ANTI-ASIC1 ANTIBODIES AND USES THEREOF

FIELD OF THE INVENTION

[0001] The present invention relates to antibodies, and antigen-binding fragments thereof, which are specific for human ASIC1, and methods of use thereof.

BACKGROUND

[0002] Acid sensing ion channels (ASICs) are proton-gated cationic channels expressed in the central and peripheral nervous systems. The ASIC family in humans includes ASIC1, ASIC2, ASIC3 and ASIC4 subunits which arrange into homo- or heteromultimeric ion channels in neuronal membranes. ASIC1, ASIC2 and ASIC3 are significantly expressed in the small and medium nociceptive sensory neurons that are able to detect noxious chemical, thermal, and high threshold mechanical stimuli. ASIC2 and ASIC3 are also expressed in large neurons that mostly correspond to low threshold mechanoreceptors.

[0003] ASICs are permeable to Na^+ and Ca^{2+} ions and are activated by external pH variations ranging from pH 6.8 to 4.0. ASICs are believed to play an important role in sensing local acidosis. Local tissue acidosis is a hallmark of pain and inflammation, and inflamed tissues frequently exhibit low pH (as low as ~4.7). Blockage of ASICs has been proposed as a method for treating a variety of disorders and conditions. Blockage of ASIC1 in particular has been proposed as a means for treating conditions such as pain, neurodegenerative diseases, and psychiatric diseases.

[0004] Pharmacologic inhibitors of ASIC1 include the tarantula peptide Psalmotoxin-1 (PcTx1) which specifically inhibits ASIC1 homomers, and the small molecule, non-selective ASIC inhibitors amiloride and A-317567. The 40 amino acid peptide toxin APETx2, isolated from sea anemone, has been shown to inhibit ASIC3 homomers as well as ASIC3/1 and ASIC3/2 heteromers.

[0005] Currently, there are no known antibodies that specifically block ASICs. Thus, there is a need in the art for novel ASIC inhibitors, such as anti-ASIC1 antibodies, that can be used to treat diseases and conditions mediated by ASIC signaling.

BRIEF SUMMARY OF THE INVENTION

[0006] The present invention provides antibodies that specifically bind human ASIC1, including, *e.g.*, antibodies that specifically bind cell surface-expressed ASIC1. The antibodies of the present invention, according to certain embodiments, inhibit acid-induced, ASIC1-mediated ion currents in cells expressing human ASIC1. The antibodies of the invention are useful, *inter alia*, for inhibiting ASIC1-mediated signaling and for treating diseases and disorders caused by or related to ASIC1 activity and/or signaling. For example, the antibodies of the present invention can be administered to a patient for the treatment or alleviation of pain and related conditions.

[0007] The antibodies of the invention can be full-length (for example, an IgG1 or IgG4 antibody) or may comprise only an antigen-binding portion (for example, a Fab, $F(ab')_2$ or scFv fragment), and may be modified to affect functionality, e.g., to eliminate residual effector functions (Reddy et al., 2000, J. Immunol. 164:1925-1933).

[0008] The present invention provides an antibody or antigen-binding fragment of an antibody comprising a heavy chain variable region (HCVR) having an amino acid sequence selected from the group consisting of SEQ ID NO: 2, 18, 34, 50, 66, 82, 98, 114, 130, 146, 162, 178, 194, 210, 226, 242, 258, 274, 290, 306, 322, 338, 354, 370, and 386, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0009] The present invention also provides an antibody or antigen-binding fragment of an antibody comprising a light chain variable region (LCVR) having an amino acid sequence selected from the group consisting of SEQ ID NO: 10, 26, 42, 58, 74, 90, 106, 122, 138, 154, 170, 186, 202, 218, 234, 250, 266, 282, 298, 314, 330, 346, 362, 378, and 394, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0010] The present invention also provides an antibody or antigen-binding fragment thereof comprising a HCVR and LCVR (HCVR/LCVR) sequence pair selected from the group consisting of SEQ ID NO: 2/10, 18/26, 34/42, 50/58, 66/74, 82/90, 98/106, 114/122, 130/138, 146/154, 162/170, 178/186, 194/202, 210/218, 226/234, 242/250, 258/266, 274/282, 290/298, 306/314, 322/330, 338/346, 354/362, 370/378, and 386/394.

[0011] The present invention also provides an antibody or antigen-binding fragment of an antibody comprising a heavy chain CDR3 (HCDR3) domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 8, 24, 40, 56, 72, 88, 104, 120, 136, 152, 168, 184, 200, 216, 232, 248, 264, 280, 296, 312, 328, 344, 360, 376, and 392, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; and a light chain CDR3 (LCDR3) domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, 240, 256, 272, 288, 304, 320, 336, 352, 368, 384, and 400, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0012] In certain embodiments, the antibody or antigen-binding portion of an antibody comprises a HCDR3/LCDR3 amino acid sequence pair selected from the group consisting of SEQ ID NO: 8/16, 24/32, 40/48, 56/64, 72/80, 88/96, 104/112, 120/128, 136/144, 152/160, 168/176, 184/192, 200/208, 216/224, 232/240, 248/256, 264/272, 280/288, 296/304, 312/320, 328/336, 344/352, 360/368, 376/384, and 392/400.

[0013] The present invention also provides an antibody or fragment thereof further comprising a heavy chain CDR1 (HCDR1) domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 4, 20, 36, 52, 68, 84, 100, 116, 132, 148, 164, 180, 196, 212, 228,

244, 260, 276, 292, 308, 324, 340, 356, 372, and 388, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; a heavy chain CDR2 (HCDR2) domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 6, 22, 38, 54, 70, 86, 102, 118, 134, 150, 166, 182, 198, 214, 230, 246, 262, 278, 294, 310, 326, 342, 358, 374, and 390, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; a light chain CDR1 (LCDR1) domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 12, 28, 44, 60, 76, 92, 108, 124, 140, 156, 172, 188, 204, 220, 236, 252, 268, 284, 300, 316, 332, 348, 364, 380, and 396, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; and a light chain CDR2 (LCDR2) domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 14, 30, 46, 62, 78, 94, 110, 126, 142, 158, 174, 190, 206, 222, 238, 254, 270, 286, 302, 318, 334, 350, 366, 382, and 398, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0014] Certain non-limiting, exemplary antibodies and antigen-binding fragments of the invention comprise HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3 domains, respectively, having the amino acid sequences selected from the group consisting of: SEQ ID NOs: 4-6-8-12-14-16 (*e.g.* H1M6712N); 20-22-24-28-30-32 (*e.g.* H1M6716N); 36-38-40-44-46-48 (*e.g.* H1M6718N); 52-54-56-60-62-64 (*e.g.* H1M7101N); 68-70-72-76-78-80 (*e.g.* H2M7103N); 84-86-88-92-94-96 (*e.g.* H3M6713N); 100-102-104-108-110-112 (*e.g.* H3M6715N); 116-118-120-124-126-128 (*e.g.* H3M6720N); 132-134-136-140-142-144 (*e.g.* H3M6721N); 148-150-152-156-158-160 (*e.g.*, H3M6721N2); 164-166-168-172-174-176 (*e.g.* H3M6726N); 180-182-184-188-190-192 (*e.g.*, H3M6760N); 196-198-200-204-206-208 (*e.g.* H3M7102N); 212-214-216-220-222-224 (*e.g.* H3M7118N); 228-230-232-236-238-240 (*e.g.* H4H6362P); 244-246-248-252-254-256 (*e.g.* H4H6363P); 260-262-264-268-270-272 (*e.g.* H4H6364P); 276-278-280-284-286-288 (*e.g.* H4H6366P); 292-294-296-300-302-304 (*e.g.* H4H6372P); 308-310-312-316-318-320 (*e.g.* H4H6374P); 324-326-328-332-334-336 (*e.g.* H4H6375P); 340-342-344-348-350-352 (*e.g.* H4H6379P); 356-358-360-364-366-368 (*e.g.* H4H6380P); 372-374-376-380-382-384 (*e.g.* H4H6381P); and 388-390-392-396-398-400 (*e.g.* H4H6383P).

[0015] In a related embodiment, the invention includes an antibody or antigen-binding fragment of an antibody which specifically binds ASIC1 (*e.g.*, cell surface-expressed ASIC1), wherein the antibody or fragment comprises the heavy and light chain CDR domains contained within heavy and light chain variable region (HCVR/LCVR) sequences selected from the group consisting of SEQ ID NO: 2/10, 18/26, 34/42, 50/58, 66/74, 82/90, 98/106, 114/122, 130/138, 146/154, 162/170, 178/186, 194/202, 210/218, 226/234, 242/250, 258/266, 274/282, 290/298, 306/314, 322/330, 338/346, 354/362, 370/378, and 386/394. Methods and techniques for identifying CDRs within HCVR and LCVR amino acid sequences are well known in the art and can be used to identify CDRs within the specified HCVR and/or LCVR amino acid sequences

disclosed herein. Exemplary conventions that can be used to identify the boundaries of CDRs include, *e.g.*, the Kabat definition, the Chothia definition, and the AbM definition. In general terms, the Kabat definition is based on sequence variability, the Chothia definition is based on the location of the structural loop regions, and the AbM definition is a compromise between the Kabat and Chothia approaches. *See, e.g.*, Kabat, "Sequences of Proteins of Immunological Interest," National Institutes of Health, Bethesda, Md. (1991); Al-Lazikani *et al.*, *J. Mol. Biol. 273*:927-948 (1997); and Martin *et al.*, *Proc. Natl. Acad. Sci. USA 86*:9268-9272 (1989). Public databases are also available for identifying CDR sequences within an antibody.

[0016] In another aspect, the invention provides nucleic acid molecules encoding anti-ASIC1 antibodies or fragments thereof. Recombinant expression vectors carrying the nucleic acids of the invention, and host cells into which such vectors have been introduced, are also encompassed by the invention, as are methods of producing the antibodies by culturing the host cells under conditions permitting production of the antibodies, and recovering the antibodies produced.

[0017] In one embodiment, the invention provides an antibody or fragment thereof comprising a HCVR encoded by a nucleic acid sequence selected from the group consisting of SEQ ID NO: 1, 17, 33, 49, 65, 81, 97, 113, 129, 145, 161, 177, 193, 209, 225, 241, 257, 273, 289, 305, 321, 337, 353, 369, and 385, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof.

[0018] The present invention also provides an antibody or fragment thereof comprising a LCVR encoded by a nucleic acid sequence selected from the group consisting of SEQ ID NO: 9, 25, 41, 57, 73, 89, 105, 121, 137, 153, 169, 185, 201, 217, 233, 249, 265, 281, 297, 313, 329, 345, 361, 377, and 393, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof.

[0019] The present invention also provides an antibody or antigen-binding fragment of an antibody comprising a HCDR3 domain encoded by a nucleotide sequence selected from the group consisting of SEQ ID NO: 7, 23, 39, 55, 71, 87, 103, 119, 135, 151, 167, 183, 199, 215, 231, 247, 263, 279, 295, 311, 327, 343, 359, 375, and 391, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof; and a LCDR3 domain encoded by a nucleotide sequence selected from the group consisting of SEQ ID NO: 15, 31, 47, 63, 79, 95, 111, 127, 143, 159, 175, 191, 207, 223, 239, 255, 271, 287, 303, 319, 335, 351, 367, 383, and 399, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof.

[0020] The present invention also provides an antibody or fragment thereof which further comprises a HCDR1 domain encoded by a nucleotide sequence selected from the group consisting of SEQ ID NO: 3, 19, 35, 51, 67, 83, 99, 115, 131, 147, 163, 179, 195, 211, 227, 243, 259, 275, 291, 307, 323, 339, 355, 371, and 387, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof; a HCDR2 domain

encoded by a nucleotide sequence selected from the group consisting of SEQ ID NO: 5, 21, 37, 53, 69, 85, 101, 117, 133, 149, 165, 181, 197, 213, 229, 245, 261, 277, 293, 309, 325, 341, 357, 373, and 389, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof; a LCDR1 domain encoded by a nucleotide sequence selected from the group consisting of SEQ ID NO: 11, 27, 43, 59, 75, 91, 107, 123, 139, 155, 171, 187, 203, 219, 235, 251, 267, 283, 299, 315, 331, 347, 363, 379, and 395, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof; and a LCDR2 domain encoded by a nucleotide sequence selected from the group consisting of SEQ ID NO: 13, 29, 45, 61, 77, 93, 109, 125, 141, 157, 173, 189, 205, 221, 237, 253, 269, 285, 301, 317, 333, 349, 365, 381, and 397, or a substantially identical sequence having at least 90%, at least 95%, at least 98%, or at least 99% homology thereof.

[0021] According to certain embodiments, the antibody or fragment thereof comprises the heavy and light chain CDR sequences encoded by the nucleic acid sequences of SEQ ID NOs: 1 and 9 (*e.g.* H1M6712N), 17 and 25 (*e.g.* H1M6716N), 33 and 41 (*e.g.* H1M6718N), 49 and 57 (*e.g.* H1M7101N), 65 and 73 (*e.g.* H2M7103N), 81 and 89 (*e.g.* H3M6713N), 97 and 105 (*e.g.* H3M6715N), 113 and 121 (*e.g.* H3M6720N), 129 and 137 (*e.g.* H3M6721N), 145 and 153 (*e.g.* H3M6721N2), 161 and 169 (*e.g.* H3M6726N), 177 and 185 (*e.g.* H3M6760N), 193 and 201 (*e.g.* H3M7102N), 209 and 217 (*e.g.* H3M7118N), 225 and 233 (*e.g.* H4H6362P), 241 and 249 (*e.g.* H4H6363P), 257 and 265 (*e.g.* H4H6364P), 273 and 281 (*e.g.* H4H6366P), 289 and 297 (*e.g.* H4H6372P), 305 and 313 (*e.g.* H4H6374P), 321 and 329 (*e.g.* H4H6375P), 337 and 345 (*e.g.* H4H6379P), 353 and 361 (*e.g.* H4H6380P), 369 and 377 (*e.g.* H4H6381P), 385 and 393 (*e.g.* H4H6383P).

[0022] The present invention includes anti-ASIC1 antibodies having a modified glycosylation pattern. In some applications, modification to remove undesirable glycosylation sites may be useful, or an antibody lacking a fucose moiety present on the oligosaccharide chain.

[0023] In another aspect, the invention provides a pharmaceutical composition comprising a recombinant human antibody or fragment thereof which specifically binds ASIC1 (*e.g.*, cell surface-expressed ASIC1) and a pharmaceutically acceptable carrier. In a related aspect, the invention features a composition which is a combination of an anti-ASIC1 antibody and a second therapeutic agent. In one embodiment, the second therapeutic agent is any agent that is advantageously combined with an anti-ASIC1 antibody. Exemplary agents that may be advantageously combined with an anti-ASIC1 antibody include, without limitation, other agents that inhibit ASIC1 activity (including other antibodies or antigen-binding fragments thereof, peptide inhibitors, small molecule antagonists, etc) and/or agents which do not directly bind ASIC1 but nonetheless interfere with, block or attenuate ASIC1-mediated ion currents in cells.

[0024] In yet another aspect, the invention provides methods for inhibiting ASIC1-mediated ion currents using an anti-ASIC1 antibody or antigen-binding portion of an antibody of the invention, wherein the therapeutic methods comprise administering a therapeutically effective

amount of a pharmaceutical composition comprising an antibody or antigen-binding fragment of an antibody of the invention. The disorder treated is any disease or condition which is improved, ameliorated, inhibited or prevented by removal, inhibition or reduction of ASIC1-mediated ion currents. The anti-ASIC1 antibodies or antibody fragments of the invention may function to block acid-induced ASIC1-mediated currents, or otherwise inhibit the signaling activity of ASIC1.

[0025] The present invention also includes the use of an anti-ASIC1 antibody or antigen binding portion of an antibody of the invention in the manufacture of a medicament for the treatment of a disease or disorder related to or caused by ASIC1-mediated ion currents in a patient.

[0026] Other embodiments will become apparent from a review of the ensuing detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0027] **Figure 1** depicts the withdrawal thresholds of mice treated with an anti-ASIC1 antibody (H1M6718N), or isotype control antibody, in response to a mechanical pinch of the tail (panel A) or the gastrocnemius muscle (panel B). Results are expressed in terms of withdrawal threshold to the pinch in grams (mean ± SEM for each cohort of mice).

[0028] **Figure 2** shows the percent change in the withdrawal threshold from baseline in acidic saline-induced muscle hyperalgesia in mice treated with an anti-ASIC1 antibody (H1M6718N) or isotype control.

[0029] **Figure 3 (panels A and B)** show the percent change in the withdrawal threshold from baseline in carrageenan-induced muscle hyperalgesia in mice treated with anti-ASIC1 antibody (H1M6718N, 10 or 40 mg/kg - **panel A**; or H4H6721N2 10 or 30 mg/kg - **panel B**), or isotype control.

[0030] **Figure 4** shows the extent of taxol-induced tactile allodynia over time in taxol-administered mice that were treated with either 30 mg/kg (s.c.) of an isotype control antibody, 30 mg/kg (s.c.) of H1M6718N, or 100 mg/kg (s.c.) of gabapentin. Results are expressed in terms of withdrawal threshold (g) as measured using Von Frey fibers (as described in Example 10).

DETAILED DESCRIPTION

[0031] Before the present invention is described, it is to be understood that this invention is not limited to particular methods and experimental conditions described, as such methods and conditions may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0032] Unless defined otherwise, all technical and scientific terms used herein have the same

meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. As used herein, the term "about," when used in reference to a particular recited numerical value, means that the value may vary from the recited value by no more than 1%. For example, as used herein, the expression "about 100" includes 99 and 101 and all values in between (*e.g.*, 99.1, 99.2, 99.3, 99.4, etc.).

[0033] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described.

Definitions

[0034] The expressions "ASIC1" and "ASIC1 fragment," as used herein refer to the human ASIC1 protein or fragment unless specified as being from a non-human species (*e.g.*, "mouse ASIC1," "mouse ASIC1 fragment," "monkey ASIC1," "monkey ASIC1 fragment," etc.). Human ASIC1 has the amino acid as set forth in SEQ ID NO:401). The expression "ASIC1," as used herein, includes soluble fragments of the ASIC1 extracellular domain (*e.g.*, polypeptides comprising or consisting of at least 30 contiguous amino acids found within amino acids 63 to 424 of SEQ ID NO:401), as well as cell surface-expressed ASIC1 (as that term is defined herein below).

[0035] As used herein, "an antibody that binds ASIC1" or an "anti-ASIC1 antibody" includes antibodies, and antigen-binding fragments thereof, that bind a soluble fragment of an ASIC1 protein (*e.g.*, a portion of the extracellular domain of ASIC1) and/or cell surface-expressed ASIC1. The expression "cell surface-expressed ASIC1" means one or more ASIC1 protein(s) that is/are expressed on the surface of a cell *in vitro* or *in vivo*, such that at least a portion of the ASIC1 protein (*e.g.*, amino acids 63 to 424 of SEQ ID NO:401) is exposed to the extracellular side of the cell membrane and accessible to an antigen-binding portion of an antibody. "Cell surface-expressed ASIC1" includes ASIC1 protein contained within the context of a functional ASIC1 ion channel in the membrane of a cell. In some instances, "cell surface-expressed ASIC1" is an ASIC1 protein that is expressed as part of a heteromultimer on the surface of a cell (*e.g.*, an ASIC1/2, ASIC1/3 or ASIC1/4 heteromultimer). In other instances, "cell surface-expressed ASIC1" is an ASIC1 protein that is expressed as part of a homomultimer on the surface of a cell. Moreover, "cell surface-expressed ASIC1" can comprise or consist of ASIC1 protein expressed on the surface of a cell which normally expressed ASIC1 protein. Alternatively, "cell surface-expressed ASIC1" can comprise or consist of ASIC1 protein expressed on the surface of a cell that normally does not express human ASIC1 on its surface but has been artificially engineered to express ASIC1 on its surface.

[0036] The term "antibody", as used herein, means any antigen-binding molecule or molecular complex comprising at least one complementarity determining region (CDR) that specifically binds to or interacts with a particular antigen (*e.g.*, ASIC1). The term "antibody" includes

immunoglobulin molecules comprising four polypeptide chains, two heavy (H) chains and two light (L) chains inter-connected by disulfide bonds, as well as multimers thereof (*e.g.*, IgM). Each heavy chain comprises a heavy chain variable region (abbreviated herein as HCVR or V_H) and a heavy chain constant region. The heavy chain constant region comprises three domains, C_H1, C_H2 and C_H3. Each light chain comprises a light chain variable region (abbreviated herein as LCVR or V_L) and a light chain constant region. The light chain constant region comprises one domain (C_L1). The V_H and V_L regions can be further subdivided into regions of hypervariability, termed complementarity determining regions (CDRs), interspersed with regions that are more conserved, termed framework regions (FR). Each V_H and V_L is composed of three CDRs and four FRs, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4. In different embodiments of the invention, the FRs of the anti-ASIC1 antibody (or antigen-binding portion thereof) may be identical to the human germline sequences, or may be naturally or artificially modified. An amino acid consensus sequence may be defined based on a side-by-side analysis of two or more CDRs.

[0037] The term "antibody", as used herein, also includes antigen-binding fragments of full antibody molecules. The terms "antigen-binding portion" of an antibody, "antigen-binding fragment" of an antibody, and the like, as used herein, include any naturally occurring, enzymatically obtainable, synthetic, or genetically engineered polypeptide or glycoprotein that specifically binds an antigen to form a complex. Antigen-binding fragments of an antibody may be derived, *e.g.*, from full antibody molecules using any suitable standard techniques such as proteolytic digestion or recombinant genetic engineering techniques involving the manipulation and expression of DNA encoding antibody variable and optionally constant domains. Such DNA is known and/or is readily available from, *e.g.*, commercial sources, DNA libraries (including, *e.g.*, phage-antibody libraries), or can be synthesized. The DNA may be sequenced and manipulated chemically or by using molecular biology techniques, for example, to arrange one or more variable and/or constant domains into a suitable configuration, or to introduce codons, create cysteine residues, modify, add or delete amino acids, etc.

[0038] Non-limiting examples of antigen-binding fragments include: (i) Fab fragments; (ii) F(ab')2 fragments; (iii) Fd fragments; (iv) Fv fragments; (v) single-chain Fv (scFv) molecules; (vi) dAb fragments; and (vii) minimal recognition units consisting of the amino acid residues that mimic the hypervariable region of an antibody (*e.g.*, an isolated complementarity determining region (CDR) such as a CDR3 peptide), or a constrained FR3-CDR3-FR4 peptide. Other engineered molecules, such as domain-specific antibodies, single domain antibodies, domain-deleted antibodies, chimeric antibodies, CDR-grafted antibodies, diabodies, triabodies, tetrabodies, minibodies, nanobodies (*e.g.* monovalent nanobodies, bivalent nanobodies, etc.), small modular immunopharmaceuticals (SMIPs), and shark variable IgNAR domains, are also encompassed within the expression "antigen-binding fragment," as used herein.

[0039] An antigen-binding fragment of an antibody will typically comprise at least one variable

domain. The variable domain may be of any size or amino acid composition and will generally comprise at least one CDR which is adjacent to or in frame with one or more framework sequences. In antigen-binding fragments having a V_H domain associated with a V_L domain, the V_H and V_L domains may be situated relative to one another in any suitable arrangement. For example, the variable region may be dimeric and contain V_H-V_H, V_H-V_L or V_L-V_L dimers. Alternatively, the antigen-binding fragment of an antibody may contain a monomeric V_H or V_L domain.

[0040] In certain embodiments, an antigen-binding fragment of an antibody may contain at least one variable domain covalently linked to at least one constant domain. Non-limiting, exemplary configurations of variable and constant domains that may be found within an antigen-binding fragment of an antibody of the present invention include: (i) V_H-C_H1; (ii) V_H-C_H2; (iii) V_H-C_H3; (iv) V_H-C_H1-C_H2; (v) V_H-C_H1-C_H2-C_H3; (vi) V_H-C_H2-C_H3; (vii) V_H-C_L; (viii) V_L-C_H1; (ix) V_L-C_H2; (x) V_L-C_H3; (xi) V_L-C_H1-C_H2; (xii) V_L-C_H1-C_H2-C_H3; (xiii) V_L-C_H2-C_H3; and (xiv) V_L-C_L. In any configuration of variable and constant domains, including any of the exemplary configurations listed above, the variable and constant domains may be either directly linked to one another or may be linked by a full or partial hinge or linker region. A hinge region may consist of at least 2 (*e.g.*, 5, 10, 15, 20, 40, 60 or more) amino acids which result in a flexible or semi-flexible linkage between adjacent variable and/or constant domains in a single polypeptide molecule. Moreover, an antigen-binding fragment of an antibody of the present invention may comprise a homo-dimer or hetero-dimer (or other multimer) of any of the variable and constant domain configurations listed above in non-covalent association with one another and/or with one or more monomeric V_H or V_L domain (*e.g.*, by disulfide bond(s)).

[0041] As with full antibody molecules, antigen-binding fragments may be monospecific or multispecific (*e.g.*, bispecific). A multispecific antigen-binding fragment of an antibody will typically comprise at least two different variable domains, wherein each variable domain is capable of specifically binding to a separate antigen or to a different epitope on the same antigen. Any multispecific antibody format, including the exemplary bispecific antibody formats disclosed herein, may be adapted for use in the context of an antigen-binding fragment of an antibody of the present invention using routine techniques available in the art.

[0042] The term "human antibody", as used herein, is intended to include antibodies having variable and constant regions derived from human germline immunoglobulin sequences. The human antibodies of the invention may include amino acid residues not encoded by human germline immunoglobulin sequences (e.g., mutations introduced by random or site-specific mutagenesis *in vitro* or by somatic mutation *in vivo*), for example in the CDRs and in particular CDR3. However, the term "human antibody", as used herein, is not intended to include antibodies in which CDR sequences derived from the germline of another mammalian species, such as a mouse, have been grafted onto human framework sequences.

[0043] The term "recombinant human antibody", as used herein, is intended to include all

human antibodies that are prepared, expressed, created or isolated by recombinant means, such as antibodies expressed using a recombinant expression vector transfected into a host cell (described further below), antibodies isolated from a recombinant, combinatorial human antibody library (described further below), antibodies isolated from an animal (e.g., a mouse) that is transgenic for human immunoglobulin genes (see e.g., Taylor et al. (1992) Nucl. Acids Res. 20:6287-6295) or antibodies prepared, expressed, created or isolated by any other means that involves splicing of human immunoglobulin gene sequences to other DNA sequences. Such recombinant human antibodies have variable and constant regions derived from human germline immunoglobulin sequences. In certain embodiments, however, such recombinant human antibodies are subjected to *in vitro* mutagenesis (or, when an animal transgenic for human Ig sequences is used, *in vivo* somatic mutagenesis) and thus the amino acid sequences of the V_H and V_L regions of the recombinant antibodies are sequences that, while derived from and related to human germline V_H and V_L sequences, may not naturally exist within the human antibody germline repertoire *in vivo*.

[0044] Human antibodies can exist in two forms that are associated with hinge heterogeneity. In one form, an immunoglobulin molecule comprises a stable four chain construct of approximately 150-160 kDa in which the dimers are held together by an interchain heavy chain disulfide bond. In a second form, the dimers are not linked via inter-chain disulfide bonds and a molecule of about 75-80 kDa is formed composed of a covalently coupled light and heavy chain (half-antibody). These forms have been extremely difficult to separate, even after affinity purification.

[0045] The frequency of appearance of the second form in various intact IgG isotypes is due to, but not limited to, structural differences associated with the hinge region isotype of the antibody. A single amino acid substitution in the hinge region of the human IgG4 hinge can significantly reduce the appearance of the second form (Angal et al. (1993) Molecular Immunology 30:105) to levels typically observed using a human IgG1 hinge. The instant invention encompasses antibodies having one or more mutations in the hinge, C_H2 or C_H3 region which may be desirable, for example, in production, to improve the yield of the desired antibody form.

[0046] An "isolated antibody," as used herein, means an antibody that has been identified and separated and/or recovered from at least one component of its natural environment. For example, an antibody that has been separated or removed from at least one component of an organism, or from a tissue or cell in which the antibody naturally exists or is naturally produced, is an "isolated antibody" for purposes of the present invention. An isolated antibody also includes an antibody *in situ* within a recombinant cell. Isolated antibodies are antibodies that have been subjected to at least one purification or isolation step. According to certain embodiments, an isolated antibody may be substantially free of other cellular material and/or chemicals.

[0047] A "neutralizing" or "blocking" antibody, as used herein, is intended to refer to an antibody whose binding to ASIC1 reduces or detectably inhibits acid-induced ASIC1-mediated ion currents. The inhibition caused by an ASIC1 neutralizing or blocking antibody need not be complete so long as it is detectable using an appropriate assay. Exemplary assays for detecting ASIC1 inhibition are described elsewhere herein.

[0048] The anti-ASIC1 antibodies disclosed herein may comprise one or more amino acid substitutions, insertions and/or deletions in the framework and/or CDR regions of the heavy and light chain variable domains as compared to the corresponding germline sequences from which the antibodies were derived. Such mutations can be readily ascertained by comparing the amino acid sequences disclosed herein to germline sequences available from, for example, public antibody sequence databases. The present invention includes antibodies, and antigen-binding fragments thereof, which are derived from any of the amino acid sequences disclosed herein, wherein one or more amino acids within one or more framework and/or CDR regions are mutated to the corresponding residue(s) of the germline sequence from which the antibody was derived, or to the corresponding residue(s) of another human germline sequence, or to a conservative amino acid substitution of the corresponding germline residue(s) (such sequence changes are referred to herein collectively as "germline mutations"). A person of ordinary skill in the art, starting with the heavy and light chain variable region sequences disclosed herein, can easily produce numerous antibodies and antigen-binding fragments which comprise one or more individual germline mutations or combinations thereof. In certain embodiments, all of the framework and/or CDR residues within the V_H and/or V_L domains are mutated back to the residues found in the original germline sequence from which the antibody was derived. In other embodiments, only certain residues are mutated back to the original germline sequence, *e.g.*, only the mutated residues found within the first 8 amino acids of FR1 or within the last 8 amino acids of FR4, or only the mutated residues found within CDR1, CDR2 or CDR3. In other embodiments, one or more of the framework and/or CDR residue(s) are mutated to the corresponding residue(s) of a different germline sequence (*i.e.*, a germline sequence that is different from the germline sequence from which the antibody was originally derived). Furthermore, the antibodies of the present invention may contain any combination of two or more germline mutations within the framework and/or CDR regions, *e.g.*, wherein certain individual residues are mutated to the corresponding residue of a particular germline sequence while certain other residues that differ from the original germline sequence are maintained or are mutated to the corresponding residue of a different germline sequence. Once obtained, antibodies and antigen-binding fragments that contain one or more germline mutations can be easily tested for one or more desired property such as, improved binding specificity, increased binding affinity, improved or enhanced antagonistic or agonistic biological properties (as the case may be), reduced immunogenicity, etc. Antibodies and antigen-binding fragments obtained in this general manner are encompassed within the present invention.

[0049] The present invention also includes anti-ASIC1 antibodies comprising variants of any of the HCVR, LCVR, and/or CDR amino acid sequences disclosed herein having one or more conservative substitutions. For example, the present invention includes anti-ASIC1 antibodies having HCVR, LCVR, and/or CDR amino acid sequences with, *e.g.*, 10 or fewer, 8 or fewer, 6 or fewer, 4 or fewer, etc. conservative amino acid substitutions relative to any of the HCVR, LCVR, and/or CDR amino acid sequences disclosed herein.

[0050] The term "epitope" refers to an antigenic determinant that interacts with a specific antigen binding site in the variable region of an antibody molecule known as a paratope. A single antigen may have more than one epitope. Thus, different antibodies may bind to different areas on an antigen and may have different biological effects. Epitopes may be either conformational or linear. A conformational epitope is produced by spatially juxtaposed amino acids from different segments of the linear polypeptide chain. A linear epitope is one produced by adjacent amino acid residues in a polypeptide chain. In certain circumstance, an epitope may include moieties of saccharides, phosphoryl groups, or sulfonyl groups on the antigen.

[0051] The term "substantial identity" or "substantially identical," when referring to a nucleic acid or fragment thereof, indicates that, when optimally aligned with appropriate nucleotide insertions or deletions with another nucleic acid (or its complementary strand), there is nucleotide sequence identity in at least about 95%, and more preferably at least about 96%, 97%, 98% or 99% of the nucleotide bases, as measured by any well-known algorithm of sequence identity, such as FASTA, BLAST or Gap, as discussed below. A nucleic acid molecule having substantial identity to a reference nucleic acid molecule may, in certain instances, encode a polypeptide having the same or substantially similar amino acid sequence as the polypeptide encoded by the reference nucleic acid molecule.

[0052] As applied to polypeptides, the term "substantial similarity" or "substantially similar" means that two peptide sequences, when optimally aligned, such as by the programs GAP or BESTFIT using default gap weights, share at least 95% sequence identity, even more preferably at least 98% or 99% sequence identity. Preferably, residue positions which are not identical differ by conservative amino acid substitutions. A "conservative amino acid substitution" is one in which an amino acid residue is substituted by another amino acid residue having a side chain (R group) with similar chemical properties (e.g., charge or hydrophobicity). In general, a conservative amino acid substitution will not substantially change the functional properties of a protein. In cases where two or more amino acid sequences differ from each other by conservative substitutions, the percent sequence identity or degree of similarity may be adjusted upwards to correct for the conservative nature of the substitution. Means for making this adjustment are well-known to those of skill in the art. *See, e.g.*, Pearson (1994) Methods Mol. Biol. 24: 307-331. Examples of groups of amino acids that have side chains with similar chemical properties include (1) aliphatic side chains: glycine, alanine, valine, leucine and isoleucine; (2) aliphatic-hydroxyl side chains: serine and threonine; (3) amide-containing side

chains: asparagine and glutamine; (4) aromatic side chains: phenylalanine, tyrosine, and tryptophan; (5) basic side chains: lysine, arginine, and histidine; (6) acidic side chains: aspartate and glutamate, and (7) sulfur-containing side chains are cysteine and methionine. Preferred conservative amino acids substitution groups are: valine-leucine-isoleucine, phenylalanine-tyrosine, lysine-arginine, alanine-valine, glutamate-aspartate, and asparagine-glutamine. Alternatively, a conservative replacement is any change having a positive value in the PAM250 log-likelihood matrix disclosed in Gonnet *et al.* (1992) Science 256: 1443-1445. A "moderately conservative" replacement is any change having a nonnegative value in the PAM250 log-likelihood matrix.

[0053] Sequence similarity for polypeptides, which is also referred to as sequence identity, is typically measured using sequence analysis software. Protein analysis software matches similar sequences using measures of similarity assigned to various substitutions, deletions and other modifications, including conservative amino acid substitutions. For instance, GCG software contains programs such as Gap and Bestfit which can be used with default parameters to determine sequence homology or sequence identity between closely related polypeptides, such as homologous polypeptides from different species of organisms or between a wild type protein and a mutein thereof. *See, e.g.*, GCG Version 6.1. Polypeptide sequences also can be compared using FASTA using default or recommended parameters, a program in GCG Version 6.1. FASTA (e.g., FASTA2 and FASTA3) provides alignments and percent sequence identity of the regions of the best overlap between the query and search sequences (Pearson (2000) supra). Another preferred algorithm when comparing a sequence of the invention to a database containing a large number of sequences from different organisms is the computer program BLAST, especially BLASTP or TBLASTN, using default parameters. *See, e.g.*, Altschul *et al.* (1990) J. Mol. Biol. 215:403-410 and Altschul *et al.* (1997) Nucleic Acids Res. 25:3389-402.

Biological Characteristics of the Antibodies

[0054] The present invention includes antibodies that specifically bind cell surface expressed ASIC1. As used herein, an antibody specifically binds cell surface expressed ASIC1 if the antibody shows detectable binding to a cell that naturally or artificially expresses ASIC1 but does not show detectable binding to an equivalent cell that does not express ASIC1. One exemplary assay format that can be used to determine whether an antibody specifically binds cell surface-expressed ASIC1 is fluorescence activated cell sorting (FACS), as illustrated in Example 3 herein. Qualitative positive FACS binding of an antibody to cells which express ASIC1, as shown in Table 2, can be used to identify an antibody as specifically binding cell surface-expressed ASIC1. FACS can also be used to quantitatively assess antibody binding to cell which express ASIC1 in terms of an EC_{50} value, as shown in Example 3, Table 3. Thus, according to certain embodiments of the present invention, an antibody "specifically binds cell surface-expressed ASIC1" if the antibody, when tested in the FACS assay format of Example 3

or a substantially similar assay format, exhibits an EC_{50} value of about 5 nM or less (*e.g.*, about 5.0 nM, 4.5 nM, 4.0 nM, 3.5 nM, 3.0 nM, 2.5 nM, 2.0 nM, 1.5 nM, 1.4 nM, 1.3 nM, 1.2 nM, 1.1 nM, 1.0 nM, 900 pM, 800 pM, 700 pM, 600 pM, 500 pM, 400 pM, 300 pM, 200 pM, 100 pM, 90 pM, 85 pM, 80 pM, 75 pM, 70 pM, or less).

[0055] The antibodies of the present invention, according to certain embodiments, may also (or alternatively) function to inhibit acid-induced, ASIC1-mediated ion currents in cells expressing human ASIC1. As used herein, the expression "inhibits acid-induced, ASIC1-mediated ion currents" means that, in an assay in which acid-induced cellular ion currents or flux can be detected and/or quantified, the addition of an antibody of the invention detectably reduces or inhibits the acid-induced ion currents as compared to the ion currents observed in the absence of the antibody (*e.g.*, in the presence of a non-specific negative control antibody). A non-limiting exemplary assay that can be used to determine if an antibody "inhibits acid-induced, ASIC1-mediated ion currents" is illustrated in Example 4 herein. In this Example, low pH-activated calcium flux is measured in ASIC1-expressing cells in the presence of anti-ASIC1 antibodies ("FLIPR assay"). By varying the amount of antibody used in this assay format, the amount of antibody required to block 50% of low pH-induced ion flux can be calculated and expressed as an IC_{50} value (*see, e.g.*, Example 4, Table 5). The present invention includes anti-ASIC1 antibodies that inhibit acid-induced, ASIC1-mediated ion currents with an IC_{50} of less than about 10 nM when tested in a FLIPR assay at pH of about 5.0 to about 6.0 (*e.g.*, at pH 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, or 6.0) as described above, or a substantially similar assay. For example, the invention includes anti-ASIC1 antibodies that exhibit an IC_{50} of less than about 9 nM, 8 nM, 7 nM, 6 nM, 5 nM, 4 nM, 3 nM, 2 nM, 1 nM, 0.9 nM, 0.8 nM, 0.7 nM, 0.6 nM, 0.5 nM, 0.4 nM, 0.3 nM, 0.2 nM, 0.1 nM, or less, when tested in a FLIPR assay at pH 5.5 as described above, or a substantially similar assay.

[0056] Other exemplary assay formats that can be used to determine whether an antibody "inhibits acid-induced, ASIC1-mediated ion currents" are illustrated in Examples 5 and 6 herein. In these Examples, automated voltage-clamp, patch-clamp assays are used to measure and/or assess the inhibition of current flux in cells that express ASIC1 at acidic pH in the presence of an anti-ASIC1 antibody, as compared to the current flux observed under equivalent circumstances in the absence of the antibody (*e.g.*, in the presence of a non-specific negative control antibody). An antibody is deemed to "inhibit acid-induced, ASIC1-mediated ion currents" if the antibody, when tested in a voltage-clamp, patch-clamp assay at an antibody concentration of about 1 nM to about 100 nM, at a pH of about 5.0 to about 6.0 (*e.g.*, at pH 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, or 6.0), causes at least a 10% current inhibition (*e.g.*, at least about 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, or greater inhibition of current flux; *see, e.g.*, Example 5, Table 6). In some instances, the antibodies of the invention completely inhibit current flux (100% inhibition) at 10 nM or higher (*e.g.*, 100 nM), when tested in a patch-clamp assay format as described above, or

a substantially similar assay.

[0057] The present invention also includes antibodies that inhibit or reduce pain response(s) in various animal pain models. Exemplary animal pain models useful for characterizing the anti-ASIC1 antibodies of the present invention are illustrated in Examples 7-9, herein. For example, the present invention includes anti-ASIC1 antibodies that attenuate or inhibit pain responses to acid-induced visceral pain in a mouse model. (*see, e.g.*, Example 7). In particular, the present invention includes anti-ASIC1 antibodies that exhibit at least a 20% inhibition of visceral pain responses (*e.g.*, abdominal constrictions in response to an intraperitoneal injection of 0.6% acetic acid) when administered at a dose of about 1 or 10 mg/kg to a mouse model as shown in Example 7, or a substantially similar model. In certain instances, the percent inhibition in pain responses due to the administration of an antibody of the present invention can be as high as about 30%, 35%, 40%, 45%, 50%, or higher when tested in the mouse animal pain model of Example 7, or a substantially similar model. Other animal pain models that can be used to characterize the anti-ASIC antibodies of the present invention include, *e.g.*, the mechanical nociception pain response models of Example 8, the muscle pain models of Example 9, and other similar animal models available in the art. Thus, the present invention includes anti-ASIC1 antibodies capable of attenuating or inhibiting pain responses to noxious mechanical stimuli (*see, e.g.*, Example 8); and/or acidic-saline- or carrageenan-induced muscle hyperalgesia (*see, e.g.*, Example 9), as demonstrated in appropriate animal models as exemplified herein.

Epitope Mapping and Related Technologies

[0058] The present invention includes anti-ASIC1 antibodies which interact with one or more amino acids found within the extracellular domain of human ASIC1 (amino acids 63 to 424 of SEQ ID NO:401). The epitope to which the antibodies bind may consist of a single contiguous sequence of 3 or more (*e.g.*, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 or more) amino acids located within the extracellular domain of ASIC1. Alternatively, the epitope may consist of a plurality of non-contiguous amino acids (or amino acid sequences) located within the extracellular domain of ASIC1.

[0059] Various techniques known to persons of ordinary skill in the art can be used to determine whether an antibody "interacts with one or more amino acids" within a polypeptide or protein. Exemplary techniques include, *e.g.*, routine cross-blocking assay such as that described Antibodies, Harlow and Lane (Cold Spring Harbor Press, Cold Spring Harb., NY), alanine scanning mutational analysis, peptide blots analysis (Reineke, 2004, Methods Mol Biol 248:443-463), and peptide cleavage analysis. In addition, methods such as epitope excision, epitope extraction and chemical modification of antigens can be employed (Tomer, 2000, Protein Science 9:487-496). Another method that can be used to identify the amino acids within a polypeptide with which an antibody interacts is hydrogen/deuterium exchange detected by mass spectrometry. In general terms, the hydrogen/deuterium exchange method involves

deuterium-labeling the protein of interest, followed by binding the antibody to the deuterium-labeled protein. Next, the protein/antibody complex is transferred to water to allow hydrogen-deuterium exchange to occur at all residues except for the residues protected by the antibody (which remain deuterium-labeled). After dissociation of the antibody, the target protein is subjected to protease cleavage and mass spectrometry analysis, thereby revealing the deuterium-labeled residues which correspond to the specific amino acids with which the antibody interacts. *See, e.g.*, Ehring (1999) *Analytical Biochemistry* 267(2):252-259; Engen and Smith (2001) *Anal. Chem. 73*:256A-265A.

[0060] The present invention further includes anti-ASIC1 antibodies that bind to the same epitope as any of the specific exemplary antibodies described herein (*e.g.* H1M6712N, H1M6716N, H1M6718N, H1M7101N, H2M7103N, H3M6713N, H3M6715N, H3M6720N, H3M6721N, H3M6721N2, H3M6726N, H3M6760N, H3M7102N, H3M7118N, H4H6362P, H4H6363P, H4H6364P, H4H6366P, H4H6372P, H4H6374P, H4H6375P, H4H6379P, H4H6380P, H4H6381P, H4H6383P etc.). Likewise, the present invention also includes anti-ASIC1 antibodies that compete for binding to ASIC1 or to cell surface-expressed ASIC1 with any of the specific exemplary antibodies described herein (*e.g.* H1M6712N, H1M6716N, H1M6718N, H1M7101N, H2M7103N, H3M6713N, H3M6715N, H3M6720N, H3M6721N, H3M6721N2, H3M6726N, H3M6760N, H3M7102N, H3M7118N, H4H6362P, H4H6363P, H4H6364P, H4H6366P, H4H6372P, H4H6374P, H4H6375P, H4H6379P, H4H6380P, H4H6381P, H4H6383P etc.).

[0061] One can easily determine whether an antibody binds to the same epitope as, or competes for binding with, a reference anti-ASIC1 antibody by using routine methods known in the art. For example, to determine if a test antibody binds to the same epitope as a reference anti-ASIC1 antibody of the invention, the reference antibody is allowed to bind to an ASIC1 protein (*e.g.*, cell surface-expressed ASIC1). Next, the ability of a test antibody to bind to the ASIC1 molecule is assessed. If the test antibody is able to bind to ASIC1 following saturation binding with the reference anti-ASIC1 antibody, it can be concluded that the test antibody binds to a different epitope than the reference anti-ASIC1 antibody. On the other hand, if the test antibody is not able to bind to the ASIC1 molecule following saturation binding with the reference anti-ASIC1 antibody, then the test antibody may bind to the same epitope as the epitope bound by the reference anti-ASIC1 antibody of the invention. Additional routine experimentation (*e.g.*, peptide mutation and binding analyses) can then be carried out to confirm whether the observed lack of binding of the test antibody is in fact due to binding to the same epitope as the reference antibody or if steric blocking (or another phenomenon) is responsible for the lack of observed binding. Experiments of this sort can be performed using ELISA, RIA, Biacore, flow cytometry or any other quantitative or qualitative antibody-binding assay available in the art. In accordance with certain embodiments of the present invention, two antibodies bind to the same (or overlapping) epitope if, *e.g.*, a 1-, 5-, 10-, 20- or 100-fold

excess of one antibody inhibits binding of the other by at least 50% but preferably 75%, 90% or even 99% as measured in a competitive binding assay (see, e.g., Junghans et al., Cancer Res. 1990:50:1495-1502). Alternatively, two antibodies are deemed to bind to the same epitope if essentially all amino acid mutations in the antigen that reduce or eliminate binding of one antibody reduce or eliminate binding of the other. Two antibodies are deemed to have "overlapping epitopes" if only a subset of the amino acid mutations that reduce or eliminate binding of one antibody reduce or eliminate binding of the other.

[0062] To determine if an antibody competes for binding with a reference anti-ASIC1 antibody, the above-described binding methodology is performed in two orientations: In a first orientation, the reference antibody is allowed to bind to an ASIC1 molecule (*e.g.*, cell surface-expressed ASIC1) under saturating conditions followed by assessment of binding of the test antibody to the ASIC1 molecule. In a second orientation, the test antibody is allowed to bind to an ASIC1 molecule under saturating conditions followed by assessment of binding of the reference antibody to the ASIC1 molecule. If, in both orientations, only the first (saturating) antibody is capable of binding to the ASIC1 molecule, then it is concluded that the test antibody and the reference antibody compete for binding to ASIC1. As will be appreciated by a person of ordinary skill in the art, an antibody that competes for binding with a reference antibody may not necessarily bind to the same epitope as the reference antibody, but may sterically block binding of the reference antibody by binding an overlapping or adjacent epitope.

Preparation of Human Antibodies

[0063] Methods for generating monoclonal antibodies, including fully human monoclonal antibodies are known in the art. Any such known methods can be used in the context of the present invention to make human antibodies that specifically bind to human ASIC1.

[0064] Using VELOCIMMUNE™ technology or any other known method for generating monoclonal antibodies, high affinity chimeric antibodies to ASIC1 are initially isolated having a human variable region and a mouse constant region. As in the experimental section below, the antibodies are characterized and selected for desirable characteristics, including affinity, selectivity, epitope, etc. The mouse constant regions are replaced with a desired human constant region to generate the fully human antibody of the invention, for example wild-type or modified IgG1 or IgG4. While the constant region selected may vary according to specific use, high affinity antigen-binding and target specificity characteristics reside in the variable region.

Bioequivalents

[0065] The anti-ASIC1 antibodies and antibody fragments of the present invention encompass proteins having amino acid sequences that vary from those of the described antibodies but that retain the ability to bind human ASIC1. Such variant antibodies and antibody fragments comprise one or more additions, deletions, or substitutions of amino acids when compared to

parent sequence, but exhibit biological activity that is essentially equivalent to that of the described antibodies. Likewise, the anti-ASIC1 antibody-encoding DNA sequences of the present invention encompass sequences that comprise one or more additions, deletions, or substitutions of nucleotides when compared to the disclosed sequence, but that encode an anti-ASIC1 antibody or antibody fragment that is essentially bioequivalent to an anti-ASIC1 antibody or antibody fragment of the invention. Examples of such variant amino acid and DNA sequences are discussed above.

[0066] Two antigen-binding proteins, or antibodies, are considered bioequivalent if, for example, they are pharmaceutical equivalents or pharmaceutical alternatives whose rate and extent of absorption do not show a significant difference when administered at the same molar dose under similar experimental conditions, either single does or multiple dose. Some antibodies will be considered equivalents or pharmaceutical alternatives if they are equivalent in the extent of their absorption but not in their rate of absorption and yet may be considered bioequivalent because such differences in the rate of absorption are intentional and are reflected in the labeling, are not essential to the attainment of effective body drug concentrations on, e.g., chronic use, and are considered medically insignificant for the particular drug product studied.

[0067] In one embodiment, two antigen-binding proteins are bioequivalent if there are no clinically meaningful differences in their safety, purity, and potency.

[0068] In one embodiment, two antigen-binding proteins are bioequivalent if a patient can be switched one or more times between the reference product and the biological product without an expected increase in the risk of adverse effects, including a clinically significant change in immunogenicity, or diminished effectiveness, as compared to continued therapy without such switching.

[0069] In one embodiment, two antigen-binding proteins are bioequivalent if they both act by a common mechanism or mechanisms of action for the condition or conditions of use, to the extent that such mechanisms are known.

[0070] Bioequivalence may be demonstrated by in vivo and in vitro methods. Bioequivalence measures include, e.g., (a) an in vivo test in humans or other mammals, in which the concentration of the antibody or its metabolites is measured in blood, plasma, serum, or other biological fluid as a function of time; (b) an in vitro test that has been correlated with and is reasonably predictive of human in vivo bioavailability data; (c) an in vivo test in humans or other mammals in which the appropriate acute pharmacological effect of the antibody (or its target) is measured as a function of time; and (d) in a well-controlled clinical trial that establishes safety, efficacy, or bioavailability or bioequivalence of an antibody.

[0071] Bioequivalent variants of anti-ASIC1 antibodies of the invention may be constructed by, for example, making various substitutions of residues or sequences or deleting terminal or internal residues or sequences not needed for biological activity. For example, cysteine

residues not essential for biological activity can be deleted or replaced with other amino acids to prevent formation of unnecessary or incorrect intramolecular disulfide bridges upon renaturation. In other contexts, bioequivalent antibodies may include anti-ASIC1 antibody variants comprising amino acid changes which modify the glycosylation characteristics of the antibodies, *e.g.*, mutations which eliminate or remove glycosylation.

Species Selectivity and Species Cross-Reactivity

[0072] According to certain embodiments of the invention, the anti-ASIC1 antibodies bind to human ASIC1 but not to ASIC1 from other species. The present invention also includes anti-ASIC1 antibodies that bind to human ASIC1 and to ASIC1 from one or more non-human species. For example, the anti-ASIC1 antibodies of the invention may bind to human ASIC1 and may bind or not bind, as the case may be, to one or more of mouse, rat, guinea pig, hamster, gerbil, pig, cat, dog, rabbit, goat, sheep, cow, horse, camel, cynomologous, marmoset, rhesus or chimpanzee ASIC1. The present invention also includes anti-ASIC1 antibodies that selectively block acid-induced ion currents through human ASIC1 channels (but not through non-human ASIC1 channels). Alternatively, according to certain embodiments, anti-ASIC1 antibodies are provided that block acid-induced ion currents through human ASIC1 channels as well as through non-human (*e.g.*, mouse, rat, etc.) ASIC1 channels (*See, e.g.*, Example 5, herein).

Immunoconjugates

[0073] The invention encompasses anti-ASIC1 monoclonal antibodies conjugated to a therapeutic moiety ("immunoconjugate"), such as a cytotoxin, a chemotherapeutic drug, an immunosuppressant or a radioisotope. Cytotoxic agents include any agent that is detrimental to cells. Examples of suitable cytotoxic agents and chemotherapeutic agents for forming immunoconjugates are known in the art, (see for example, WO 05/103081).

Multispecific Antibodies

[0074] The antibodies of the present invention may be monospecific, bi-specific, or multispecific. Multispecific antibodies may be specific for different epitopes of one target polypeptide or may contain antigen-binding domains specific for more than one target polypeptide. See, e.g., Tutt et al., 1991, J. Immunol. 147:60-69; Kufer *et al.*, 2004, Trends Biotechnol. 22:238-244. The anti-ASIC1 antibodies of the present invention can be linked to or co-expressed with another functional molecule, e.g., another peptide or protein. For example, an antibody or fragment thereof can be functionally linked (e.g., by chemical coupling, genetic fusion, noncovalent association or otherwise) to one or more other molecular entities, such as another antibody or antibody fragment to produce a bi-specific or a multispecific antibody with a second binding specificity. For example, the present invention includes bi-specific antibodies wherein one arm of an immunoglobulin is specific for human ASIC1 or a fragment thereof, and

the other arm of the immunoglobulin is specific for a second therapeutic target or is conjugated to a therapeutic moiety.

[0075] An exemplary bi-specific antibody format that can be used in the context of the present invention involves the use of a first immunoglobulin (Ig) C_H3 domain and a second Ig C_H3 domain, wherein the first and second Ig C_H3 domains differ from one another by at least one amino acid, and wherein at least one amino acid difference reduces binding of the bispecific antibody to Protein A as compared to a bi-specific antibody lacking the amino acid difference. In one embodiment, the first Ig C_H3 domain binds Protein A and the second Ig C_H3 domain contains a mutation that reduces or abolishes Protein A binding such as an H95R modification (by IMGT exon numbering; H435R by EU numbering). The second C_H3 may further comprise a Y96F modification (by IMGT; Y436F by EU). Further modifications that may be found within the second C_H3 include: D16E, L18M, N44S, K52N, V57M, and V82I (by IMGT; D356E, L358M, N384S, K392N, V397M, and V422I by EU) in the case of IgG1 antibodies; N44S, K52N, and V82I (IMGT; N384S, K392N, and V422I by EU) in the case of IgG2 antibodies; and Q15R, N44S, K52N, V57M, R69K, E79Q, and V82I (by IMGT; Q355R, N384S, K392N, V397M, R409K, E419Q, and V422I by EU) in the case of IgG4 antibodies. Variations on the bi-specific antibody format described above are contemplated within the scope of the present invention.

Therapeutic Formulation and Administration

[0076] The invention provides pharmaceutical compositions comprising the anti-ASIC1 antibodies or antigen-binding fragments thereof of the present invention. The pharmaceutical compositions of the invention are formulated with suitable carriers, excipients, and other agents that provide improved transfer, delivery, tolerance, and the like. A multitude of appropriate formulations can be found in the formulary known to all pharmaceutical chemists: Remington's Pharmaceutical Sciences, Mack Publishing Company, Easton, PA. These formulations include, for example, powders, pastes, ointments, jellies, waxes, oils, lipids, lipid (cationic or anionic) containing vesicles (such as LIPOFECTIN™, Life Technologies, Carlsbad, CA), DNA conjugates, anhydrous absorption pastes, oil-in-water and water-in-oil emulsions, emulsions carbowax (polyethylene glycols of various molecular weights), semi-solid gels, and semi-solid mixtures containing carbowax. See also Powell et al. "Compendium of excipients for parenteral formulations" PDA (1998) J Pharm Sci Technol 52:238-311.

[0077] The dose of antibody administered to a patient may vary depending upon the age and the size of the patient, target disease, conditions, route of administration, and the like. The preferred dose is typically calculated according to body weight or body surface area. When an antibody of the present invention is used for treating a condition or disease associated with ASIC1 activity in an adult patient, it may be advantageous to intravenously administer the antibody of the present invention normally at a single dose of about 0.01 to about 20 mg/kg body weight, more preferably about 0.02 to about 7, about 0.03 to about 5, or about 0.05 to

about 3 mg/kg body weight. Depending on the severity of the condition, the frequency and the duration of the treatment can be adjusted. Effective dosages and schedules for administering anti-ASIC1 antibodies may be determined empirically; for example, patient progress can be monitored by periodic assessment, and the dose adjusted accordingly. Moreover, interspecies scaling of dosages can be performed using well-known methods in the art (*e.g.*, Mordenti *et al.*, 1991, *Pharmaceut. Res. 8*:1351).

[0078] Various delivery systems are known and can be used to administer the pharmaceutical composition of the invention, e.g., encapsulation in liposomes, microparticles, microcapsules, recombinant cells capable of expressing the mutant viruses, receptor mediated endocytosis (see, e.g., Wu et al., 1987, J. Biol. Chem. 262:4429-4432). Methods of introduction include, but are not limited to, intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, epidural, and oral routes. The composition may be administered by any convenient route, for example by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (e.g., oral mucosa, rectal and intestinal mucosa, etc.) and may be administered together with other biologically active agents. Administration can be systemic or local.

[0079] A pharmaceutical composition of the present invention can be delivered subcutaneously or intravenously with a standard needle and syringe. In addition, with respect to subcutaneous delivery, a pen delivery device readily has applications in delivering a pharmaceutical composition of the present invention. Such a pen delivery device can be reusable or disposable. A reusable pen delivery device generally utilizes a replaceable cartridge that contains a pharmaceutical composition. Once all of the pharmaceutical composition within the cartridge has been administered and the cartridge is empty, the empty cartridge can readily be discarded and replaced with a new cartridge that contains the pharmaceutical composition. The pen delivery device can then be reused. In a disposable pen delivery device, there is no replaceable cartridge. Rather, the disposable pen delivery device comes prefilled with the pharmaceutical composition held in a reservoir within the device. Once the reservoir is emptied of the pharmaceutical composition, the entire device is discarded.

[0080] Numerous reusable pen and autoinjector delivery devices have applications in the subcutaneous delivery of a pharmaceutical composition of the present invention. Examples include, but are not limited to AUTOPEN™ (Owen Mumford, Inc., Woodstock, UK), DISETRONIC™ pen (Disetronic Medical Systems, Bergdorf, Switzerland), HUMALOG MIX 75/25™ pen, HUMALOG™ pen, HUMALIN 70/30™ pen (Eli Lilly and Co., Indianapolis, IN), NOVOPEN™ I, II and III (Novo Nordisk, Copenhagen, Denmark), NOVOPEN JUNIOR™ (Novo Nordisk, Copenhagen, Denmark), BD™ pen (Becton Dickinson, Franklin Lakes, NJ), OPTIPEN™, OPTIPEN PRO™, OPTIPEN STARLET™, and OPTICLIK™ (sanofi-aventis, Frankfurt, Germany), to name only a few. Examples of disposable pen delivery devices having applications in subcutaneous delivery of a pharmaceutical composition of the present invention

include, but are not limited to the SOLOSTAR™ pen (sanofi-aventis), the FLEXPEN™ (Novo Nordisk), and the KWIKPEN™ (Eli Lilly), the SURECLICK™ Autoinjector (Amgen, Thousand Oaks, CA), the PENLET™ (Haselmeier, Stuttgart, Germany), the EPIPEN (Dey, L.P.), and the HUMIRA™ Pen (Abbott Labs, Abbott Park IL), to name only a few.

[0081] In certain situations, the pharmaceutical composition can be delivered in a controlled release system. In one embodiment, a pump may be used (see Langer, supra; Sefton, 1987, CRC Crit. Ref. Biomed. Eng. 14:201). In another embodiment, polymeric materials can be used; see, Medical Applications of Controlled Release, Langer and Wise (eds.), 1974, CRC Pres., Boca Raton, Florida. In yet another embodiment, a controlled release system can be placed in proximity of the composition's target, thus requiring only a fraction of the systemic dose (see, *e.g.*, Goodson, 1984, in Medical Applications of Controlled Release, supra, vol. 2, pp. 115-138). Other controlled release systems are discussed in the review by Langer, 1990, Science 249:1527-1533.

[0082] The injectable preparations may include dosage forms for intravenous, subcutaneous, intracutaneous and intramuscular injections, drip infusions, etc. These injectable preparations may be prepared by methods publicly known. For example, the injectable preparations may be prepared, *e.g.*, by dissolving, suspending or emulsifying the antibody or its salt described above in a sterile aqueous medium or an oily medium conventionally used for injections. As the aqueous medium for injections, there are, for example, physiological saline, an isotonic solution containing glucose and other auxiliary agents, etc., which may be used in combination with an appropriate solubilizing agent such as an alcohol (e.g., ethanol), a polyalcohol (e.g., propylene glycol, polyethylene glycol), a nonionic surfactant [e.g., polysorbate 80, HCO-50 (polyoxyethylene (50 mol) adduct of hydrogenated castor oil)], etc. As the oily medium, there are employed, e.g., sesame oil, soybean oil, etc., which may be used in combination with a solubilizing agent such as benzyl benzoate, benzyl alcohol, etc. The injection thus prepared is preferably filled in an appropriate ampoule.

[0083] Advantageously, the pharmaceutical compositions for oral or parenteral use described above are prepared into dosage forms in a unit dose suited to fit a dose of the active ingredients. Such dosage forms in a unit dose include, for example, tablets, pills, capsules, injections (ampoules), suppositories, etc. The amount of the aforesaid antibody contained is generally about 5 to about 500 mg per dosage form in a unit dose; especially in the form of injection, it is preferred that the aforesaid antibody is contained in about 5 to about 100 mg and in about 10 to about 250 mg for the other dosage forms.

Therapeutic Uses of the Antibodies

[0084] The antibodies of the invention are useful, *inter alia*, for the treatment, prevention and/or amelioration of any disease or disorder associated with or mediated by ASIC1 activity or treatable by blocking or attenuating acid-induced, ASIC1-mediated ion currents in neuronal cells

of an individual. Exemplary diseases and disorders that can be treated with the anti-ASIC1 antibodies of the present invention include pain conditions such as nociceptive pain and visceral pain (*e.g.*, pain from inflammatory bowel disease/irritable bowel syndrome, interstitial cystitis, pancreatitis, endometriosis, chronic pelvic pain syndrome, etc.), as well as pain associated with inflammation (*e.g.*, inflammatory muscle pain), polymyositis, post-operative incision (*e.g.*, post-surgical pain), neuropathy (*e.g.*, diabetic neuropathy), sciatica, post-herpetic neuralgia, myofascial pain syndromes (*e.g.*, chronic myofascial pain), arthritis, sickle cell, enteric nerve ischemia, claudication pain, bone fracture, burn, osteoporotic fracture, gout, migraine headache, fibromyalgia, complex regional pain syndrome, acute herpetic pain, etc. The antibodies of the invention may also be used to treat, prevent and/or ameliorate conditions such as, *e.g.*, neurodegenerative diseases (*e.g.*, demyelinating diseases such as multiple sclerosis, amyotrophic lateral sclerosis, etc.), brain injury (*e.g.*, stroke, traumatic brain injury, brain acidosis), neurological disorders (*e.g.*, seizures, seizure disorders), and psychiatric diseases (*e.g.*, depression, anxiety disorders, post-traumatic stress disorder, panic disorder, etc.).

[0085] The anti-ASIC1 antibodies of the present invention are also useful for treating or preventing cancer-associated pain. "Cancer-associated pain" includes, *e.g.*, bone cancer pain, including pain from cancer that has metastasized to bone (*e.g.*, breast cancer, prostate cancer, lung cancer, sarcoma, kidney cancer, multiple myeloma, etc.). "Cancer-associated pain" also includes pain more generally associated with cancerous conditions such as, *e.g.*, renal cell carcinoma, pancreatic carcinoma, breast cancer, head and neck cancer, prostate cancer, malignant gliomas, osteosarcoma, colorectal cancer, gastric cancer, malignant mesothelioma, multiple myeloma, ovarian cancer, small cell lung cancer, non-small cell lung cancer, synovial sarcoma, thyroid cancer, or melanoma. The anti-ASIC1 antibodies of the present invention are also useful for treating or preventing pain caused by or associated with cancer therapy or anti-cancer medical treatments, *e.g.*, chemotherapy-induced neuropathic pain such as pain caused by or associated with treatment with paclitaxel (Taxol™), docetaxel (Taxotere®); nitrosourea, cyclophosphamide, doxorubicin, epirubicin, 5-fluorouracil, topotecan, irinotecan, carmustine, estramustine, and platinum-based chemotherapeutic compounds, such as cisplatin, carboplatin, and iproplatin.

Combination Therapies

[0086] The present invention includes therapeutic administration regimens which comprise administering an anti-ASIC1 antibody of the present invention in combination with at least one additional therapeutically active component. Non-limiting examples of such additional therapeutically active components include other ASIC inhibitors such as, *e.g.*, a second anti-ASIC1 antibody, an antibody directed against a different ASIC component (*e.g.*, anti-ASIC2 antibody, anti-ASIC3 antibody, anti-ASIC4 antibody, etc.), a peptide ASIC inhibitor (*e.g.*, psalmotoxin-1 [PcTx1], APETx2, etc.), and/or a small molecule ASIC inhibitor (*e.g.*, amiloride,

A-317567, etc.).

[0087] Other agents that may be beneficially administered in combination with the anti-ASIC1 antibodies of the invention include cytokine inhibitors (including small-molecule cytokine inhibitors and antibodies that bind to cytokines such as IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-8, IL-9, IL-11, IL-12, IL-13, IL-17, IL-18, or to their respective receptors), antivirals, antibiotics, analgesics, corticosteroids and/or NSAIDs.

[0088] The additional therapeutically active component(s) may be administered prior to, concurrent with, or after the administration of an anti-ASIC1 antibody of the present invention; (for purposes of the present disclosure, such administration regimens are considered the administration of an anti-ASIC1 antibody "in combination with" an additional therapeutically active component).

Diagnostic Uses of the Antibodies

[0089] The anti-ASIC1 antibodies of the present invention may also be used to detect and/or measure ASIC1, or ASIC1-expressing cells in a sample, *e.g.*, for diagnostic purposes. For example, an anti-ASIC1 antibody, or fragment thereof, may be used to diagnose a condition or disease characterized by aberrant expression (*e.g.*, over-expression, under-expression, lack of expression, etc.) of ASIC1. Exemplary diagnostic assays for ASIC1 may comprise, *e.g.*, contacting a sample, obtained from a patient, with an anti-ASIC1 antibody of the invention, wherein the anti-ASIC1 antibody is labeled with a detectable label or reporter molecule. Alternatively, an unlabeled anti-ASIC1 antibody can be used in diagnostic applications in combination with a secondary antibody which is itself detectably labeled. The detectable label or reporter molecule can be a radioisotope, such as ^{3}H, ^{14}C, ^{32}P, ^{35}S, or ^{125}I; a fluorescent or chemiluminescent moiety such as fluorescein isothiocyanate, or rhodamine; or an enzyme such as alkaline phosphatase, beta-galactosidase, horseradish peroxidase, or luciferase. Specific exemplary assays that can be used to detect or measure ASIC1 in a sample include enzyme-linked immunosorbent assay (ELISA), radioimmunoassay (RIA), and fluorescence-activated cell sorting (FACS).

[0090] Samples that can be used in ASIC1 diagnostic assays according to the present invention include any tissue or fluid sample obtainable from a patient which contains detectable quantities of ASIC1 protein, or fragments thereof, under normal or pathological conditions. Generally, levels of ASIC1 in a particular sample obtained from a healthy patient (*e.g.*, a patient not afflicted with a disease or condition associated with abnormal ASIC1 levels or activity) will be measured to initially establish a baseline, or standard, level of ASIC1. This baseline level of ASIC1 can then be compared against the levels of ASIC1 measured in samples obtained from individuals suspected of having a ASIC1 related disease or condition.

EXAMPLES

[0091] The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the methods and compositions of the invention, and are not intended to limit the scope of what the inventors regard as their invention. Efforts have been made to ensure accuracy with respect to numbers used (e.g., amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

Example 1. Generation of Human Antibodies to Human ASIC1

[0092] To generate anti-human ASIC1 antibodies, a DNA immunization procedure was used in which a DNA plasmid encoding full-length human ASIC1, together with a separate plasmid encoding adjuvant, were injected intradermally into a VELOCIMMUNE® mouse (Regeneron Pharmaceuticals, Inc., Tarrytown, NY). The site of injection was then electroporated to induce host cell transfection of the plasmids. The VELOCIMMUNE® mice used for the immunization comprise DNA encoding human immunoglobulin heavy and kappa light chain variable regions and lack the endogenous mouse *asic1a* gene. The antibody immune response was monitored by a cell binding assay using cells engineered to express human ASIC1. When a desired immune response was achieved, splenocytes were harvested and fused with mouse myeloma cells to preserve their viability and form hybridoma cell lines. The hybridoma cell lines were screened and selected to identify cell lines that produce ASIC1-specific antibodies. Using this technique several anti-ASIC1 chimeric antibodies (*i.e.*, antibodies possessing human variable domains and mouse constant domains) were obtained; exemplary antibodies generated in this manner were designated as follows: H1M6712N, H1M6716N, H1M6718N, H1M7101N, H2M7103N, H3M6713N, H3M6715N, H3M6720N, H3M6721N, H3M6721N2, H3M6726N, H3M6760N, H3M7102N, and H3M7118N.

[0093] Anti-ASIC1 antibodies were also isolated directly from antigen-positive B cells without fusion to myeloma cells, as described in US 2007/0280945A1. Using this method, several fully human anti-ASIC1 antibodies (*i.e.*, antibodies possessing human variable domains and human constant domains) were obtained; exemplary antibodies generated in this manner were designated as follows: H4H6362P, H4H6363P, H4H6364P, H4H6366P, H4H6372P, H4H6374P, H4H6375P, H4H6379P, H4H6380P, H4H6381P, and H4H6383P.

[0094] Certain biological properties of the exemplary anti-ASIC1 antibodies generated in accordance with the methods of this Example are described in detail in the Examples set forth below.

Example 2. Heavy and Light Chain Variable Region Amino Acid Sequences

[0095] Table 1 sets forth the heavy and light chain variable region amino acid sequence pairs of selected anti-ASIC1 antibodies and their corresponding antibody identifiers.

Table 1

	SEQ ID NOs:							
Antibody Designation	HCVR	HCDR1	HCDR2	HCDR3	LCVR	LCDR1	LCDR2	LCDR3
6712N	2	4	6	8	10	12	14	16
6716N	18	20	22	24	26	28	30	32
6718N	34	36	38	40	42	44	46	48
7101N	50	52	54	56	58	60	62	64
7103N	66	68	70	72	74	76	78	80
6713N	82	84	86	88	90	92	94	96
6715N	98	100	102	104	106	108	110	112
6720N	114	116	118	120	122	124	126	128
6721N	130	132	134	136	138	140	142	144
6721N2	146	148	150	152	154	156	158	160
6726N	162	164	166	168	170	172	174	176
6760N	178	180	182	184	186	188	190	192
7102N	194	196	198	200	202	204	206	208
7118N	210	212	214	216	218	220	222	224
6362P	226	228	230	232	234	236	238	240
6363P	242	244	246	248	250	252	254	256
6364P	258	260	262	264	266	268	270	272
6366P	274	276	278	280	282	284	286	288
6372P	290	292	294	296	298	300	302	304
6374P	306	308	310	312	314	316	318	320
6375P	322	324	326	328	330	332	334	336
6379P	338	340	342	344	346	348	350	352
6380P	354	356	358	360	362	364	366	368
6381P	370	372	374	376	378	380	382	384
6383P	386	388	390	392	394	396	398	400

[0096] Antibodies are typically referred to herein according to the following nomenclature: Fc prefix (*e.g.* "H4H", "H1M", "H2M"), followed by a numerical identifier (*e.g.* "6712" or "6362" as shown in Table 1), followed by a "P" or "N" suffix. Thus, according to this nomenclature, an antibody may be referred to herein as, *e.g.*, "H1M6712N" or "H4H6362P". The H4H, H1M, and H3M prefixes on the antibody designations used herein indicate the particular Fc region of the antibody. For example, an "H1M" antibody has a mouse IgG1 Fc, whereas an "H4H" antibody has a human IgG4 Fc. As will be appreciated by a person of ordinary skill in the art, an H1M or H3M antibody can be converted to an H4H antibody, and *vice versa*, but in any event, the variable domains (including the CDRs) – which are indicated by the numerical identifiers shown in Table 1 – will remain the same.

Example 3. Antibody Binding to Cells Expressing Full-Length Human or Mouse ASIC1

[0097] To further characterize anti-ASIC1 antibodies, their ability to bind either (a) a mouse fibroblast 3T3 cell line stably transfected to overexpress full length human ASIC1 (3T3/hASIC1; amino acids 1-528 of NCBI accession number NP_001086.2 [SEQ ID NO:401]), (b) a 3T3 cell line stably transfected to over express full length mouse ASIC1a (3T3/mASIC1a; amino acids 1-526 of NCBI accession number NP_033727), or (c) a ND7 cell line (ECACC, # 92090903) that is a fusion cell line of mouse neuroblastoma and rat dorsal root ganglia that endogenously expresses rat ASIC1, was determined using flow cytometry (FACS). ND7 cells were differentiated by replacing the culture media with low-serum media (0.5% FBS) containing 1 mM dibutyryl-cAMP (Cat. No. sc-201567A, Santa Cruz Biotechnology, Inc., Santa Cruz, CA). FACS binding was tested for some antibodies on both undifferentiated ND7 cells and differentiated ND7 cells.

[0098] To perform the FACS binding experiments, adherent cells were collected using 1 mM EDTA in PBS, then washed, and re-suspended in cold PBS containing 5% FBS. For each binding experiment, each anti-ASIC1 antibody (at final concentrations of 10 nM of purified antibodies or 3.3 nM for antibody supernatants for binding to 3T3/hASIC1 cells and 5nM for binding to 3T3/mASIC1a or ND7 cells) was added to 250,000 cells in 500 µL of PBS with 5% FBS. After incubation for 20 minutes at room temperature, a secondary antibody which recognizes human Fc (Cat. No. 109-136-098, Jackson ImmunoResearch Laboratories, Inc., West Grove, PA) or mouse Fc (Cat. No. 550826, BD Biosciences, San Jose, CA) and is conjugated to allophycocyanin, was then added to the cell mixture at a final concentration of 13.3 nM. After incubating for 20 minutes on ice, the cells were washed and resuspended in PBS containing 5% FBS, then sorted and analyzed on a flow cytometer (FACSCalibur, BD Biosciences, San Jose, CA) to determine relative binding by the candidate antibodies to the tested cell lines. Histograms of cells stained with anti-ASIC1 antibodies were compared with those of cells stained with secondary antibody alone. Percentage of ASIC1 signal over secondary antibody alone was calculated using FlowJo software (Tree Star, Ashland, OR). The samples stained with anti-ASIC1 antibodies were recorded as FACS positive when gated greater than 10%. The samples stained with anti-ASIC1 antibodies were recorded as FACS negative when gated lower than 1%. The samples stained with anti-ASIC1 antibody were recorded as weak when gated between 1%-10%. The binding specificities of the anti-ASIC1 antibodies to 3T3/hASIC1 cells, 3T3/mASIC1a cells and ND7 cells are summarized in Table 2 (ND = not determined).

Table 2: Binding Specificity of Anti-ASIC1 Antibodies As Determined by FACS

Antibody	FACS Binding to 3T3/hASIC1	FACS Binding to 3T3/mASIC1a	FACS Binding to Undifferentiated ND7 cells	FACS Binding to Differentiated ND7 cells
H1M6712N	Positive	ND	ND	ND
H3M6721N	Positive	Positive	Negative	ND
H1M6718N	Positive	Positive	Positive	Positive
H4H6372P	Negative	ND	ND	ND
H4H6374P	Negative	ND	ND	ND
H4H6375P	Negative	ND	ND	ND
H4H6379P	Negative	ND	ND	ND
H4H6380P	Negative	ND	ND	ND
H4H6381P	Negative	ND	ND	ND
H4H6383P	Negative	ND	ND	ND
H4H6362P	Negative	ND	ND	ND
H4H6363P	Positive	ND	ND	ND
H4H6364P	Positive	ND	ND	ND
H1M7101N	Positive	Positive	Positive	ND
H1M6716N	Positive	ND	ND	ND
H3M6726N	Positive	Positive	Positive	Positive
H3M6720N	Positive	Negative	Negative	Negative
H3M6713N	Positive	ND	ND	ND
H3M7102N	Positive	Positive	Positive	ND
H3M6760N	Positive	ND	ND	ND
H2M7103N	Positive	Positive	Negative	Negative
H3M6715N	Positive	ND	ND	ND
H3M7118N	Positive	Weak	Weak	Positive
H4H6366P	Positive	Positive	Positive	Positive
H4H6721N2	Positive	Positive	Positive	Positive

[0099] Binding affinity of selected antibodies to 3T3/hASIC1 cells was further examined by FACS using multiple antibody concentrations (67 nM, 6.7 nM, 0.67 nM, 67 pM, and 6.7 pM) from which approximate EC_{50} values were calculated. The mean fluorescence intensity (MFI) signal observed for the anti-ASIC1 antibodies was subtracted by the background signal (secondary antibody alone) and plotted as a function of antibody concentration to determine EC_{50} values using GraphPad Prism (Table 3).

Table 3: EC_{50} Values for Select Anti-ASIC1 Antibodies Binding to 3T3/hASIC1 Cells

Antibody	EC_{50}
H1M6712N	< 100 pM
H3M6721N	85 pM
H1M6718N	550 pM
H4H6363P	836 pM
H3M6713N	215 pM
H3M6715N	72 pM
H1M6716N	23 pM
H3M6720N	1.1 nM
H3M6726N	2.6 nM
H3M6760N	853 pM

H1M7101N	720 pM
H3M7102N	5.4 nM
H3M7118N	>67 nM
H2M7103N	1.7 nM
H4H6364P	1.5 nM
H4H6366P	1.0 nM
H4H6721N2	1.7 nM

[0100] As shown in Table 2, seventeen of the 25 antibodies tested demonstrated specific binding to 3T3/hASIC1 cell line; eight of 10 antibodies tested demonstrated positive binding to the 3T3/mASIC1a cells; six of 10 antibodies tested demonstrated positive binding to the undifferentiated ND7 cell line; and five of 7 antibodies tested demonstrated positive binding to the differentiated ND7 cell line. Notably, one antibody (H3M7118N) demonstrated weak binding to both 3T3/mASIC1a and undifferentiated ND7 cell lines but positive binding to 3T3/hASIC1 cells. As shown in Table 3, the anti-ASIC1 antibodies tested at multiple antibody concentrations demonstrated high affinity FACS binding with approximate EC_{50} values as low as 23 pM for binding to the 3T3/hASIC1 cells.

Example 4. Anti-ASIC1 Antibodies Block Acid-Mediated Cell Signaling in a Cellular Calcium Flux Assay

[0101] To characterize functional blocking of acid-mediated cell signaling by anti-ASIC1 antibodies, an assay that measures cellular calcium flux was implemented using a cell line, HEK293 CL:1F10 (1F10), that was transiently transfected to express human ASIC1 (amino acids 1-528 of NCBI accession number NP_0010862.2 [SEQ ID NO:401]). This cell line was created from the parental line HEK293/D9 that was stably transfected to express human Par2. Transfected cells were incubated at 37°C, 5% CO_2 for 2 days before replating into a 96-well black, clear bottom assay plate at a concentration of 100,000 cells per well. Cells were allowed to adhere to the plate at room temperature for 20 minutes then incubated overnight at 37°C, 5% CO_2.

[0102] The Fluo-4 NW calcium assay kit (Invitrogen, # F36206) was used to determine the level of intracellular calcium flux within cells activated by low pH buffers. Assay buffer was prepared according to the manufacturer's specifications. Fifty µL of probenecid (77 µg/uL) was added to 5 mL of buffer C (2xHBSS), which was then added to component A (Fluo-4 dye). Anti-ASIC1 antibodies were diluted in the Fluo-4 dye to a concentration of 250 nM for the single point blocking assay. The antibodies that blocked calcium flux stimulated by low pH buffers were further characterized in this assay using multiple antibody concentrations. Anti-ASIC1 antibodies were diluted to a concentration of 250 nM in the dye and an 8 point 1:3 dilution series (ranging from 250 to 0.1 nM) was used to determine the blocking IC_{50} of each antibody. The cell culture media was removed from the assay plate containing cells and 50 µL of the Fluo-4 dye containing anti-ASIC1 antibody was then added. The plates were incubated at 37°C, 5%

CO_2 for 1 hour before reading by FLIPR Tetra (Molecular Devices).

[0103] The pH of buffer C was adjusted to pH 5.0 or pH 5.5 and added to a reservoir plate before addition to the cells. The FLIPR Tetra then added 50 µL of the low pH buffer from the reservoir plate to the cells in the assay plate at a speed of 50 µl per second. The calcium signal produced by each well for 10 seconds prior to buffer addition (pre-read) and for 100 seconds after buffer addition was measured by FLIPR Tetra using an excitation wavelength setting of 470-490 nm and an emission wavelength setting of 515-575 nm. The difference between the maximum observed value obtained after buffer addition and the minimum value during the entire assay including both the pre-read and after buffer addition was calculated and graphed using GraphPad Prism. Results are shown in Tables 4 and 5.

Table 4: Blocking of Acid-Mediated Cellular Calcium Flux by 250 nM of Anti-ASIC1 Antibodies at pH 5.5 and 5.0

	FLIPR	
	250 nM Single Point	
Antibody	pH 5.5	pH 5.0
H1M6712N	Weak	Neg
H3M6721N	Pos	Pos
H1M6718N	Pos	Pos
H1M7101N	Neg	Neg
H1M6716N	Weak	Weak
H3M6726N	Neg	Neg
H3M6720N	Neg	Neg
H3M6713N	Weak	Weak
H3M7102N	Neg	Neg
H3M6760N	Pos	Weak
H2M7103N	Neg	Neg
H3M6715N	Weak	Weak
H3M7118N	Neg	Neg
H4H6372P	Weak	Neg
H4H6374P	Weak	Neg
H4H6375P	Weak	Weak
H4H6379P	Neg	Neg
H4H6380P	Weak	Neg
H4H6381P	Weak	Neg
H4H6383P	Neg	Neg
H4H6362P	Neg	Neg
H4H6363P	Neg	Neg
H4H6364P	Neg	Neg

H4H6366P	Neg	Neg

Table 5: Dose dependent blocking of acid-mediated cellular calcium flux by anti-ASIC1 antibodies at pH 5.5 and 5.0

	FLIPR Dose Curve			
Antibody	**pH 5.5 % Block**	**pH 5.5 IC_{50} nM**	**pH 5.0 % Block**	**pH 5.0 IC_{50} nM**
H1M6712N	64%	6 nM	10%, No dose dep.	No dose dep.
H3M6721N	44%	0.3 nM	25%	IC*
H1M6718N	78%	0.6 nM	48%	IC*
H3M6713N	63%	0.2 nM	23%, No dose dep.	No dose dep.
H3M6715N	39%	0.1 nM	10%, No dose dep.	No dose dep.
H1M6716N	37%	1.1 nM	25%, No dose dep.	No dose dep.
H3M6760N	71%	0.9 nM	56%	1 nM
H4H6375P	27%	0.1 nM	10%, No dose dep.	No dose dep.
H4H6380P	Neg	Neg	Neg	Neg
H4H6381P	Neg	Neg	Neg	Neg

[0104] As shown in Table 4, two of the 24 antibodies, H3M6721N and H1M6718N, exhibited greater than 30% blockade of the calcium flux (Pos) at the single concentration of 250 nM at both pH 5.5 and pH 5.0, and one antibody (H3M6760N) exhibited greater than 30% block at only pH 5.5. Twelve of the 24 antibodies at pH 5.5 and 17 of the 24 antibodies at pH 5.0 tested at the single concentration of 250 nM did not exhibit measurable blockade (Neg). Nine of the 24 antibodies at pH 5.5, and 5 of the 24 antibodies at pH 5.0, tested at the single concentration of 250 nM exhibited a reduction in calcium flux between 10-30% (Weak).

[0105] As shown in Table 5, eight of the 10 antibodies tested for dose dependent blocking at pH 5.5 exhibited a percent blockade of the calcium flux ranging from 27% to 78% and IC_{50} values ranging from 0.1 nM to 6 nM. Two of the antibodies tested for dose dependent calcium flux blockade at pH 5.5, H4H6380P and H4H6381P, exhibited no measurable blockade. Two of the 10 antibodies tested for dose dependent blocking at pH 5.0, H3M6721N and H1M6718N, exhibited a 25% and 48% blockade of the calcium flux, respectively, but IC_{50} values could not be determined (IC*) despite showing dose dependence. One of the 10 antibodies tested for dose dependent blocking at pH 5.0, H3M6760N, exhibited a 56% blockade of the calcium flux and an IC_{50} value of 1 nM. Five of the 10 antibodies tested for dose dependent calcium flux blockade at pH 5.0 exhibited no dose dependent blockade but blocked between 10% and 25% of the calcium flux at each of the antibody concentrations tested. Two of the 10 antibodies tested for dose dependent blocking at pH 5.0, H4H6380P and H4H6381P, exhibited no measurable blockade.

Example 5. Anti-ASIC1 Antibodies Block Acid-Induced ASIC1 Ion Currents in an Automated Voltage-Clamp Patch-Clamp Assay [Q-Patch]

[0106] The Q-Patch (Sophion Bioscience, Inc., Ballerup, Denmark), a microchip-based automated patch-clamp system, was used to determine the ability of the anti-ASIC1 antibodies to inhibit either the human ASIC1 current in a stably transfected HEK293 cell line expressing the full length human ASIC1 channel (HEK/hASIC1; amino acids 1-528 of NCBI accession number NP_001086.2) or the mouse ASIC1a current in a stably transfected 3T3 cell line expressing the full-length mouse ASIC1a channel (3T3/mASIC1a; amino acids 1-526 of NCBI accession number NP_033727).

[0107] HEK/hASIC1 cells were cultured in DMEM high glucose media, 10% fetal bovine serum (FBS), 1% non-essential amino acids and 500 µg/mL Geneticin® (Invitrogen, # 10131). 3T3/mASIC1a cells were cultured in DMEM high glucose media, 10% FBS, 1% penicillin / streptomycin / glutamine (Invitrogen, #10378-016), and 400ug/mL Geneticin®. On the day of the recordings, cells were harvested with Detachin cell detachment solution (Genlantis, San Diego, CA, # T100100), centrifuged and resuspended in 1.4 mL serum free solution [CHO-SFM-II media (Invitrogen, # 31033), HEPES 25 mM and penicillin/streptomycin 100 units/mL]. The cell suspension was then incubated on a shaker for 40 minutes at room temperature (RT). Two or three anti-ASIC1 antibodies and a control antibody were run in parallel in one experiment. Thus, at the end of the incubation, the cell suspension was dispensed into 4 tubes (approximately $5x10^6$ cells in 300 µL/tube) and the antibodies were diluted to a final concentration of 100 nM directly in the tubes for single point experiments, or at a range of concentrations for dose response experiments and then incubated on a shaker for 20 minutes at RT. At the end of the incubation, cells were loaded on the Q-Patch.

[0108] Cells were first perfused with a buffer at pH 7.4 (NaCl 140 mM, KCl 4 mM, $MgCl_2$ 1 mM, $CaCl_2$ 2 mM, glucose 5 mM and HEPES 10 mM) containing 0.2% (w/v) bovine serum albumin (extracellular buffer) and the antibody of interest at a final concentration of 100 nM for single point experiments, or at a range of concentrations for dose response experiments, was added and allowed to incubate for about 3 minutes. Then, the human ASIC1 current was elicited for one second by the addition of the extracellular buffer adjusted to pH 6.0 while cells were maintained at a holding potential of -80 mV. Thirty µM of amiloride was added after each recording on the Q-Patch to demonstrate that the cells were responsive through the duration of the assay. The composition of the intracellular recording solution was CsCl 140 mM, $MgCl_2$ 4 mM, EGTA 10 mM and HEPES 10 mM; adjusted to pH 7.3 with CsOH.

[0109] All anti-ASIC1 antibodies were tested in quadruplicate in parallel with the control irrelevant antibody. Channel blocking was measured as percent inhibition of current flux in the presence of anti-ASIC1 antibody relative to current flux in the presence of the control irrelevant antibody, averaged over multiple blocking experiments. Results are summarized in Table 6.

Table 6: Percent Inhibition of Acid-Induced Human ASIC1 Currents by Anti-ASIC1 Antibodies at 100 nM

Antibody	Number of wells tested	Antibody concentration (nM)	Current inhibition (%)
H1M6712N	10	100	0
H3M6715N	7	100	30
H3M6720N	7	100	82
H3M6726N	3	100	85
H3M6721N	14	100	100
H1M6718N	8	100	100
H4H6372P	4	100	0
H4H6374P	8	100	0
H4H6375P	5	100	0
H4H6379P	4	100	30
H4H6380P	5	100	0
H4H6381P	6	100	25
H4H6383P	4	100	15
H4H6362P	4	100	29
H4H6363P	4	100	0
H4H6364P	2	100	0
H4H6366P	8	100	72
H3M7099N	4	100	25
H1M7101N	4	100	97
H3M7102N	3	100	100
H2bM7103N	7	100	92
H3M7104N	7	100	35
H1M7117N	4	100	30

[0110] As shown in Table 6, seventeen of the 23 antibodies tested at 100 nM on the Q-Patch demonstrated functional inhibition of human ASIC1 current with 9 of the 17 antibodies showing a blockade greater than 70%. Eleven antibodies (H1M6718N, H3M6720N, H3M6721N, H3M6726N, H4H6366P, H1M7101N, H3M7102N, H2bM7103N, H3M7118N, H4H6718N, and H4H6721N2) were further tested for their ability to inhibit the human ASIC1 current at different concentrations on the Q-Patch, and nine antibodies (H4H6718N, H3M6720N, H3M6721N, H1M7101N, H3M7102N, H2bM7103N, H3M6726N, H4H6366P, and H3M7118N) were tested for their ability to inhibit the mouse ASIC1 current. The percentage of blockade observed for these antibodies is summarized in Table 7 (human ASIC1) and Table 8 (mouse ASIC1).

Table 7: Percent Inhibition of Acid-Induced Human ASIC1 Currents by Anti-ASIC1 Antibodies at Various Antibody Concentrations

Antibody	Number of wells tested	Antibody concentration (nM)	% Current inhibition ± SEM
H1M6718N	4	100	100 ± 0
	18	10	99 ± 1
	13	1	63 ± 13
	8	0.1	0 ± 0
H3M6720N	13	100	83 ± 9
	8	50	88 ± 6
	3	10	70
	4	1	0
H3M6721N	14	100	100
	8	50	100
	11	10	75 ± 10
	6	1	30
H3M6726N	14	100	77 ± 3
	12	10	30 ± 11
	7	1	15 ± 15
H4H6366P	7	100	76 ± 6
	6	10	53 ± 8
	7	1	38 ± 15
H1M7101N	4	100	97
	10	10	99 ± 0.7
	4	5	96
	10	1	57 ± 18
	4	0.1	7
H3M7102N	4	100	99
	8	10	96 ± 1
	3	5	35
	10	1	0 ± 0
H2bM7103N	7	100	96 ± 3
	3	50	96
	5	10	61 ± 15
	4	1	0

H3M7118N	2	100	99
	2	10	89
	2	1	30
H4H6718N	7	10	100
	6	5	98 ± 2
	3	1	97
	8	0.6	66 ± 6
	4	0.3	54
	4	0.1	12
H4H6721N2	7	10	95 ± 2
	13	5	93 ± 1
	7	1	59 ± 10
	8	0.6	32.7 ± 0.1
	3	0.3	40
	4	0.1	1

Table 8: Percent Inhibition of Acid-Induced Mouse ASIC1a Currents by Anti-ASIC1 Antibodies at Various Antibody Concentrations

Antibody	Number of wells tested	Antibody concentration (nM)	% Current inhibition ± SEM
H4H6718N	10	10	90
	4	5	98
	3	2	96
	3	1	71
	9	0.3	36 ± 3
	2	0.1	20
H3M6720N	4	100	83
	4	50	83
	3	10	46
	4	5	19
	10	1	12 ± 3
	6	0.1	21 ± 8
H3M6721N	4	100	91
	3	10	57
	4	1	0
H4H6721N2	8	25	99 ± 1
	7	10	62

H1M7101N	4	100	90
H3M7102N	4	100	100
H2bM7103N	8	100	67 ± 2
	3	50	77
	3	10	30
	2	5	32
	10	1	33 ± 5
	7	0.1	3 ± 1
H3M6726N	4	100	51
	3	50	38
	3	5	23
	4	1	3
H4H6366P	1	100	46
	4	10	30
	3	5	28
	4	1	10
H3M7118N	7	100	92 ± 3
	3	50	87
	8	10	36 ± 23
	4	5	12
	6	1	6 ± 6

[0111] As shown in Table 7, one antibody, H3M6726N, blocked the human ASIC1 current with an apparent IC_{50} greater than 10 nM, while six antibodies (H3M6720N, H3M6721N, H4H6366P, H3M7102N, H2bM7103N and H3M7118N) blocked the human ASIC1 current with an apparent IC_{50} of 10 nM or less. Four of the antibodies, H1M6718N, H1M7101N, H4H6718N, and H4H6721N2, blocked the human ASIC1 current with an apparent IC_{50} less than 1nM.

[0112] As shown in Table 8, six of the 10 anti-ASIC1 antibodies (H4H6718N, H3M6721N, H4H6721N2, H1M7101N, H3M7102N and H3M7118N) tested on the mouse ASIC1 expressing cells inhibited 90 to 100% of the mouse ASIC1 current at highest antibody concentration tested, while four antibodies (H3M6720N, H3M6726N, H4H6366P, and H2bM7103N) only inhibited the current by approximately 80% or less. H3M7118N, H2bM7103N, H3M6720N and H3M6721N blocked the mouse ASIC1 current with an apparent IC_{50} less than 25 nM. H4H6718N blocked the human ASIC1 current with an apparent IC_{50} less than 1nM.

[0113] The Q-Patch was also used to determine the ability of the anti-ASIC1 antibody H4H6718N to inhibit the ASIC1 current in the ND7/23 cell line (ECACC, # 92090903), which is a fusion cell line of mouse neuroblastoma and rat dorsal root ganglia that endogenously expresses rat ASIC1.

[0114] ND7/23 cells were cultured in DMEM high glucose media containing 10% FBS, 2mM glutamine, 1% penicillin-streptomycin (Invitrogen, # 10378-016). The day after seeding, ND7/23 cells were differentiated by replacing the culture media with low-serum media (0.5% FBS) containing 1 mM dibutyryl-cAMP (Santa Cruz, # sc-201567A). On the day of the recordings, cells were harvested using StemPro Accutase cell dissociation reagent (Invitrogen, # A11105-01), centrifuged, and resuspended in 1 mL of extracellular buffer solution. The cell suspension was then loaded on the Q-Patch.

[0115] Cells were first perfused with an extracellular buffer solution at pH 7.4 (NaCl 140 mM, KCl 4 mM, $MgCl_2$ 1 mM, $CaCl_2$ 2 mM, glucose 5 mM and HEPES 10 mM, adjusted to pH 7.4 with NaOH) containing 0.2% (w/v) bovine serum albumin for 6 minutes to stabilize the patch. The rat ASIC1 current was then elicited for one second by the addition of the extracellular buffer, which was adjusted to pH 6.0, while the cells were maintained at a holding potential of -80 mV. The rat ASIC1 current was elicited 2 times in extracellular buffer at pH 6 and then 2 additional times in the same extracellular buffer containing either 10 nM of an isotype control antibody or 10 nM of the anti-ASIC1 antibody (H4H6718N, H3M6720N, H2bM7103N, H3M6726N, H4H6366P and H3M7118N). After the anti-ASIC1 antibody recordings 10 nM of the selective ASIC1 antagonist PcTx1 (Alomone Labs, # STP-200) was added to the cells to evaluate the contribution of ASIC1-specific currents to the current elicited by extracellular buffer at pH 6. The composition of the intracellular recording solution was CsF 120 mM, NaCl 15 mM, EGTA 10 mM and HEPES 10 mM; adjusted to pH 7.3 with CsOH.

[0116] Channel blocking was measured as percent inhibition of current flux in the presence of anti-ASIC1 antibody relative to the current flux measured before the application of the antibody and was compared to the percent inhibition of current flux in the presence of PcTx1, which was used to define the maximum ASIC1-specific current blockade. Results are shown in Table 9.

Table 9: Percent Inhibition of Acid-Induced Rat ASIC1a Currents in ND7 Cells by Anti-ASIC1 Antibodies

Antibody	Number of Wells Tested	Antibody Concentration (nM)	Percent Current Inhibition ± SEM
H4H6718N	9	10	100
H3M6720N	4	10	43 ± 15
H2bM7103N	5	10	26 ± 14
H3M6726N	5	10	7 ± 6
H4H6366P	3	10	36 ± 20
H3M7118N	10	10	65 ± 11
Isotype Control	21	10	15 ± 3

[0117] As shown in Table 9, H4H6718N demonstrated a 100% inhibition of the rat ASIC1 currents in differentiated ND7/23 cells at a concentration of 10 nM (n= 9) while H3M6720N and H3M7118N inhibited the current by approximately 43% and 65%, respectively. Three antibodies (H2bM7103N, H3M6726N and H4H6366P) did not demonstrate significant inhibition

of rat ASIC1 currents at 10 nM in these experiments.

Example 6. An Anti-ASIC1 Antibody Blocks Acid-Induced ASIC1 Ion Currents in an Automated Voltage-Clamp Patch-Clamp Assay [Port-A-Patch]

[0118] The Port-a-Patch (Nanion Technologies Inc., North Brunswick, NJ), a microchip-based automated patch-clamp system, was used to determine the half maximal inhibitory concentration (IC_{50}) of the anti-ASIC1 antibody H1M6718N needed to inhibit the human ASIC1 current in a stably transfected HEK293 cell line expressing the full length human ASIC1 channel (HEK/hASIC1; amino acids 1-528 of NCBI accession number NP_001086.2).

[0119] HEK/hASIC1 cells were cultured in DMEM high glucose media, 10% fetal bovine serum, 1% non-essential amino acids and 500 µg/mL Geneticin® (Invitrogen, # 10131). On the day of the recordings, cells were harvested with Detachin cell detachment solution (Genlantis, San Diego, CA, #T100100), centrifuged, and resuspended in 500 uL extracellular buffer solution (NaCl 140 mM, KCl 4 mM, $MgCl_2$ 1 mM, $CaCl_2$ 2 mM, glucose 5 mM and HEPES 10 mM, pH 7.4 with NaOH). The cell suspension was then loaded on the Port-a-Patch.

[0120] Cells were first perfused with extracellular buffer at pH 7.4 containing 0.1% (w/v) bovine serum albumin for about 5 minutes to stabilize the patch. Then, the human ASIC1 current was elicited for three seconds by the addition of the extracellular buffer adjusted to pH 6.0 while cells were maintained at a holding potential of -80 mV. The human ASIC1 current was elicited 3 times (2 minutes apart) in pH 6.0 extracellular buffer and 3 times in pH 6.0 extracellular buffer containing either 100nM of an isotype control antibody or 10, 3, 1, 0.8 or 0.6 nM of the anti-ASIC1 antibody H1M6718N. Thirty µM of amiloride in pH 6 extracellular buffer was added after completing the pH-stimulated measurements to demonstrate that the cells were responsive through the duration of the assay. The composition of the intracellular recording solution was CsF 120 mM, $NaCl_2$ 15 mM, EGTA 10 mM and HEPES 10 mM; adjusted to pH 7.3 with CsOH.

[0121] Channel blocking was measured as percent inhibition of current flux in the presence of anti-ASIC1 antibody relative to current flux before application of the antibody. This was averaged over multiple blocking experiments.

[0122] The percentage of blockade of the human ASIC1 current by 10, 3, 1, 0.8 and 0.6 nM of H1M6718N is summarized in Table 10.

Table 10: Percent Inhibition of Human ASIC1 Current by An Anti-ASIC1 Antibody At Various Concentrations

Antibody	Number of wells tested	Antibody concentration (nM)	% Current Inhibition ± SEM
H1M6718N	3	10	94 ± 1
	3	3	86 ± 7

	4	1	76 ± 6
	3	0.8	33 ± 6
	4	0.6	17 ± 9
isotype control	3	100	0

[0123] H1M6718N showed a dose-dependent inhibition of human ASIC1 current with a calculated IC_{50} of 860 pM, while the isotype control antibody showed no inhibition of the current at a concentration of 100 nM.

Example 7. An Anti-ASIC1 Antibody Reduces Visceral Pain Responses in a Mouse Model

[0124] In this example, the ability of the anti-ASIC1 antibody H1M6718N to attenuate visceral pain in a model of acetic acid induced abdominal constrictions was assessed. Wild-type C57BL/6 mice from Jackson Laboratory (Bar Harbor, ME) were used in this experiment. Separate cohorts of mice (n=10) received 10 mg/kg (s.c.) of an isotype control mAb or 1 or 10 mg/kg (s.c.) of H1M6718N. Twenty-four hours after antibody dosing all cohorts received an intraperitoneal injection of 0.6% acetic acid, which produced stereotypical abdominal stretching behaviors (e.g. constrictions) that were counted by a blinded observer for up to 30 minutes post-injection. The results of this experiment, expressed in terms of the percent change in the total number of abdominal constrictions, are shown in Table 11 (all data are represented as mean ± SEM).

Table 11: Effect of Anti-ASIC1 Antibody on Abdominal Constrictions Induced by Acetic Acid Injection

Dose of H1M6718N	Percent Change in Abdominal Constrictions Relative to Control
1	-32.06 ± 15.8
10	-46.57 ± 19.3

[0125] This example demonstrates that anti-ASIC1 antibody (H1M6718N), which was shown to potently block acid-induced ASIC1 ion currents (*see* Examples 4 through 6), was effective in alleviating acid-induced visceral pain responses in a mouse model. .

Example 8. An Anti-ASIC1 Antibody Produces Analgesia to a Noxious Mechanical Stimulus in a Mouse Model

[0126] In this Example, the ability of an anti-ASIC1 antibody (H1M6718N) to produce analgesia in response to noxious pinch/pressure stimuli was assessed.

[0127] Wild-type C57BL/6 mice from Jackson Laboratory (Bar Harbor, ME) were used in this experiment. Separate cohorts of mice received 1, 10, or 40 mg/kg (s.c.) of H1M6718N, or 10 mg/kg (s.c) of an isotype control antibody. Twenty-four hours after antibody dosing, separate

cohorts (n=10) were tested for their mechanical nociception thresholds, which were measured by the withdrawal threshold to a pinch of the gastrocnemius muscle or the tail (Model #2455, IITC Life Science, Woodland Hills, CA). Mechanical nociception in the tail was measured in mice treated with 1 mg/kg and 10 mg/kg of H1M6718N in addition to those treated with an isotype control. Mechanical nociception in the gastrocnemius muscle was measured in mice treated with 10 mg/kg and 40 mg/kg of H1M6718N in addition to those treated with an isotype control. The results of these experiments, expressed as withdrawal threshold to the pinch in grams (mean ± SEM for each cohort of mice), are shown in Figure 1, panels A and B.

[0128] For both experiments, H1M6718N treatment resulted in a significant increase in the withdrawal threshold at the highest antibody dose tested (10 mg/kg in tail experiment [Figure 1, panel A] and 40 mg/kg in the gastrocnemius muscle experiment [Figure 1, panel B]) compared with the isotype control as determined by ANOVA ($p=0.0015$ for the tail and 0.0228 for the gastrocnemius muscle) and by Bonferonni post-hoc test (* = $p<0.05$).

Example 9. An Anti-ASIC1 Antibody Attenuates Muscle Pain in Mouse Models

[0129] In this Example, the ability of anti-ASIC1 antibodies H1M6718N and H4H6721N2 to attenuate muscle pain resulting from injection of either acidic saline (pH 5.5) or 3% carrageenan was assessed. Wild-type C57BL/6 mice from Jackson Laboratory (Bar Harbor, ME) were used in these experiments.

[0130] In a first experiment, separate cohorts of mice received 10 mg/kg (s.c) of an isotype control antibody or 10 mg/kg (s.c.) of H1M6718N. Twenty-four hours after antibody dosing all mice received an intramuscular injection of acidic saline (pH 5.5) into the gastrocnemius muscle, which produced robust primary mechanical hyperalgesia of several days as measured by the withdrawal threshold to a pinch of the muscle (Model #2455, IITC Life Science, Woodland Hills, CA). Results are shown in Figure 2.

[0131] In a second experiment, separate cohorts of mice received 10 mg/kg (s.c.) of an isotype control mAb; 10, or 40 mg/kg (s.c.) of H1M6718N; or 10 or 30 mg/kg (s.c.) of H4H6721N2. Twenty-four hours after antibody dosing all mice received an intramuscular injection of 3% carrageenan (w/v) into the gastrocnemius muscle, which produced robust primary mechanical hyperalgesia of several days as measured by the withdrawal threshold to a pinch of the muscle (Model #2455, IITC Life Science, Woodland Hills, CA). Results are shown in Figures 3A (10 and 40 mg/kg H1M6718N) and 3B (10 and 30 mg/kg H4H6721N2).

[0132] The results of these experiments, as shown in Figures 2 and 3, are expressed in terms of the percent change in the withdrawal threshold from baseline (all data are represented as mean ± SEM). For both experiments, a significant main effect of the H1M6718N treatment was observed by repeated measures ANOVA ($p=0.0363$ for acidic saline and 0.0193 for carrageenan). For the second experiment, a significant main effect of the H1M6721N2 treatment was observed by repeated measures ANOVA ($p= 0.0018$). * = $p<0.05$ and ** = p

<0.01 by Bonferonni post-hoc test for the given time point. Thus, both antibodies demonstrate substantial efficacy in alleviating muscle pain in the experimental systems used herein.

Example 10. Efficacy of Anti-ASIC1 Antibody in a Model of Chemotherapy-Induced Neuropathic-Like Pain

[0133] In this Example, the ability of the anti-ASIC1 antibody H4M6718N to attenuate neuropathic-like pain resulting from systemic exposure the chemotherapeutic agent taxol was assessed. Wild-type C57BL/6 male mice from Jackson Laboratory (Bar Harbor, ME) were used in these experiments. After baseline behavioral testing, all mice received a regimen of taxol (4 mg/kg, every other day for a total of 4 doses) prior to initiating therapeutic dosing. Separate cohorts of mice received 30 mg/kg (s.c.) of an isotype control mAb, 30 mg/kg (s.c.) of H1M6718N, or 100 mg/kg (s.c.) of gabapentin. The antibodies were administered 24 hours prior to each weekly behavioral test and gabapentin was administered 2 hours prior to each weekly behavioral test. Tactile allodynia was measured in all cohorts using von Frey fibers (#58011, Stoelting Co., Wood Dale, IL) according to the up-down method of Dixon (Chaplan et al., *J Neurosci Methods*. 53(1):55-63). The results of this experiment are shown in Figure 4 (all data are represented as mean ± SEM).

[0134] As illustrated in Figure 4, a significant main effect of both H1M6718N treatment and gabapentin treatment was observed compared to the isotype control cohort by repeated measures ANOVA ($p=0.0003$ for H4H6718N, $p<0.00001$ for gabapentin). Thus, this Example suggests that anti-ASIC1 antibodies of the present invention are highly effective in alleviating chemotherapy-induced pain responses.

[0135] Collectively, the results of the foregoing Examples support the use of anti-ASIC1 blocking antibodies for the treatment of a variety of pain conditions.

[0136] The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and the accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. An isolated antibody or antigen-binding fragment thereof that specifically binds cell surface-expressed ASIC1 (SEQ ID NO:401).

2. The antibody or antigen-binding fragment of claim 1, wherein the antibody or antigen-binding fragment thereof specifically binds cell surface-expressed ASIC1 with an EC_{50} of 1 nM or less as measured using fluorescence activated cell sorting (FACS).

3. The antibody or antigen-binding fragment of claim 1 or 2, wherein the antibody or antigen-binding fragment thereof inhibits acid-induced, ASIC1-mediated ion currents in cells expressing human ASIC1.

4. The antibody or antigen-binding fragment of claim 3, wherein the antibody or antigen-binding fragment thereof inhibits acid-induced cellular calcium flux in cells expressing ASIC1 at pH of about 5.0 to about 6.0 with an IC_{50} of 6 nM or less as measured using a FLIPR assay.

5. The antibody or antigen-binding fragment of claim 3, wherein the antibody or antigen-binding fragment thereof inhibits acid-induced ion currents at pH of about 5.0 to about 6.0 with an IC_{50} of 10 nM or less as measured using a patch-clamp assay.

6. An isolated antibody or antigen-binding fragment thereof that competes for binding to cell surface-expressed ASIC1 with a reference antibody comprising an HCVR/LCVR sequence pair selected from the group consisting of SEQ ID NOs: 2/10; 34/42; 50/58; 66/74; 114/122; 130/138; 146/154; 162/170; 194/202; 210/218; 242/250; 258/266; and 274/282.

7. The antibody or antigen-binding fragment of claim 6, wherein the antibody or antigen-binding fragment thereof inhibits acid-induced ASIC1-mediated ion currents in cells expressing human ASIC1.

8. An isolated antibody, or antigen-binding fragment thereof, that specifically binds cell surface-expressed ASIC1 (SEQ ID NO:401), wherein the antibody or antigen-binding fragment comprises: (a) the complementarity determining regions (CDRs) of a heavy chain variable region (HCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 34, 50, 66, 114, 130, 146, 162, 194, 210, 242, 258, and 274 ; and (b) the CDRs of a light chain variable region (LCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 42, 58, 74, 122, 138, 154, 170, 202, 218, 250, 266, and 282.

9. The isolated antibody or antigen-binding fragment of claim 8, wherein the antibody or antigen-binding fragment comprises the heavy and light chain CDRs of a HCVR/LCVR amino

acid sequence pair selected from the group consisting of: SEQ ID NOs: 2/10; 34/42; 50/58; 66/74; 114/122; 130/138; 146/154; 162/170; 194/202; 210/218; 242/250; 258/266; and 274/282.

10. The isolated antibody or antigen-binding fragment of claim 8, wherein the antibody or antigen-binding fragment comprises HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3 domains, respectively, selected from the group consisting of: SEQ ID NOs: 4-6-8-12-14-16; 36-38-40-44-46-48; 52-54-56-60-62-64; 68-70-72-76-78-80; 116-118-120-124-126-128; 132-134-136-140-142-144; 148-150-152-156-158-160; 164-166-168-172-174-176; 196-198-200-204-206-208; 212-214-216-220-222-224; 244-246-248-252-254-256; 260-262-264-268-270-272; and 276-278-280-284-286-288.

11. An isolated antibody, or antigen-binding fragment thereof, that specifically binds cell surface-expressed ASIC1 (SEQ ID NO:401), wherein the antibody or antigen-binding fragment comprises: (a) a heavy chain variable region (HCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 34, 50, 66, 114, 130, 146, 162, 194, 210, 242, 258, and 274; and (b) a light chain variable region (LCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 42, 58, 74, 122, 138, 154, 170, 202, 218, 250, 266, and 282.

12. The isolated antibody or antigen-binding fragment of claim 11, wherein the antibody or antigen-binding fragment comprises a HCVR/LCVR amino acid sequence pair selected from the group consisting of: SEQ ID NOs: 2/10; 34/42; 50/58; 66/74; 114/122; 130/138; 146/154; 162/170; 194/202; 210/218; 242/250; 258/266; and 274/282.

13. A pharmaceutical composition comprising the antibody or antigen-binding fragment of any one of claims 1 to 12 and a pharmaceutically acceptable carrier or diluent.

14. A pharmaceutical composition comprising the antibody or antigen-binding fragment of any one of claims 1 to 12 for use in treating or attenuating pain in a human patient.

15. The pharmaceutical composition of claim 14, wherein the pain is nociceptive pain or visceral pain.

16. The pharmaceutical composition of claim 15, wherein the pain is associated with a condition selected from the group consisting of inflammation, post-operative incision, neuropathy, bone fracture, burn, osteoporotic fracture, bone cancer, gout, migraine headache, and fibromyalgia.

17. The pharmaceutical composition of claim 14, wherein the pain is cancer-associated pain or chemotherapy-induced pain.

18. A method for treating or attenuating pain, the method comprising administering to a patient in need thereof an antibody or antigen-binding fragment thereof that specifically binds cell surface-expressed ASIC1 (SEQ ID NO:401).

19. The method of claim 18, wherein the antibody or antigen-binding fragment thereof comprises the heavy and light chain CDRs of a HCVR/LCVR amino acid sequence pair selected from the group consisting of: SEQ ID NOs: 2/10; 34/42; 50/58; 66/74; 114/122; 130/138; 146/154; 162/170; 194/202; 210/218; 242/250; 258/266; and 274/282.

20. The method of claim 19, wherein the antibody or antigen-binding fragment thereof comprises HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3 domains, respectively, selected from the group consisting of: SEQ ID NOs: 4-6-8-12-14-16; 36-38-40-44-46-48; 52-54-56-60-62-64; 68-70-72-76-78-80; 116-118-120-124-126-128; 132-134-136-140-142-144; 148-150-152-156-158-160; 164-166-168-172-174-176; 196-198-200-204-206-208; 212-214-216-220-222-224; 244-246-248-252-254-256; 260-262-264-268-270-272; and 276-278-280-284-286-288.