A Family of K⁺ Channel Ancillary Subunits Regulate Taste Sensitivity in Caenorhabditis elegans

Received for publication, March 11, 2005, and in revised form, March 28, 2005
Published, JBC Papers in Press, March 30, 2005, DOI 10.1074/jbc.M502732200

Ki Ho Park, Leonardo Hernandez, Shi-Qing Cai, Yi Wang, and Federico Sestì†
From the Department of Physiology & Biophysics, Robert Wood Johnson Medical School, University of Medicine and Dentistry of New Jersey, Piscataway, New Jersey 08854

We have identified a family of ancillary subunits of K⁺ channels in Caenorhabditis elegans. MPS-1 and its related members MPS-2, MPS-3, and MPS-4 are detected in the nervous system of the nematode. Electrophysiological analysis in ASE neurons and mammalian cells and epigenetic inactivation by double-stranded RNA interference (RNAi) in vivo show that each MPS can associate with and functionally endow the voltage-gated K⁺ channel KVS-1. In the chemosensory neuron ADF, three different MPS subunits combine with KVS-1 to form both binary (MPS-1-KVS-1) and ternary (MPS-2-MPS-3-KVS-1) complexes. RNAi of mps-2, mps-3, or both, enhance the taste of the animal for sodium without altering the susceptibility to other attractants. When sodium is introduced in the test plate as background or as antagonist, the nematode loses the ability to recognize a second attractant. Thus, it appears that the chemosensory apparatus of C. elegans uses sensory thresholds and that a voltage-gated K⁺ channel is specifically required for this mechanism.

Chemosensory function plays a crucial role in the life of the nematode Caenorhabditis elegans. The animal lives in the soil, feeds on bacteria, and adapts to the environment based on chemical cues (1). C. elegans can detect several classes of attractants including salts, amino acids, cyclic nucleotides, and vitamins (2). Chemotaxis to water-soluble attractants is mediated by a group of five bilateral amphid neurons, ASE, ADF, ASG, ASI, and ASK, which are located in the head of the animal (3). Individual amphid neurons can detect multiple cues that are distinguished by the animal (2). It is not clear, however, how the sensory neuron integrates signals corresponding to different attractants to produce a specific output signal and what role of K⁺ currents is in this process. In a previous paper (4) we reported the identification of a voltage-gated A-type K⁺ channel, KVS-1, that is expressed and operates in C. elegans chemosensory neurons. We further found that KVS-1 can be functionally differentiated by assembly with a beta subunit, a KCNE-related peptide termed MPS-1. Amphid neurons have been reported to exhibit a large variety of A-type K⁺ currents (5). Hence, we speculated that single-transmembrane subunits such as MPS-1 might represent a way to generate functional diversity, and we hypothesized that, by analogy with other species (6, 7), MPS-1-related proteins might exist and operate in C. elegans. This effort led us to discover three novel mps members that establish, together with MPS-1, the C. elegans family of KCNE ancillary subunits of K⁺ channels. MPS-2, -3, and -4 are shown to associate with and to modulate the A-type K⁺ current mediated by KVS-1 in vitro and in vivo. Moreover we show that one of these complexes, resulting from the assembly of MPS-2 and MPS-3 with KVS-1, is specifically involved in tuning the responsiveness of the animal for sodium.

MATERIALS AND METHODS

Cloning of MPS-2, MPS-3, and MPS-4—Cloning was performed with a Smart Race kit (Clontech) using poly(A)⁺ mRNA extracted from total C. elegans RNA with a Oligotex kit (Qiagen). cDNA was amplified by PCR and inserted in pCI-neo vector (Promega) for functional expression in Chinese hamster ovary (CHO) cells. All sequences were confirmed by automated DNA sequencing. Transcripts were quantified with spectroscopy and compared with control samples that were separated by agarose gel electrophoresis and stained with ethidium bromide. The novel genes have been assigned the following accession numbers by the Genome Database Nomenclature Committee: AY255666 (mps-2.a), AY255666 (mps-2.b), AY255668 (mps-3), and AY255668 (mps-4).

Construction of Tagged Reporter Fusions to GFP—To obtain transgenic nematodes expressing GFP-tagged MPS-2, MPS-3, and MPS-4, the last ~1 kb of these genes was amplified by PCR from genomic DNA and joined in-frame to the GFP reporter gene in the pPD 95.75 vector (Fire Vector Kit). The reporter constructs and the cosmids were linearized, annealed at 65 °C for 5 min, and co-injected with the transformation marker lin-15(+) into the syncytial gonad of adult hermaphrodite lin-15(−) nematodes at a concentration of 25, 100, and 50 ng/µl, respectively. Five transgenic lines carrying extrachromosomal arrays were identified for each construct. Because the constructs intentionally lack the promoter and the initial methionine, they are not translated without recombination with the cosmid (which contains the entire gene and its promoter). Worms were analyzed and photographed with an Olympus BX61 microscope equipped with a digital camera.

Dye-filling Experiments—To identify amphid neurons, transgenic worms were picked to a plate containing 1,1,3,3-tetramethylindodicarbocyanine, 4-chlorobenzinesulfonate (Molecular Probes) diluted in M9 buffer (0.01 mg/ml), and allowed to stain for 2–3 h at room temperature. Worms were then transferred to an agar plate and allowed to crawl on the bacterial lawn for about 15 min to destain.

RNA Interference—For double-stranded RNA (dsRNA) production, ~0.5-kb regions of mps-2, mps-3, and mps-4 genomic DNA were amplified by PCR with oligonucleotides that added 5′ T7 promoter sequence. dsRNA in vitro synthesis was with MEGAscript kit (Ambion) using the PCR products as templates. The reactions were annealed at 37 °C for 30 min after denaturation (65 °C for 10 min). RNA was analyzed by agarose gel electrophoresis to verify that it was double stranded. Approximately 100 pl of dsRNA (1.5 µg/µl in H₂O) was injected into both gonads of young adults. Worms were allowed to lay the eggs contained

*This work was supported by National Institutes of Health Grant R01GM68851 and American Heart Association Grant 0235470T (to F. S.). The costs of publication of this article were defrayed in part by the payment of page charges. This article must therefore be hereby marked "advertisement" in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.
†To whom correspondence should be addressed: Dept. of Physiology & Biophysics, Robert Wood Johnson Medical School, University of Medicine and Dentistry of New Jersey, 683 Hoes Lane, Piscataway, NJ 08854. E-mail: sestife@umdnj.edu.

The abbreviations used are: CHO, Chinese hamster ovary; GFP, green fluorescent protein; dsRNA, double-stranded RNA; RNAi, RNA interference; ASER neuron, ASE right neuron; CI, chemotaxis index.

‡ To whom correspondence should be addressed: Dept. of Physiology & Biophysics, Robert Wood Johnson Medical School, University of Medicine and Dentistry of New Jersey, 683 Hoes Lane, Piscataway, NJ 08854. E-mail: sestife@umdnj.edu.
in the uterus for 2–3 h and then transferred separately onto fresh plates. F1 progeny of injected worms were analyzed.

Embryonic Cultured Cells—Cultured ASE right (ASER) neurons were prepared from mec-3 strains using a method developed by Christensen et al. (8). Gravid adult worms were lysed using 0.5 mM NaOH and 1% NaOCl. Released eggs were washed three times with sterile egg buffer containing 118 mM NaCl, 48 mM KCl, 2 mM CaCl₂, 2 mM MgCl₂, and 25 mM Hepes (pH 7.3, 340 mosm), and adult carcasses were separated from washed eggs by centrifugation in sterile 30% sucrose. Egg shells were removed by resuspending pelleted eggs in a sterile egg buffer containing 1 unit/ml chitinase at room temperature for 20 min. Embryos were resuspended in L-15 cell culture medium containing 10% fetal bovine serum, 50 units/ml penicillin, and 50 µg/ml streptomycin (Sigma) and dissociated by gentle pipetting. The osmolarity of the culture medium was adjusted to 340 mosM with sucrose and filter-sterilized. Embryo clumps of cells, and larvae were removed from the cell dispersion by filtration. Dissociated cells were plated on glass coverslips previously coated with peanut lectin (0.1 mg/ml) dissolved in water.

Electrophysiology—CHO cells were transiently transfected with cDNA ligated into pcDNA neo using Superfect kit (Qiagen) and studied after 24–36 h. Data were recorded with an Axopatch 200B (Axon), a personal computer (Dell), and Clampex software (Axon); filtered at 1 kHz; and sampled at 2.5 kHz. Bath solution was (in mM) 400 NaCl, 10 Hepes (pH 7.5 with NaOH), 1.8 CaCl₂, and 1.0 MgCl₂. Pipette solution was (in mM) 100 KCl, 10 Hepes (pH 7.5 with KOH), 1.0 MgCl₂, 1.0 CaCl₂, and 10 EGTA (pH 7.5 with KOH). For recording from embryonic cultured cells, bath solution was (in mM) 145 NaCl, 5 KCl, 1 CaCl₂, 1 MgCl₂, 10 Hepes, 100 KCl, 10 Hepes, 0.7 CaCl₂, 2 MgCl₂, 10 Hepes, 100 KCl, 50 units/ml penicillin, and 50 µg/ml streptomycin (Sigma) and dissociated by gentle pipetting. The osmolarity of the culture medium was adjusted to 340 mosM with sucrose and filter-sterilized. Embryo clumps of cells, and larvae were removed from the cell dispersion by filtration. Dissociated cells were plated on glass coverslips previously coated with peanut lectin (0.1 mg/ml) dissolved in water.

RESULTS
Cloning the Family of MPS Proteins—We blasted MPS-1 sequence against the C. elegans genome, and we identified four new MPS-1-related proteins, MPS-2.a and MPS-2.b (K01A2.8.a,b), MPS-3 (T06A4.2), and MPS-4 (F09G8.9), and confirmed their expression and primary sequences by analysis of reverse transcription-PCR products (Fig. 1A). All sequences, with the exception of K01A2.8b, turned out to be as predicted, although a third putative K01A2.8 isoform, K01A2.8.e, was not present in our libraries. Like other KCNE proteins, C. elegans members exhibit the strongest conservation in the transmembrane spanning domain. Overall, however, the C. elegans genes appeared to be more related to each other than to genes of other species.

MPS Proteins Are Expressed in the Nervous System of the Nematode—To determine the cellular expression patterns of the novel genes we constructed transgenic nematodes harboring translational GFP reporter fusions (9). We detected strong MPS-2 signals in the ADF amphid sensory neurons (Fig. 1B). MPS-2 was expressed in the enteric muscle (Fig. 1E), albeit signals were fainter compared with those of ADF cells. MPS-3 was also intensely expressed in ADF neurons (Fig. 1C) and, in addition, in two neurons of the pharynx anterior bulb (Fig. 1F), in PVC and PVN neurons (not shown). MPS-4 was present in the neurons that we tentatively identified as AIA (Fig. 1D) and AUA. The latter have been shown to regulate social feeding behavior (10). Less intense but perceptible MPS-4 signals were also detected in enteric muscle (Fig. 1G) and PVC neurons (not shown).

Each MPS Can Interact with K⁺ Channel KVS-1 in Mammalian Cells—Some cells, including the ADF neurons and the enteric muscle, express the voltage-gated K⁺ channel KVS-1, a previously identified partner for MPS-1 (4). This suggests that in addition to MPS-1 the other members of the family might also interact with this channel. To test whether the novel MPS proteins could work as ion channel subunits we co-expressed them with KVS-1 in Chinese hamster ovary cells and used the whole-cell configuration of the patch clamp to characterize currents. Each MPS altered the characteristics of the current, suggesting interaction (Fig. 2A). Fig. 2B shows the peak current density at +120 mV of KVS-1 alone and with each of the four MPS subunits (MPS-2.b gave results similar to the “a” isoforms, not shown). MPS-1 and MPS-4 inhibited the current roughly 3–5-fold, and MPS-3 increased this quantity significantly (3-fold). Inactivation, a physiologically relevant characteristic of A-type channels, was also affected by the MPS proteins (Fig. 2C). The time course of inactivation at +120 mV, fitted to a single exponential, varied from τ = 50 ms for channels formed with MPS-3 to τ = 7 ms with MPS-4, a 7-fold change. Recovery from inactivation was quantified by using a 1.2-s and a 0.2-s depolarizing pulse at +60 mV spaced out by progressively longer periods at −80 mV. Recovery was slowed down by MPS-3 and speeded up by the other members (Fig. 2D). Moreover, MPS-1 and MPS-3 co-immunoprecipitated with KVS-1 (not shown), suggesting the formation of stable complexes between the pore-forming subunit and the MPS accessory proteins.

KVS-1 Forms Functional Complexes with the MPS Proteins in Native Cells—To corroborate the notion that KVS-1 and the MPS proteins form functional complexes in native cells we recorded currents from cultured C. elegans ASE neurons (8) that express KVS-1 and MPS-1 (4). Cells were obtained from P_gcy-5:gfp nematodes that express GFP in the ASE right neuron under the guanylyl cyclase gene gcy-5 promoter (11). To our knowledge, specific markers for other cells expressing KVS-1 and the MPS proteins such as ADF neurons are not currently available, and further, the GFP fluorescence of cells cultured from mps-2::gfp or mps-3::gfp transformants was not sufficiently intense to allow reliable identification using our patch clamp microscope. Voltage pulses from −80 mV to +80 mV evoked robust outward currents (Fig. 3A) that reversed at −44.3 ± 9.1 mV. Unlike untreated neurons, cells created by kvs-1 RNAi (Fig. 3B) or mps-1 RNAi (Fig. 3C) were characterized by slow activation and lack of inactivation (Fig. 3D). Treatment by RNAi (Fig. 3E) or application of 10 mM 4-aminopyridine (not shown) led to an ~35% decrease of the peak current suggesting, first, that a MPS-1/KVS-1 channel complex is functional in ASE neurons, and second, that knockdown of each subunit is sufficient to destabilize the entire channel. We showed previously (4), that mps-1 RNAi in kvs-1::gfp animals (that express full KVS-1 proteins fused to GFP) suppressed KVS-1 signals only in the neurons in which the two subunits co-localized, and similar effects were observed with kvs-1 RNAi in mps-1::gfp strains (see also Fig. 4, B and C). Moreover RNAi had no effect on transgenic strains expressing transcriptional reporters (P_kvs-1::gfp, and P_mps-1::gfp) that express GFP protein driven by kvs-1 or mps-1 promoter sequences (not shown), indicating that RNAi does not interfere with gene transcript-
tion. Probably, if two subunits are assembled in the rough endoplasmic reticulum, disruption of one subunit is sufficient to interrupt the biosynthesis of the complex. Because it is reasonable to assume that the assembly of KVS-1 with the other MPS subunits follows a route similar to that of MPS-1 we used the RNAi method to detect subunit-subunit interactions in native neurons. Thus, kvs-1 RNAi suppressed mps-2:gfp and mps-3:gfp fluorescence in ADF neurons (Fig. 4, A, D, and E), and mps-2 and mps-3 RNAi also affected kvs-1:gfp signals in the same neurons albeit to a lesser extent (Fig. 4B). Moreover, kvs-1 RNAi was very effective against mps-4:gfp signals in AUA and vice versa (not shown). Thus, each MPS appears to be

FIG. 1. The C. elegans family of MPS proteins localize in the nervous system of the animal. A, MPS proteins sequences and alignments. The red, green, and blue colors indicate identical, strongly similar, and weakly similar residues respectively. Sequence alignment was obtained by ClustalW analysis (available at npsa-pbil.ibcp.fr). B–D, fluorescent microscopy images taken from mps-2:gfp, mps-3:gfp, and mps-4:gfp transgenic nematode heads. In these focal plans GFP fluorescence (arrows) is detectable in ADF (MPS-2 and MPS-3) and AIA (MPS-4) neurons. Fluorescence in the intestine is due to endogenous rhodamin granules. Expression in ADF amphid neurons was confirmed by 1,1′-dioctadecyl-3,3,3′,3′-tetramethylindocarbocyanine, 4-chlorobenzenesulfonate staining (under “Materials and Methods”). E, MPS-2 expression in the enteric muscle (arrow); F, MPS-3 fluorescence in a neuron of the pharynx anterior bulb (arrow); G, MPS-4, likewise MPS-2, is expressed in the enteric muscle (arrow).
**Fig. 2.** *C. elegans* MPS proteins endow KVS-1 in heterologous expression systems. CHO cells were transiently transfected with KVS-1 alone or with MPS-X cDNAs and studied after 24–36 h. Currents were elicited by voltage jumps from −80 mV to +120 mV in 20-mV increments and 1-s interpulse intervals, filtered at 1.0 kHz, and sampled at 2.5 kHz. A, whole-cell current envelopes recorded from cells expressing KVS-1 alone or with MPS-1, MPS-2, MPS-3, and MPS-4, respectively. B, peak current densities obtained by normalizing peak currents at +120 mV to the cell capacitance. Each bar represents averages from groups of 20 cells or more. Statistically significant differences from KVS-1 currents are indicated with *, p ≤ 0.01, and **, p ≤ 0.001 (unpaired t tests). C, inactivation rates for KVS-1 alone (●), +MPS-1 (○), +MPS-2 (□), +MPS-3 (△), and +MPS-4 (▲) at various voltages. Time constants were calculated by fitting macroscopic currents to a single exponential function, \( I_0 + I_1 \exp(-t/\tau) \), with \( \tau = 40 \pm 3, 17 \pm 2, 30 \pm 5, 50 \pm 5, \) and \( 7 \pm 2 \) ms for KVS-1 alone or with MPS-1, MPS-2, MPS-3, and MPS-4, respectively. Data are from groups of 20 or more cells. D, dependence of the normalized peak current on the length of the recovery phase for KVS-1 alone and with the MPS proteins. Data are from groups of 7–11 cells. Data were fitted to a single exponential function with \( \tau = 8.7 \pm 0.3, 16.4 \pm 0.9, 15.4 \pm 1.1, 5.9 \pm 0.2, \) and 21.3 ± 1.3 ms, for KVS-1 alone or with MPS-1, MPS-2, MPS-3, and MPS-4 respectively.

**Fig. 3.** A MPS-1-KVS-1 complex is functional in ASER neurons. A, whole-cell currents recorded from cultured ASER neurons. Currents were elicited by voltage jumps from −80 mV to +80 mV in 20-mV increments. B–C, same as in A from cells incubated with kvs-1 or mps-1 dsRNA (15 μg/ml). D, macroscopic currents could be fitted to a single exponential function, \( I_0 + I_1 \exp(-t/\tau) \) (inset). Time constants for control (○, 9 cells) or for cells incubated with kvs-1 RNAi (●, 8 cells) or mps-1 RNAi (■, 4 cells). E, I-V relationships for peak currents measured 30 ms after voltage stimulation from control (9 cells) or from cells incubated with kvs-1 RNAi (8 cells) or mps-1 RNAi (4 cells). Peak currents were normalized to the steady-state value calculated at the end of the voltage jump.
MPS-3 and KVS-1 (Fig. 5), whereas inactivation kinetics were similar to that of binary complexes formed by the functional ternary complex. Therefore, these sensory cells represented an optimal system to investigate the interactions between the MPS and KVS-1 channels. The current model for chemotaxis to water-soluble attractants predicts that this sensory function is controlled by a network of five amphid neurons organized hierarchically (1, 12). Thus a single pair of neurons, the ASEs, determine the primary response, and the group composed by the remaining four pairs, ADF ASG, ASI, and ASK, mediate a residual response (3). To elucidate the physiological role of K+ channels formed by the assembly of MPS-1, MPS-2, MPS-3, and KVS-1 in ADF neurons we evaluated the ability of animals treated by RNAi to recognize classic attractants such as Na+, Cl−, cAMP, biotin, and lysine. Inactivation of mps-1 or mps-3, which is expressed in several neurons of the network including the ASE pair, leads to defective chemotaxis to these cues (4). In contrast, mps-2 and mps-3, or mps-2 + mps-3 RNAi did not alter susceptibility to Cl−, cAMP, biotin, and lysine (Fig. 6A). These nematodes exhibited an unexpected behavior, however, in that their taste for Na+ was enhanced (Fig. 6B). Co-injection of dsRNAs encoding mps-2 and mps-3 did not further augment Na+ sensibility, suggesting that the two subunits contribute similarly to this behavior probably as...
parts of the same channel complex. Moreover, when mps-2 was co-injected with mps-1 the nematodes retained the phenotype of mps-1 animals. We explain the dominant effect of mps-1 by the fact that this gene is expressed in several neurons of the network including the ASE pair (4). The broad MPS-1 expression pattern also limited our ability to further dissect the specific role of this complex in ADF neurons. Fig. 6C shows that mps-2 nematodes were more responsive to lower Na\(^{+}\) gradients than were wild-type animals. When the concentration was increased, however, both groups exhibited the same phenotype. Thus, the chemosensory apparatus of C. elegans is such that it can detect few sodium ions (2) (~700,000 ions/mm\(^2\) in a 1.0 \(\mu\)M sodium acetate agar medium), but a behavioral response is triggered only above a certain threshold. We next sought to evaluate the impact of lowering the sodium threshold on the other sensory activities. In a first group of experiments we
KCNE proteins are an emerging family of accessory subunits of K+ channels. The ubiquity of their expression together with the ability to assemble with multiple K+ channels (13) underscores a potentially very important role of these proteins in human physiology. In fact, mutations in KCNE1, KCNE2, KCNE3, and KCNE5 genes have been linked to congenital and acquired disease (6, 14–17). Several analogies appear to exist between the acquired disease (6, 14–17). Several analogies appear to exist between the KCNE accessory subunits and the mammalian subfamilies. Like human KCNE proteins that individually assemble with the voltage-gated K+ channel KCNQ1 (18–23), each MPS endows KVS-1. We suggest that this class of ancillary subunits is an integral part of K+ channels and that these subunits probably operate through conserved mechanisms.

C. elegans MPS proteins can form ternary complexes with KVS-1, that is, complexes containing more than one MPS member. It is interesting to note that the subunit composition of ternary complexes appears to be tightly regulated because combinations such as MPS-1/MPS-2 and MPS-1/MPS-3 are apparently forbidden. The existence of these complexes is an observation relevant to mammalian physiology because it raises the possibility that the KCNE proteins that have been shown to associate individually with KCNQ1 might also form ternary complexes in human tissues (18–23). For instance Lundquist et al. (24) recently speculated that in human heart, a balance of KCNE accessory subunits may be important for cardiac K(V) channel function.

ACKNOWLEDGMENTS—We thank Dr. Lenard for helpful comments and Drs. Monica Driscoll and Martha Soto for advice. Cinzia Sesti helped with the graphics, and Suk-Mei Kwok was involved in the cloning effort. The gcy-5::gfp strain was a gift of Dr. Cornelia Bargmann.

REFERENCES

1. Bargmann, C., and Mori, I. (1997) in C. elegans II (Riddle, D. L., Blumenthal, T., Meyer, B. J., and Priess, J. R., eds) Vol. 1, pp. 717–737, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY
2. Ward, S. (1973) Proc. Natl. Acad. Sci. U. S. A. 70, 817–821
3. Bargmann, C. I., and Horvitz, H. R. (1993) Neuron 7, 729–742
4. Bistochi, L., Kwok, S. M., Driscoll, M., and Sesti, F. (2003) J. Biol. Chem. 278, 12145–121424
5. Goodman, M., Hall, D., Avery, L., and Lockery, S. (1998) Neuron 20, 763–772
6. Abbott, G., Sesti, F., Sipavski, I., Buck, M., Lehman, M., Timothy, K., Keating, M., and Goldstein, S. (1999) Cell 97, 175–187
7. Anantharam, A., Lewis, A., Pauaghie, G., Gordon, E., McCrossan, Z. A., Lerner, P. B., and Lockery, S. (2001) Neuron 33, 503–514
8. Mello, C. C., Kramer, J. M., Stinchcomb, D., and Ambros, V. (1991) EMBO J. 10, 3699–3700
9. De Bono, M., Tobin, D., Davis, M. A., Avery, L., and Bargmann, C. I. (2002) Nature 419, 899–903
10. Yu, S., Avery, L., Baude, E., and Garbers, D. (1997) Proc. Natl. Acad. Sci. U. S. A. 94, 3334–3338
11. Pierce-Simomura, J., Faumont, S., Gaston, M., Pearson, B., and Lockery, S. (2001) Nature 410, 694–698
12. McCrossan, Z. A., and Abbott, G. W. (2004) Neuropharmacology 47, 787–821
13. Abbott, G., Butler, M., Bendahhou, S., Dalaks, M., Pteacek, L., and Goldstein, S. (2001) Cell 104, 217–231
14. Sipavski, I., Ptaszynski, P. R., Lehman, M. H., Sanguinetti, M. C., and Keating, M. T. (1997) Nature 384, 338–340
15. Sesti, F., Abbott, G. W., Wei, J., Murray, K. T., Saksena, S., Schwartz, P. J., Priori, S. G., Roden, D. M., George, A. L., Jr., and Goldstein, S. A. (2000) Proc. Natl. Acad. Sci. U. S. A. 97, 10613–10618
16. Piccin, M., Vitelli, F., Sieri, M., Gallietta, L., Moran, O., Bullone, A., Banfi, S., Pobar, B., and Renieri, A. (1999) Genomics 60, 251–257
17. Barbanin, J., Lesage, F., Guillemare, E., Fink, M., Lazdunski, M., and Boulanger, C. G. (1996) Nature 384, 78–80
18. Sanguinetti, M. C., Curran, M. E., Zou, A., Shen, J., Spector, P. S., Atkinson, D. L., and Keating, M. T. (1996) Nature 384, 80–83
19. Schroeder, B., Waldeger, S., Fehr, S., Bleich, M., Warth, R., Gregor, B., and Jentsch, T. (2000) Nature 403, 196–199
20. Tinel, N., Duchot, S., Borsotti, M., Lazdunski, M., and Barhanin, J. (2000) EMBO J. 19, 6326–6339
21. Grunnet, M., Rasmussen, H. B., Hay-Schmidt, A., Rosenstierne, M., Klaerke, D. A., Olesen, S. P., and Jespersen, T. (2003) Biophys. J. 85, 1525–1537
22. Grunnet, M., Rasmussen, H. B., Hay-Schmidt, A., Rosenstierne, M., Klaerke, D. A., Olesen, S. P., and Jespersen, T. (2003) Biophys. J. 85, 1525–1537
23. Olesen, S. P., and Jespersen, T. (2002) Biophys. J. 83, 1997–2006
24. Lundquist, A. L., Manderfield, L. J., Vanoye, C. G., Rogers, C. S., Donahue, B. S., Chang, P. A., Drinkwater, D. C., Murray, K. T., and George, A. L., Jr. (2005) J. Mol. Cell Cardiol. 39, 277–287
A Family of K\(^+\) Channel Ancillary Subunits Regulate Taste Sensitivity in *Caenorhabditis elegans*

Ki Ho Park, Leonardo Hernandez, Shi-Qing Cai, Yi Wang and Federico Sesti

*J. Biol. Chem. 2005, 280:21893-21899.*

doi: 10.1074/jbc.M502732200 originally published online March 30, 2005

Access the most updated version of this article at doi: 10.1074/jbc.M502732200

Alerts:
- When this article is cited
- When a correction for this article is posted

Click here to choose from all of JBC's e-mail alerts

This article cites 24 references, 6 of which can be accessed free at [http://www.jbc.org/content/280/23/21893.full.html#ref-list-1](http://www.jbc.org/content/280/23/21893.full.html#ref-list-1)