nitrate transporter AtNRT1.1 (CHL1) functions in stomatal opening and contributes to drought susceptibility in *Arabidopsis*. *Plant Cell*, **15**, 107-117.
- Gussarson, M., Asp, H., Adalsteinsson, S. and Jensen, P.** (1996) Enhancement of Cd effects on growth and nutrient composition of birch (*Betula pendula*) by buthionine sulphoximine. *J. Exp Bot*, **47**, 211-215.
- Hafke, J.B., Hafke, Y., Smith, J.A., Lutge, U. and Thiel, G.** (2003) Vacuolar malate uptake is mediated by an anion selective inward rectifier. *Plant Journal*, **35**, 116-128.
- Hall, J.L.** (2002) Cellular mechanisms for heavy metal detoxification and tolerance. *J. Exp. Bot*, **366**, 1-11.
- Hanson, J.B.** (1984) The function of calcium in plant nutrition. *Advances in Plant nutrition*, **1**, 149-208.
- Harada, H., Kuromori, T., Hirayama, T., Shinozaki, K. and Leigh, R.A.** (2004) Quantitative trait loci analysis of nitrate storage in *Arabidopsis* leading to an investigation of the contribution of the anion channel gene, AtCLC-c, to variation in nitrate levels. *Journal of Experimental Botany*, **55**, 2005-2014.
- Hart, J.J., Welch, R.M., Norvell, W.A., Sullivan, L.A. and Kochian, L.V.** (1998) Characterization of cadmium binding, uptake, and translocation in intact seedlings of bread and durum wheat cultivars. *Plant Physiology*, **116**, 1413-1420.

- Hasegawa, P.M., Bressan, R.A., Zhu, J.K. and Bohnert, H.J.** (2000) Plant cellular and molecular response to high salinity. *Annu. Rev. Plant Physiol. Plant Mol. Biol.*, **51**, 463-499.
- Hauser, M.T., Morikami, A. and Benfey, P.N.** (1995) Conditional root expansion mutants of *Arabidopsis*. *Development*, **121**, 1237-1252
- Hechenberger, M. Schwappach, B. Fischer, W.N. Frommer, W.B. Jentsch, T.J. and Steinmeyer, K.** (1996) A family of putative chloride channels from *Arabidopsis* and functional complementation of a yeast strain with a CLC gene disruption. *Journal of Biological Chemistry*, **271**, 33632-33638.
- Hedrich, R. and Kurkdjian, A.** (1988) Characterization of an anion-permeable channel from sugar beet vacuoles: effect of inhibitors. *EMBO Journal*, **7**, 3661-3666.
- Hedrich, R., Busch, H. and Raschke, K.** (1990) Ca<sup>2+</sup> and nucleotide dependent regulation of voltage dependent anion channels in the plasma membrane of guard cells. *EMBO J*, **9**, 3889-3892.
- Higgins, C.F.** (1995) The ABC of channel regulation, *Cell*, **82**, 693-696.
- Hille, B.** (1992) Ionic channels of Excitable Membranes, 2nd Ed. Sinauer Associates, Sunderland, MA.
- Hirschi, K.D., Korenkov, V.D., Wilganowski, N.L. and Wagner, G.J.** (2000) Expression of *Arabidopsis* CAX2 in tobacco. Altered metal accumulation and increased manganese tolerance. *Plant Physiology*, **124**, 125-133.
- Hoekenga, O.A., Maron, L.G., Pineros, M.A., Cancado, G.M., Shaff, J., Kobayashi, Y., Ryan, P.R., Dong, B., Delhaize, E., Sasaki, T., Matsumoto, H., Yamamoto, Y., Koyama, H. and Kochian, L.V.** (2006) AtALMT1, which encodes a malate transporter, is identified as one of several critical genes for aluminum tolerance in *Arabidopsis*. *Proc. Natl. Acad. Sci. USA*, **103**, 9738-9750.
- Hurth, A., Suh, S., Kretzschmar, T., Geis, T., Bregante, M., Gambale, F., Martinoia, E. and Neuhaus, E.** (2005) Impaired pH homeostasis in *Arabidopsis* lacking the vacuolar dicarboxylate transporter and analysis of carboxylic acid transport across the tonoplast. *Plant physiology*, **137**, 901-910.
- Jagodin, B., Govorina, V., Vinogradova, S., Zamaraev, A. and Chapovskaja G.** (1995) Cadmium and lead accumulation in some agricultural crops, grown in podzolic soils. *Izvestija TSHA*, **2**, 85-99 (in Russ.).
- Jentsch, T.J. Poet, M. Fuhrmann, J.C. and Zdebik, A.A.** (2005) Physiological function of CLC Cl<sup>-</sup> channels gleaned from human genetic disease and mouse models. *Annu. Rev. Physiology*, **67**, 779-807.
- Jentsch, T.J. Stein, V. Weinreich, F. and Zdebik, A.A.** (2002) Molecular structure and physiological function of chloride channels. *Physiol. Rev.* **82**, 503-568.
- Jentsch, T.J.** (1996) Chloride channels: a molecular perspective, *Curr. Opin. Neurobiol.*, **6**, 303-310.
- Jentsch, T.J., Friedrich, T., Schriever, A. and Yamada, H.** (1999) The ClC chloride channel family. *Journal physiology*, **437**, 783-795.
- Jentsch, T.J., Gunter, W., Pusch, M. and Schwappach, B.** (1995) Properties of voltage-gated chloride channels of the ClC gene family. *Journal Physiology*, **482**, 198-258.
- Jentsch, T.J., Maritzen, T. and Zdebik, A.A.** (2005) Chloride channel diseases resulting from impaired transepithelial transport or vesicular function. *The Journal of Clinical Investigation. Rev.*, **115**, 2039-2046.
- Jentsch, T.J., Stein, V., Weinreich, F. and Zdebik, A.A.** (2002) Molecular structure and physiological function of chloride channel. *Plant Physiology*, **82**, 503-568.
- Jentsch, T.J., Steinmeyer, K. and Schwarz, G.** (1990) Primary structure of *Torpedo marmorata* chloride channel isolated expression cloning in *Xenopus oocytes*. *Nature*, **348**, 510-514.
- Johannes, E., Crofts, A. and Sanders, D.** (1998) Control of Cl<sup>-</sup> efflux in *Chara corallina* by cytosolic pH, free Ca<sup>2+</sup>, and phosphorylation indicates a role of plasma membrane anion channels in cytosolic pH regulation. *Plant Physiology*, **118**, 173-181.



## References

- Kafkafi, U. Valoras, N. and Letey, J.** (1982) Chloride interaction with nitrate and phosphoate nutrition in tomato (*Lycopersicon esculentum* L). *Journal of Plant Nutrition*. **5**, 1369-1385.
- Keller, B.U., Hedrich, R. and Raschke, k.** (1989) Voltage-dependent anion channels in the plasma membrane of guard cells. *Nature.*, **341**, 450-453.
- Kiegle, E., Gilliham, M., Haseloff, J. and Tester, M.** (2000) Hyperpolarisation-activated calcium currents found only in cells from the elongation zone of *Arabidopsis thaliana* roots. *Plant Journal.*, **21**, 225-229.
- Kim, Y., Yang, Y.Y. and Lee, Y.** (2002) Pb and Cd uptake in rice roots. *Physiology Plant*, **116**, 368-372.
- Kinraide, T.B.** (1998) Three mechanisms for the calcium alleviation of mineral toxicities. *Plant Physiology*, **118**, 513-520.
- Kinraide, T.B., Perler, J.F. and Parker, D.R.** (2004) Relative effectiveness of calcium and magnesium in the alleviation of rhizotoxicity in wheat induced by copper, zinc, aluminium, sodium, and low pH. *Plant and Soil*, **259**, 201-208.
- Klimyuk, V.I., Carroll, B.J., Thomas, C.M. and Jones, J.D.** (1993) Alkali treatment for rapid preparation of plant material for reliable PCR analysis. *The Plant Journal.*, **3**, 493-494.
- Köhler, B. and Raschke, K.** (2000) The delivery of Salts to the Xylem. Three Types of Anion Conductance in the Plasmalemma of the Xylem Parenchyma of Roots of Barley. *Plant Physiol.*, **122**, 243-254.
- Köhler, B., Wegner, L.H., Osipov. and V., Raschke, K.** (2002) Loading of nitrate into the xylem: apoplastic nitrate controls the voltage dependence of X-QUAC, the main anion conductance in xylem-parenchyma cells of barley root. *Plant Journal.*, **30**, 133-142.
- Kwak, J.M., Mori, I.C., Pei, Z.M., Leonhardt, N., Torres, M.A., Dangl, J.L., Bloom, R.E., Bodde, S., Jones, J.D. and Schroeder, J.I.** (2003) NADPH oxidase *AtrbohD* and *AtrbohF* genes function in ROS-dependent ABA signalling in Arabidopsis. *EMBO J.* **22**, 2623-2633.
- Lanfermeijer, F.C. , Staal, M., Malinowski, R., Stratmann, J.W., Elzenga, J.T.M.** (2008) Micro-Electrode Flux Estimation Confirms that the *Solanum pimpinellifolium* cu3 Mutant Still Responds to Systemin. *Plant Physiol.*, **146**, 129-139.
- Larsson, E.H., Bornman, J.F. and Asp, H.** (1998) Influence of UV-B radiation and Cd on chlorophyll fluorescence, growth and nutrient content in *Brassica napus*. *J. Exp. Bot.* **323**, 1031-1039.
- Le, J., Vandenbussche, F., Van Der Straeten, D. and Verbelen, J.P.** (2001) In the early response of *Arabidopsis* root to ethylene, cell elongation is up and down regulated and uncoupled from differentiation. *Plant Physiology*. **125**, 519-522.
- Leonhardt, N., Kwak, J.M., Robert, N., Waner, D., Leonhardt, G. and Schroeder, J.I.** (2004) Microarray expression analyses of Arabidopsis guard cells and isolation of a recessive abscisic acid hypersensitive protein phosphatase 2C mutant. *Plant Cell*, **16**, 596-615.
- Leonhardt, N., Vavasseur, C. and Forestier, C.** (1999) ATP binding cassette modulators control abscisic acid regulated slow anion channels in guard cells. *Plant Cell.*, **11**, 1141-1152.
- Lewis, B.D., Karlin-Neumann, G., Davis, R.W. and Spalding, E.P.** (1997) Ca<sup>2+</sup>-activated anion channels and membrane depolarizations induced by blue light and cold in Arabidopsis seedlings. *Plant Physiology*, **114**, 1327-1334.
- Li, J., Yang, H., Peer, W.A., Richter, G., Blakeslee, J., Bandyopadhyay, A., Titapiwantalakun, B., Undurraga, S., Khodakovskaya, M., Richards, E.L., Krizek, B., Murphy, A.S., Gilroy, S. and Gaxiola, R.** (2005) *Arabidopsis* H<sup>+</sup>-Ppase AVP1 regulates auxin-mediated organ development. *Science.*, **310**, 121-125.
- Lisal, J and Maduke, M** (2008) The ClC-0 chloride channel is a 'broken' Cl<sup>-</sup>/H<sup>+</sup> antiporter. *Nat Struct Mol Biol.* , **15**, 805-810.
- Lorenzen, I. Aberle, T. and Plieth, C.** (2004) Salt stress-induced chloride flux: a study using transgenic *Arabidopsis* expressing a fluorescent anion prob. *Plant Journal*. **38**, 539-544.

- Lou, M., Garay, R. and Alda, J.O.** (1991) Cadmium uptake through the anion exchanger in human red blood cells. *J. Physiology*, **443**, 123-136.
- Lu, Y.P., Li, S.Z. and Rea, P.A.** (1997) AtMRP1 gene of *Arabidopsis* encodes a glutathione S-conjugate pump: isolation and functional definition of a plant ATP-binding cassette transporter gene. *Proc. Natl. Acad. Sci. USA.*, **94**, 8243-8248.
- Luan, S.** (2008) The CBL-CIPK network in plant calcium signalling. *Trends in Plant Science*, **14**, 37-42.
- Lurine, C. Geelen, D. Barbier-Brygoo, H. Guern, J. and Maurel, C.** (1996) Cloning and functional expression of plant voltage-dependent chloride channel. *The Plant Cell*, **8**, 701-711.
- Lv, Q.D. Tang, R.J. Liu, H. Gao, X.S. Li, Y.Z. Zheng, H.Q. and Zhang, H.X.** (2009) Cloning and molecular analyses of the *Arabidopsis thaliana* chloride channel gene family. *Plant Science*, **176**, 650-661.
- Lynch, J.** (1995) Root architecture and plant productivity. *Plant physiology* **109**, 7-13
- Maathuis, F.J. and Sanders, D.** (1994) Mechanism of high-affinity potassium uptake in roots of *Arabidopsis thaliana*. *Cell Biology.*, **91**, 9272-9276.
- MacLennan, H., Beevers, H. and Harley, J.L.** (1963) Compartmentation of acid in plant tissues. *Biochem. Journal.*, **89**, 316-327.
- Malayev, A. and Nelson, D.J.** (1995) Extracellular pH modulates the Ca<sup>2+</sup> current activated by depletion of intracellular Ca<sup>2+</sup> stores in human macrophages. *Journal Membrane Biology.*, **146**, 101-111.
- Malik, D., Sheoran, I. and Singh, R.** (1992) Carbon metabolism in leaves of cadmium treated wheat seedling. *Plant Physiology. Biochem*, **30**, 223-229.
- Marigo, G., Bouyssou, H. and Belkoura, M.** (1985) Vacuolar efflux of malat and its influence on nitrate accumulation in *Catharanthus roseus* cell. *Plant Science.*, **29**, 193-213.
- Marmagne, A., Vinauger-Douard, M., Monachello, D., De Longevialle, A.F., Charon, C., Allot, M., Rappaport, F., Wollman, F.A., Barbier-Brygoo, H. and Ephritikhine, G.** (2007) Two members of the *Arabidopsis* CLC (chloride channel) family, AtCLCe and AtCLCf, are associated with thylakoid and Golgi membranes, respectively. *Journal of Experimental Botany*, **14**, 1-9.
- Mazess, R. and Barden, H.** (1991) Bone density in premenopausal women; effect of age, dietary intake, physical activity, smoking and birth control pills. *Am.J. Clin. Nutr*, **53**, 132-142.
- McQueen-Mason, S., Durachko, D.M. and Cosgrove, D.J.** (1992) Two endogenous proteins that induce cell wall extension in plants. *Plant Cell*, **4**, 1425-1433.
- Meyer, S., Savaresi, S., Forster, I.G. and Dutzler, R.** (2007) Nucleotide recognition by the cytoplasmic domain of the human chloride transporter CIC-5. *Nat. Struct. Mol. Biol.*, **14**, 60-67.
- Meyer, S., Savaresi, S., Forster, I.G. and Dutzler, R.** (2007) Nucleotide recognition by the cytoplasmic domain of the human chloride transporter CIC-5. *Nat. Struct. Mol. Biol.*, **14**, 60-67.
- Miller, A.J. and Smith, S.J.** (1996) Nitrate transport and compartmentation in cereal root cells. *Journal of Experimental Botany*, **47**, 843-845.
- Miller, C.** (2006) CIC chloride channels viewed through a transporter lens. *Nature.*, **440**, 484-488.
- Mindell, J.A.** (2008) The chloride channel's appendix. *Nature Structural & Molecular Biology* **15**, 781-783.
- Mitsuda, N., Enami, k., Nakata, M., Takeyasu, K. and Sato, M.H.** (2001) Novel type *Arabidopsis thaliana* H<sup>+</sup>-PPase is localized to the Golgi apparatus. *FEBS Lett.*, **488**, 29-35.
- Moreno, I., Norambuena, L., Maturana, D., Toro, M., Vergara, C., Orellana, A., Zurita-Silva, A. and Ordenes, V.R.** (2008) AtHMA1 is a thapsigargin sensitive Ca<sup>2+</sup>/heavy metal pump. *American Society for Biochemistry and Molecular Biology*, 1-21.
- Murata, Y., Pei, Z.M., Mori, I.C. and Schroeder, J.I.** (2001) Abscisic acid activation of plasma membrane Ca<sup>2+</sup> channels in guard cells requires cytosolic NAD(P)H and is

## References

- differentially disrupted upstream and downstream of reactive oxygen species production in *abi1-1* and *abi2-1* protein phosphatase 2C mutants. *Plant Cell*, **13**, 2513-2523.
- Nelson, M.T.** (1986) Interactions of divalent cations with single calcium channels from rat brain synaptosomes. *J. Gen. Physiol.*, **87**, 201-222.
- Newman, I. A.** (2001) Ion transport in roots: measurement of fluxes using ion-selective microelectrodes to characterise transporter function. *Plant, Cell & Environment*, **24**, 103-112.
- Nguitra, W. and Miller, C.** (2006) Uncoupling of a Cl<sup>-</sup>/H<sup>+</sup> exchange transporter by polyatomic anions. *Journal of Molecular Biology*, **362**, 682-690
- Nuhse, T.S., Peck, S.C., Hirt, H. and Boller, T.** (2000) Microbial elicitors induce activation and dual phosphorylation of the *Arabidopsis thaliana* MAPK 6. *Journal of Biological Chemistry*, **275**, 7521-7526.
- Nurnberger, T., Nennstiel, D., Jabs, T., Sacks, W.R., Hahlbrock, K. and Scheel, D.** (1994) High affinity binding of fungal oligopeptide elicitor to parsley plasma membranes triggers multiple defense responses. *Cell*, **78**, 449-460.
- O'Neill, R.A. and Scott, T.K.** (1983) Proton flux and elongation in primary roots of barley (*Hordeum vulgare* L.). *Plant Physiology*, **73**, 199-201.
- O'Neill, R.A. and Scott, T.K.** (1983) Proton flux and elongation in primary roots of barley (*Hordeum vulgare* L.). *Plant Physiology*, **73**, 199-201.
- Orlowski, J. and Grinstein, S.** (1997) Na<sup>+</sup>/H<sup>+</sup> exchangers of mammalian cells. *J. Biol. Chem.*, **272**, 22373-22376.
- Østergaard, L. and Yanofsky, M.F.** (2004) Establishing gene function by mutagenesis in *Arabidopsis thaliana*. *The Plant Journal*, **39**, 682-696.
- Pandey, S., Zhang, W. and Assmann, S.M.** (2007) Roles of ion channels and transporters in guard cell signal transduction. *FEBS Letters*, **581**, 2325-2336.
- Park, S., Rancour, D.M. and Bednare, S.Y.** (2008) In planta analysis of the cell cycle-dependent localization of AtCDC48A and its critical roles in cell division, expansion, and differentiation. *Plant Physiology* **148**, 246-258.
- Patrick, J.W. and Offler, C.E.** (2001) Compartmentation of transport and transfer events in developing seeds. *J. Exp. Bot.*, **52**, 551-564.
- Pei, Z.M., Kuchitsu, K., Ward, J.M., Schwarz, M. and Schroeder, J.I.** (1997) Differential abscisic acid regulation of guard cell anion channels in *Arabidopsis* wild-type and *abi1* and *abi2* mutants. *Plant Cell*, **9**, 409-423.
- Perlin, D.S., Kasamo, K., Brookers, R.J. and Slayman, C.W.** (1984) Electrogenic H<sup>+</sup> translocation by the plasma membrane ATPase of *Neurospora*. *Journal of Biological Chemistry*. **259**, 7884-7892.
- Peters, W.S. and Felle, H.H.** (1999) The correlation of profiles of surface pH and elongation growth in maize roots. *Plant Physiology*, **121**, 905-912.
- Piccolo, A. and Pusch, M.** (2005) Chloride/proton antiporter activity of mammalian ClC proteins ClC-4 and ClC-5. *Nature*, **436**, 420-423.
- Pilet, P.E., Versel, J.M. and Mayor, G.** (1983) Growth distribution and surface pH patterns along the maize roots. *Planta*. **158**, 398-402.
- Pineros, M.A., Shaff, J.E. and Kochian, L.V.** (1998) Development, characterization, and application of a cadmium-selective microelectrode for the measurement of cadmium fluxes in roots of *Thlaspi* species and wheat. *Plant physiology*. **116**, 1393-1401.
- Pinto, A.P., Mota, A.M., De Varennes, A. and Pinto, F.C.** (2004) Influence of organic matter on the uptake of Cd, Zinc, copper and iron by sorghum plant. *Sci Tot Environ*, **326**, 239-274.
- Plan, P.J., Gelli, A. and Blumwald, E.** (1994) Vacuolar chloride regulation of an anion-selective tonoplast channel. *The Journal of Membrane Biology*, **140**, 1-12.
- Purdy, M.D., Wiener, M.C.** (2000) Expression, purification, and initial structural characterization of YadQ, a bacterial homolog of mammalian ClC chloride channel proteins. *FEBS Lett.*, **466**, 26-28.
- Pusch, M., Ludwig, U., Rehfeldt, A. and Jentsch, T.J.** (1995) Gating of the voltage-dependent chloride channel ClC-0 by the permeant anion. *Nature*. **327**, 527-531

- Putnam, R.** (1998) Intracellular pH regulation. In N Sperelakis, ed, *Cell physiology Source Book*. Academic Press, San Diego, 293-305.
- Qi, Z., Kishigami, A., Nakagawa, Y., Iida, H. and Sokabe, M.** (2004) A mechanosensitive anion channel in *Arabidopsis thaliana* mesophyll cells. *Plant Cell Physiology.*, **45**, 1704-1708.
- Rayle, D. and Cleland, R.E.** (1970) Enhancement of wall loosening and elongation by acid solution. *Plant Physiology.* **46**, 250-253.
- Rayle, D. and Cleland, R.E.** (1992) The acid growth theory of auxin-induced cell elongation is alive and well. *Plant physiology.* **99**, 1271-1274.
- Rea, P.A., Li, Z.S., Lu, Y.P, Drozdowicz, Y.M. and Martinoia, E.** (1998) From vacuole GS-X pumps to multispecific ABC transporters. *Annu. Rev. Plant Physiology. Plant Mol. Biol.*, **49**, 727-760.
- Rivetta, A., Negrini, N. and Cocucci, M.** (1997) Involvement of  $Ca^{2+}$ -calmodulin in  $Cd^{2+}$  toxicity during the early phases of radish (*Raphanus sativus* L.) seed germination. *Plant Cell Environ*, **20**, 600-608.
- Rodriguez-Serrano, M., Romerro-Puertas, M.C., Pazmino, D.M., Testillano, P.S., Risueno, M.C., Del-Rio, L.A. and Sandalio, L.M.** (2009) Cellular response of pea plants to cadmium toxicity: cross-talk between reactive oxygen species, nitric oxide and calcium. *Plant Physiology Preview*, **108**, 1-37.
- Romero, J.M., Maronon, T. and Murillo.** (1994) Long term responses of *Melilotus segatalis* to salinity. II Nutrient absorption and utilization. *Plant Cell Environment.*, **17**, 1249-1255.
- Romero-Aranda, R., Moya, J.L., Tadeo, F.R., Legaz, F., Primo-Millo, E, and Talon, M.**(1998) Physiological and anatomical disturbances induced by chloride salt in sensitive and tolerant citrus: beneficial and detrimental effects of cations. *Plant Cell and Environment*, **21**, 1243-1253.
- Rubio, F., Gassmann, W. and Schroeder JI.** (1995) Sodium-driven potassium uptake by the plant potassium transporter HKT1 and mutations conferring salt tolerance. *Science*.**270**,1660–1663.
- Ryan, J.A., Pahren, H.R, and Lucas, J.B.** (1982) Controlling cadmium in the human food chain: a review and rationale based on health effects. *Environ. Res*, **28**, 251-302.
- Salinas, T., Duchene, A.M., Delage, L., Nilsson, S., Glaser, E., Zaepfel, M. and Marechal-Drouard, L.** (2006) The voltage-dependent anion channel, a major component of the tRNA import machinery in plant mitochondria. *Plant Biology.*, **103**, 18362-18367.
- Salt, D.E. and Wagner, G.J.** (1993) Cadmium transport across tonoplast of vesicles from oat root. Evidence for a  $Cd^{2+}/H^{+}$  antiport activity, *J. Biol. Chem*, **17**, 12297-12302.
- Sanchez-Fernandez, R., Aldiles-Diaz, W., Van Montagu, M., Inze, D. and May, M.J.** (1998) Cloning and expression analyses of AtMRP4, a novel MRP-like gene from *Arabidopsis thaliana*. *Mol. Gen. Genet.*, **258**, 655-662.
- Sandalio, L.M., Dalurzo, H.C., Gomez, M., Romero-Puertas, M.C. and Del-Rio, L.A.** (2001) Cd-induced changes in the growth and oxidative metabolism of pea plants. *J. Exp. Bot*, **52**, 2115-2126.
- Sanders, D., Brownlee, C. and Harper JF.** Communicating with calcium. (1999) *Plant Cell.*; **11**:691–706.
- Sarafian, V., Kim, Y., Poole, R.J. and Rea, P.A.** (1992) Molecular cloning and sequence of cDNA encoding the pyrophosphate-energized vacuolar membrane proton pump of *Arabidopsis thaliana*. *Proc Natl Acad Sci U S A.*, **89**, 1775-1779.
- Sarath, G., Hou, G., Baird, L.M. and Mitchell, R.B.** (2007) Reactive oxygen species, ABA and nitric oxide interactions on the germination of warm season C4-grasses. *Planta*, **226**, 697-708.
- Sauer, M.R.** (1968) Effects of vine rootstock on chloride concentration in *Sultana* scions. *Vitis.*, **7**, 223-226.
- Scheel, C., Zdebik, A.A., Lourdel, S. and Jentsch, T.J.** (2005) Voltage-dependent electrogenic chloride/proton exchange by endosomal CLC proteins. *Nature*. **436**, 424-427.

## References

- Scherese, B., Benfey P. and Dolan L. (2002) Root development. *The Arabidopsis book*. 1-18.
- Schiefelbein, J.W., Masucci, J.D., Wang, H. (1997) Building a root: the control of patterning and morphogenesis during root development. *Plant Cell*. **9**, 1089-1098.
- Schmidt, C. and Schroeder, J.I. (1994) Anion selectivity of slow anion channels in the plasma membrane of guard cells. *Plant Physiology*., **106**, 383-391.
- Schmidt-Rose, T. and Jentsch, T.J. (1997) Transmembrane topology of a Cl<sup>-</sup> chloride channel. *Proc Natl Acad Sci USA*., **94**, 7633-7638.
- Schroeder, J.I. (1995) Anion channels as central mechanisms for signal transduction in guard-cells and putative functions in roots for plant-soil interactions. *Plant Molecular Biology*., **28**, 353-361.
- Schroeder, J.I. and Hagiwara, S. (1989) Cytosolic calcium regulates ion channels in the plasma membrane of *Vicia faba* guard cells. *Nature*, **338**, 427-430.
- Schroeder, J.I. and Keller, B.U. (1992) Two types of anion channel currents in guard cells with distinct voltage regulation. *Proceedings of the National Academy of Sciences*., **89**, 5025-5029.
- Schutzendubel, A., Schwanz, P., Teichmann, T., Gross, K., Langenfeld-Heyser, R., Godbold, D.L. and Polle, A. (2001) Cadmium-induced changes in antioxidative systems, hydrogen peroxide content, and differentiation in Scots pine roots. *Plant Physiology*, **127**, 887-898.
- Scott, A.C. and Allen, N.S. (1999) Changes in Cytosolic pH within *Arabidopsis* root Columella cells play a key role in the early signaling pathway for root gravitropism. *Plant Physiology*., **121**, 1291-1298.
- Segonzac, C., Boyer, J.C., Ipotesi, E., Szponarski, W., Tillard, P., Touraine, B., Sommerer, N., Rossignol, M. and Gibrat, R. (2007) Nitrate efflux at the root plasma membrane: identification of an *Arabidopsis* excretion transporter. *The Plant Cell*. **19**, 3760-3777.
- Serrano, R., Mulet, J.M., Rios, G., de Marquez, J.A., Larrinoa, I., Leube, M.P., Mendizabal, I., Pascual-Ahuir, A., Proft, M., Ros, R. and Montesinos, C. (1999) A glimpse of the mechanisms of ion homeostasis during salt stress. *J. Exp. Bot.*, **50**, 1023-1036.
- Shabala, S., Shabala, L. and Van Volkenburgh, E. (2003) Effect of calcium on root development and root ion fluxes in salinised barley seedlings. *Funct Plant Biol.*, **30**, 507-514.
- Shabala, L., Cuin, T.A. and Newman, I.A. (2005) Salinity-induced ion flux patterns from the excised roots of *Arabidopsis* sos mutants. *Planta*., **222**, 1041-1050.
- Shabala, S.N. and Lew, R.R. (2002) Turgor Regulation in Osmotically Stressed Arabidopsis Epidermal Root Cells. Direct Support for the Role of Inorganic Ion Uptake as Revealed by Concurrent Flux and Cell Turgor Measurements. *Plant Physiol*, **129**, 290-299.
- Shabala, S.N. and Newman I.A. (1997) Proton and calcium flux oscillations in the elongation region correlate with root nutation. *Physiol Plant*. **100**, 917-926
- Sheoran, I., Singal, H. and Singh, R. (1990) Effect of cadmium and nickel on photosynthesis and the enzymes of the photosynthetic carbon reduction cycle in pigeon pea (*Cajanus cajan* L.). *Photosynthesis Research*, **23**, 345-351.
- Showalter, A.M. (1993) Structure and function of plant cell wall proteins. *Plant Cell*. **5**, 9-23.
- Sidler, M., Hassa, P., Hassan, S., Ringli, C. and Dudler, R. (1998) Involvement of an ABC transporter in a developmental pathway regulating hypocotyls cell elongation in the light. *Plant Cell*. **10**, 1632-1636.
- Simons, T.J.B. (1986) The role of anion transport in the passive movement of lead across the human red blood cell membrane. *J. Physiology*, **378**, 287-312.
- Sivaguru, M., Fujiwara, T., Samaj, J., Baluska, F., Yang, Z., Osawa, H., Maeda, T., Mori, T., Volkmann, D. and Matsumoto, H. (2000) Aluminium-induced 1-3-β-D-glucan inhibits cell to cell trafficking of molecules through plasmodesmata. A new mechanism of aluminium toxicity in plants. *Plant Physiology*. **124**, 991-1005.
- Spalding, E.P. (2000) Ion channels and the transduction of light signals. *Plant, Cell, Environment*., **23**, 665-674.

- Staal, M., Elzenga, J.T.M., Van Elk, A.G., Prins, H.B.A. & Van Volkenburgh, E.** (1994) Red and blue light-stimulated proton efflux by epidermal leaf cells of the argenteum mutant of *Pisum sativum*. *J. Exp. Bot.* **45**: 1213-1218.
- Stein, W.D.** (1990) Channel, carriers and pumps, An introduction to membrane transport. *Academic press, San Diego*
- Storey, R., Schachtman, D.P. and Thomas, M.R.** (2003) Root structure and cellular chloride, sodium and potassium distribution in salinized grapevines. *Plant, Cell & Environment.*, **26**, 789-800.
- Stosh, S.J. and Bagchi, D.** (1995) Oxidative mechanisms in the toxicity of metal ions. *Free Radic. Biol. Med.* **18**, 321-336.
- Strompen, G., Dettmer, J., Stierhof, Y.D., Schumacher, K., Jurgens, G. and Mayer, U.** (2004) *Arabidopsis* vacuolar H<sup>+</sup>-ATPase subunit E isoform 1 is required for Golgi organization and vacuole function in embryogenesis. *The Plant Journal.*, **41**, 125-132.
- Su, G.H., Magen, H., Tarchitzky, J. and Kafkafi, U.** (2000) Advances in chloride nutrition of plants. *Advances in Agronomy.*, **68**, 97-150.
- Suh, S.J., Wang, Y.F., Frelet, A., Leonhardt, N., Klein, M., Forestier, C., Mueller-Roeber, B., Cho, M.H., Martinoia, E. and Schroeder, J.I.** (2007) The ATP Binding Cassette Transporter AtMRP5 Modulates Anion and Calcium Channel Activities in *Arabidopsis* Guard Cells. *Cell death and differentiation.*, **282**, 1916-1924.
- Suru, S.M.** (2008) Onion and garlic extracts lessen cadmium-induced nephrotoxicity in rats. *Biometals*, **21**, 623-633.
- Suzuki, N.** (2005) Alleviation by Calcium of Cd-induced root growth inhibition in *Arabidopsis* seedling. *Plant Biotechnolo*, **22**, 19-25.
- Swanson, S.J. and Jones, R.L.** (1996) Gibberellic acid induces vacuolar acidification in barley aleuron. *Plant Cell.*, **8**, 2211-2221.
- Swarup, R., Paula Perry, P., Hagenbeek, D., Der Straeten, D.V., Beemster, G.T.S., Sandberg, G., Bhalerao, R., Ljung, K. and Malcolm J. Bennett, M.J.** (2007) Ethylene upregulates auxin biosynthesis in *Arabidopsis* seedlings to enhance inhibition of root cell elongation. *The Plant Cell* **19**, 2186-2196.
- Sze, H., Li, X. and Palmgren, M.G.** (1999) Energization of plant cell membranes by H<sup>+</sup>-pumping ATPases: regulation and biosynthesis. *The Plant Cell.*, **11**, 677-689.
- Tanner, W. and Caspari.** (1996) Membrane transport carriers. *Annu Rev. Plant physiology: Plant Mol. Bio.* **47**, 595-627.
- Tapper, H. and Sundler, R.** (1995) Protein-Kinase-C and intracellular pH regulate zymosan-induced lysosomal-enzyme secretion in macrophages. *Journal Leukocyte Biology.*, **58**, 485-494.
- Termaat, A. and Munns, R.** (1986) Use of concentrated macronutrient solutions to separate osmotic from NaCl- specific effects on plant growth. *Australian Journal of Plant Physiology.*, **13**, 509-522.
- Thomine, S., Zimmermann, S., Guern, J. and Barbier-Brygoo, H.** (1995) ATP-dependent regulation of an anion channel at the plasma membrane of protoplasts from epidermal cells of *Arabidopsis* hypocotyls. *Plant Cell.*, **7**, 2091-2100.
- Tommasini, R., Vogt, E., Fromenteau, M., Hortensteiner, S., Matile, P., Amrhein, N. and Martinoia, E.** (1998) An ABC-transporter of *Arabidopsis thaliana* has both glutathione-conjugate and chlorophyll catabolite transport activity. *Plant J.* **13**, 773-780.
- Tretyn, A., Wagner, G. and Felle, H.** (1991) signal transduction in *Sinapis alba* root hairs: auxin as external messenger. *Journal of Plant Physiology.*, **139**, 187-193.
- Trewavas, A.** (1999) Le calcium, c'est la vie: calcium makes waves. *Plant Physiol.*, **120**, 1-6.
- Trouverie, J., Vidal, G., Zhang, Z., Sirichandra, C., Madiona, K., Amir Zahia, Prioul, J.L., Jeannette, E., Rona, J.P. and Brault, M.** (2008) Anion channel activation and proton pumping inhibition involved in the plasma membrane depolarization induced by ABA in *Arabidopsis thaliana* suspension cell are both ROS dependent. *Plant Cell Physiology.* **49**, 1495-1507.

## References

- Vahisalu, T., Kollist, H., Wang, Y.F., Nishimura, N., Chan, W.Y., Valerio, G., Lamminmäki, A., Brosché, M., Moldau, H., Desikan, R., Schroeder, J.I. & Kangasjärvi, J.** (2008) SLAC1 is required for plant guard cell S-type anion channel function in stomatal signalling. *Nature*, **452**, 487-491.
- Van der Leij, M., Smith, S.J. and Miller, A.J.** (1998) Remobilisation of vacuolar stored nitrate in barley root cells. *Planta*, **205**, 64-72.
- Vara, F. and Serrano, R.** (1982) Partial purification and properties of the proton-translocating ATPase of plant plasma membranes. *Journal of Biological Chemistry*, **257**, 12826-12830.
- Verbelen, J.P., Vissenberg, K., Kerstens, S. and Le, J.** (2001) Cell expansion in the epidermis: microtubules, cellulose orientation and wall loosening enzymes. *J. of Plant Physiology*, **158**, 537-543.
- Vreeburg, R.A.M., Benschop, J.J., Peeters, A.J., Colmer, T.D., Ammerlaan, A.H., Staal, M., Elzenga, J.T.M., Staals, R.H.J., Darley, C.P., McQueen-Mason, S.J. and Voeselek, L.A.** (2005) Ethylene regulates fast apoplastic acidification and expansin A transcription during submergence-induced petiole elongation in *Rumex palustris*. *Plant J.* **43**, 597-610.
- Wagner, L.H. and Raschke** (1994) Ion channels in the xylem parenchyma of barley roots. A procedure to isolate protoplasts from this tissue and a patch clamp exploration of salt passages into xylem vessels. *Plant Physiology*, **105**, 799-813.
- Ward, J.M., Pei, Z.M., Schroeder, J.I.** (1995) Roles of ion channels in initiation of signal transduction in higher plants. *Plant Cell*, **7**, 833-844.
- Wellhauser, L., Kuo, H.H., Stratford, F.L., Ramjeesingh, M., Huan, L.J., Luong, W., Li, C., Deber, C.M. and Bear, C.E.** (2006) Nucleotides bind to the C-terminus of ClC-5. *Biochem. J.* **398**, 289-294.
- Wellhauser, L., Kuo, H.H., Stratford, F.L., Ramjeesingh, M., Huan, L.J., Luong, W., Li, C., Deber, C.M. and Bear, C.E.** (2006) Nucleotides bind to the C-terminus of ClC-5. *Biochem. J.* **398**, 289-294.
- White, P.J. and Broadley, M.R.** (2001) Chloride in soil and plants. *Annals of Botany*, **967-988**.
- Woll, K.H., Leibowitz, M.K., Neumcke, B. and Hill, B.** (1987) A high-conductance anion channel in adult amphibian skeletal muscle. *European Journal of Physiology*, **410**, 632-640.
- Yamamoto, Y., Hachia, A., Hamada, H. and Matsumoto, H.** (1998) Phenylpropanoids as a protectant of aluminium toxicity in cultured tobacco cells. *Plant Cell Physiology*, **39**, 950-957.
- Yin, J., Kuang, Z., Mahankali, U. and Beck, T.L.** (2004) Ion transit pathways and gating in ClC chloride channels. *Proteins: Structure, Function, and Bioinformatics*, **57**, 414-421.
- Zeiger, E., Bloom, A.J. and Hepler, P.K.** (1978) Ion transport in stomatal guard cells. A chemiosmotic hypothesis. What's new. *Plant Physiol.*, **9**, 29-32.
- Zepeda-Jazo, I., Shabala, S., Chen, Z. and Pottosin, I.I.** (2008) Na<sup>+</sup>-K<sup>+</sup> transport in roots under salt stress. *Plant Signal Behav.* **3**, 401-403.
- Zhang, W.H., Walker, N.A., Patrick, J.W. and Tyerman, S.D.** (2004) Pulsing Cl<sup>-</sup> channels in coat cells of developing bean seeds linked to hypo-osmotic turgor regulation. *J. Exp. Bot.*, **55**, 993-1001.
- Zhu, J.K.** (2002) Salt and drought stress signal transduction in plants. *Annu. Rev. Plant Biology*, **53**, 247-273.
- Zhu, J.K., Liu, J. and Xiong, L.** (1998) Genetic analysis of salt tolerance in *Arabidopsis thaliana*: evidence of a critical role for potassium nutrition. *Plant Cell*, **10**, 1181-1191.
- Zimmermann, S., Ehrhardt, T., Plesch, G. and Muller-Rober, B.** (1999) Ion channels in plant signaling. *Cell Mol Sci.*, **55**, 183-203.
- Zimmermann, S., Frachisse, J.M., Thomine, S., Barbier-Brygoo, H. and Guern, J.** (1998) Elicitor induced chloride influx and anion channels in tobacco cell suspensions. *Plant Physiology and Biochemistry*, **36**, 665-674.