

TECHNICAL WHITE PAPER: GENE LISTS

Table 1. 343 Genes Selected for Anatomic Structures ISH Survey (AS)

| Gene Symbol | EntrezID | Name | Studies Used |
|-------------|----------|---|--------------|
| ABCC3 | 8714 | ATP-binding cassette, sub-family C (CFTR/MRP), member 3 | AS |
| ABCC8 | 6833 | ATP-binding cassette, sub-family C (CFTR/MRP), member 8 | AS |
| ABL1 | 25 | c-abl oncogene 1, non-receptor tyrosine kinase | AS |
| ACVR1 | 90 | activin A receptor, type I | AS |
| ACVR1B | 91 | activin A receptor, type IB | AS |
| ACVR1C | 130399 | activin A receptor, type IC | AS |
| ACVRL1 | 94 | activin A receptor type II-like 1 | AS |
| ADH1B | 125 | alcohol dehydrogenase 1B (class I), beta polypeptide | AS |
| ADH1C | 126 | alcohol dehydrogenase 1C (class I), gamma polypeptide | AS |
| AKR1A1 | 10327 | aldo-keto reductase family 1, member A1 (aldehyde reductase) | AS |
| AKT1 | 207 | v-akt murine thymoma viral oncogene homolog 1 | AS,SS |
| ALDH3A2 | 224 | aldehyde dehydrogenase 3 family, member A2 | AS |
| ALDH9A1 | 223 | aldehyde dehydrogenase 9 family, member A1 | AS |
| ALDOA | 226 | aldolase A, fructose-bisphosphate | AS |
| ALDOB | 229 | aldolase B, fructose-bisphosphate | AS |
| ANGPTL4 | 51129 | angiopoietin-like 4 | AS |
| ANKRD22 | 118932 | ankyrin repeat domain 22 | AS |
| ANXA5 | 308 | annexin A5 | AS |
| APOBEC3C | 27350 | apolipoprotein B mRNA editing enzyme, catalytic polypeptide-like 3C | AS |
| APOD | 347 | apolipoprotein D | AS |
| AR | 367 | androgen receptor | AS |
| ARMCX6 | 54470 | armadillo repeat containing, X-linked 6 | AS |
| ARSJ | 79642 | arylsulfatase family, member J | AS |
| ATM | 472 | ataxia telangiectasia mutated | AS |
| ATP1A1 | 476 | ATPase, Na ⁺ /K ⁺ transporting, alpha 1 polypeptide | AS |
| ATP1A2 | 477 | ATPase, Na ⁺ /K ⁺ transporting, alpha 2 polypeptide | AS |
| ATP1A3 | 478 | ATPase, Na ⁺ /K ⁺ transporting, alpha 3 polypeptide | AS |
| ATP1B1 | 481 | ATPase, Na ⁺ /K ⁺ transporting, beta 1 polypeptide | AS |
| ATP2A2 | 488 | ATPase, Ca ⁺⁺ transporting, cardiac muscle, slow twitch 2 | AS |
| ATP2B1 | 490 | ATPase, Ca ⁺⁺ transporting, plasma membrane 1 | AS |
| ATP2B3 | 492 | ATPase, Ca ⁺⁺ transporting, plasma membrane 3 | AS |
| ATP6V0E1 | 8992 | ATPase, H ⁺ transporting, lysosomal 9kDa, V0 subunit e1 | AS |
| ATP6V1G2 | 534 | ATPase, H ⁺ transporting, lysosomal 13kDa, V1 subunit G2 | AS |
| BAX | 581 | BCL2-associated X protein | AS,SS |

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|----------|--------|--|----------|
| BBS9 | 27241 | Bardet-Biedl syndrome 9 | AS |
| BIN1 | 274 | bridging integrator 1 | AS |
| BLM | 641 | Bloom syndrome, RecQ helicase-like | AS |
| BMP7 | 655 | bone morphogenetic protein 7 | AS |
| BMPR1A | 657 | bone morphogenetic protein receptor, type IA | AS |
| BMPR2 | 659 | bone morphogenetic protein receptor, type II (serine/threonine kinase) | AS |
| BPGM | 669 | 2,3-bisphosphoglycerate mutase | AS |
| BRAF | 673 | v-raf murine sarcoma viral oncogene homolog B1 | AS |
| BRCA1 | 672 | breast cancer 1, early onset | AS |
| BRSK1 | 84446 | BR serine/threonine kinase 1 | AS |
| C12orf23 | 90488 | chromosome 12 open reading frame 23 | AS |
| C1orf106 | 55765 | chromosome 1 open reading frame 106 | AS |
| C1orf112 | 55732 | chromosome 1 open reading frame 112 | AS |
| C1orf162 | 128346 | chromosome 1 open reading frame 162 | AS |
| C1orf187 | 374946 | chromosome 1 open reading frame 187 | AS |
| C1R | 715 | complement component 1, r subcomponent | AS |
| C5orf15 | 56951 | chromosome 5 open reading frame 15 | AS |
| C5orf62 | 85027 | chromosome 5 open reading frame 62 | AS |
| C7orf49 | 78996 | chromosome 7 open reading frame 49 | AS |
| C8orf4 | 56892 | chromosome 8 open reading frame 4 | AS,SG |
| CACNA1B | 774 | calcium channel, voltage-dependent, N type, alpha 1B subunit | AS |
| CACNA1C | 775 | calcium channel, voltage-dependent, L type, alpha 1C subunit | AS |
| CACNB1 | 782 | calcium channel, voltage-dependent, beta 1 subunit | AS |
| CACNG4 | 27092 | calcium channel, voltage-dependent, gamma subunit 4 | AS |
| CAMK2A | 815 | calcium/calmodulin-dependent protein kinase II alpha | AS |
| CANX | 821 | calnexin | AS |
| CASP8 | 841 | caspase 8, apoptosis-related cysteine peptidase | AS |
| CAV1 | 857 | caveolin 1, caveolae protein, 22kDa | AS |
| CCDC109B | 55013 | coiled-coil domain containing 109B | AS |
| CCDC80 | 151887 | coiled-coil domain containing 80 | AS |
| CCNB1 | 891 | cyclin B1 | AS |
| CCND1 | 595 | cyclin D1 | AS |
| CCND2 | 894 | cyclin D2 | AS,SS |
| CD163 | 9332 | CD163 molecule | AS,SG |
| CD164 | 8763 | CD164 molecule, sialomucin | AS |
| CD44 | 960 | CD44 molecule (Indian blood group) | AS,SS,SR |
| CD53 | 963 | CD53 molecule | AS |
| CD63 | 967 | CD63 molecule | AS |
| CDC42 | 998 | cell division cycle 42 (GTP binding protein, 25kDa) | AS |
| CDCA7 | 83879 | cell division cycle associated 7 | AS |
| CDH1 | 999 | cadherin 1, type 1, E-cadherin (epithelial) | AS |
| CDK4 | 1019 | cyclin-dependent kinase 4 | AS |
| CDK6 | 1021 | cyclin-dependent kinase 6 | AS |
| CDKN1A | 1026 | cyclin-dependent kinase inhibitor 1A (p21, Cip1) | AS |
| CDKN1B | 1027 | cyclin-dependent kinase inhibitor 1B (p27, Kip1) | AS |
| CDKN2B | 1030 | cyclin-dependent kinase inhibitor 2B (p15, inhibits CDK4) | AS |

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|-------------------|--------|--|-------|
| CDKN2C | 1031 | cyclin-dependent kinase inhibitor 2C (p18, inhibits CDK4) | AS |
| CENPK | 64105 | centromere protein K | AS |
| CHEK1 | 1111 | checkpoint kinase 1 | AS |
| CHI3L1 | 1116 | chitinase 3-like 1 (cartilage glycoprotein-39) | AS |
| CKAP2L | 150468 | cytoskeleton associated protein 2-like | AS |
| CLCN3 | 1182 | chloride channel, voltage-sensitive 3 | AS |
| CLCN4 | 1183 | chloride channel, voltage-sensitive 4 | AS |
| COL1A1 | 1277 | collagen, type I, alpha 1 | AS |
| COL4A1 | 1282 | collagen, type IV, alpha 1 | AS |
| COL4A2 | 1284 | collagen, type IV, alpha 2 | AS |
| COX11 | 1353 | COX11 cytochrome c oxidase assembly homolog (yeast) | AS |
| COX4I1 | 1327 | cytochrome c oxidase subunit IV isoform 1 | AS |
| COX5B | 1329 | cytochrome c oxidase subunit Vb | AS |
| COX7A2L | 9167 | cytochrome c oxidase subunit VIIa polypeptide 2 like | AS |
| CREBBP | 1387 | CREB binding protein | AS |
| CRISPLD1 | 83690 | cysteine-rich secretory protein LCCL domain containing 1 | AS |
| CS | 1431 | citrate synthase | AS |
| CSDC2 | 27254 | cold shock domain containing C2, RNA binding | AS |
| CTGF | 1490 | connective tissue growth factor | AS,SS |
| CTNNA2 | 1496 | catenin (cadherin-associated protein), alpha 2 | AS |
| CTNNB1 | 1499 | catenin (cadherin-associated protein), beta 1, 88kDa | AS |
| CUL5 | 8065 | cullin 5 | AS |
| CUL9 | 23113 | cullin 9 | AS |
| DESI2 | 51029 | desumoylating isopeptidase 2 | AS |
| DICER1 | 23405 | dicer 1, ribonuclease type III | AS |
| DIRAS3 | 9077 | DIRAS family, GTP-binding RAS-like 3 | AS |
| DKK1 | 22943 | dickkopf 1 homolog (<i>Xenopus laevis</i>) | AS,SG |
| DLD | 1738 | dihydrolipoamide dehydrogenase | AS |
| DLEU1 | 10301 | deleted in lymphocytic leukemia 1 (non-protein coding) | AS |
| DNMT1 | 1786 | DNA (cytosine-5-)-methyltransferase 1 | AS |
| DOCK2 | 1794 | dedicator of cytokinesis 2 | AS |
| DOCK3 | 1795 | dedicator of cytokinesis 3 | AS |
| DRAM1 | 55332 | DNA-damage regulated autophagy modulator 1 | AS |
| DTL | 51514 | denticleless E3 ubiquitin protein ligase homolog (<i>Drosophila</i>) | AS |
| DTNA | 1837 | dystrobrevin, alpha | AS |
| EFEMP1 | 2202 | EGF containing fibulin-like extracellular matrix protein 1 | AS,SG |
| EGFR ^z | 1956 | epidermal growth factor receptor | AS |
| EIF4E2 | 9470 | eukaryotic translation initiation factor 4E family member 2 | AS |
| EMP3 | 2014 | epithelial membrane protein 3 | AS |
| ENO1 | 2023 | enolase 1, (alpha) | AS |
| EP300 | 2033 | E1A binding protein p300 | AS |
| EP400NL | 347918 | EP400 N-terminal like | AS |
| EPHB1 | 2047 | EPH receptor B1 | AS |
| EPHB6 | 2051 | EPH receptor B6 | AS |
| ERBB2 | 2064 | v-erb-b2 erythroblastic leukemia viral oncogene homolog 2, neuro/glioblastoma derived oncogene homolog (avian) | AS,SS |

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|----------|--------|---|----------|
| ERBB3 | 2065 | v-erb-b2 erythroblastic leukemia viral oncogene homolog 3 (avian) | AS,SS |
| EXT1 | 2131 | exostosin 1 | AS |
| FABP4 | 2167 | fatty acid binding protein 4, adipocyte | AS |
| FAM114A1 | 92689 | family with sequence similarity 114, member A1 | AS |
| FAM129A | 116496 | family with sequence similarity 129, member A | AS,SG |
| FAM20A | 54757 | family with sequence similarity 20, member A | AS |
| FAM70A | 55026 | family with sequence similarity 70, member A | AS |
| FAM83D | 81610 | family with sequence similarity 83, member D | AS |
| FANCI | 55215 | Fanconi anemia, complementation group I | AS |
| FAS | 355 | Fas (TNF receptor superfamily, member 6) | AS,SG |
| FBP1 | 2203 | fructose-1,6-bisphosphatase 1 | AS |
| FBXW7 | 55294 | F-box and WD repeat domain containing 7, E3 ubiquitin protein ligase | AS |
| FCGR2B | 2213 | Fc fragment of IgG, low affinity IIb, receptor (CD32) | AS |
| FERMT1 | 55612 | fermitin family member 1 | AS |
| FGF1 | 2246 | fibroblast growth factor 1 (acidic) | AS |
| FGFR1 | 2260 | fibroblast growth factor receptor 1 | AS |
| FIGF | 2277 | c-fos induced growth factor (vascular endothelial growth factor D) | AS |
| FLJ45482 | 645566 | uncharacterized LOC645566 | AS |
| FLNA | 2316 | filamin A, alpha | AS |
| FOSL2 | 2355 | FOS-like antigen 2 | AS |
| FOXO3 | 2309 | forkhead box O3 | AS,SS |
| FXYD1 | 5348 | FXYD domain containing ion transport regulator 1 | AS |
| GABBR1 | 2550 | gamma-aminobutyric acid (GABA) B receptor, 1 | AS |
| GABBR2 | 9568 | gamma-aminobutyric acid (GABA) B receptor, 2 | AS |
| GALM | 130589 | galactose mutarotase (aldose 1-epimerase) | AS |
| GFAP | 2670 | glial fibrillary acidic protein | AS |
| GFRA1 | 2674 | GDNF family receptor alpha 1 | AS |
| GFRA2 | 2675 | GDNF family receptor alpha 2 | AS |
| GFRA3 | 2676 | GDNF family receptor alpha 3 | AS |
| GJA1 | 2697 | gap junction protein, alpha 1, 43kDa | AS |
| GLA | 2717 | galactosidase, alpha | AS |
| GLIPR2 | 152007 | GLI pathogenesis-related 2 | AS |
| GNAS | 2778 | GNAS complex locus | AS |
| GOLPH3 | 64083 | golgi phosphoprotein 3 (coat-protein) | AS |
| GRB2 | 2885 | growth factor receptor-bound protein 2 | AS |
| GRM7 | 2917 | glutamate receptor, metabotropic 7 | AS |
| H3F3A | 3020 | H3 histone, family 3A | AS |
| HDAC1 | 3065 | histone deacetylase 1 | AS |
| HDAC6 | 10013 | histone deacetylase 6 | AS |
| HES1 | 3280 | hairy and enhancer of split 1, (Drosophila) | AS |
| HIF1A | 3091 | hypoxia inducible factor 1, alpha subunit (basic helix-loop-helix transcription factor) | AS,SS,SR |
| HK2 | 3099 | hexokinase 2 | AS |
| HMG2P46 | 283651 | high mobility group nucleosomal binding domain 2 pseudogene 46 | AS |
| HN1L | 90861 | hematological and neurological expressed 1-like | AS |
| HS6ST1 | 9394 | heparan sulfate 6-O-sulfotransferase 1 | AS |
| HSP90AA1 | 3320 | heat shock protein 90kDa alpha (cytosolic), class A member 1 | AS |

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|--------------------|--------|---|----------------|
| HTATIP2 | 10553 | HIV-1 Tat interactive protein 2, 30kDa | AS |
| IDH1 | 3417 | isocitrate dehydrogenase 1 (NADP+), soluble | AS |
| IDH2 | 3418 | isocitrate dehydrogenase 2 (NADP+), mitochondrial | AS |
| IGFBP2 | 3485 | insulin-like growth factor binding protein 2, 36kDa | AS,SS,SR |
| IL10RA | 3587 | interleukin 10 receptor, alpha | AS |
| IRS1 | 3667 | insulin receptor substrate 1 | AS |
| ITGA5 | 3678 | integrin, alpha 5 (fibronectin receptor, alpha polypeptide) | AS |
| JAG1 | 182 | jagged 1 | AS |
| KCNH3 | 23416 | potassium voltage-gated channel, subfamily H (eag-related), member 3 | AS |
| KCNJ4 | 3761 | potassium inwardly-rectifying channel, subfamily J, member 4 | AS |
| KCNMB4 | 27345 | potassium large conductance calcium-activated channel, subfamily M, beta member 4 | AS |
| KCNS1 | 3787 | potassium voltage-gated channel, delayed-rectifier, subfamily S, member 1 | AS |
| KDR | 3791 | kinase insert domain receptor (a type III receptor tyrosine kinase) | AS |
| KHDRBS2 | 202559 | KH domain containing, RNA binding, signal transduction associated 2 | AS |
| KIAA0101 | 9768 | KIAA0101 | AS |
| KIAA1143 | 57456 | KIAA1143 | AS |
| KIF2C | 11004 | kinesin family member 2C | AS |
| KIT | 3815 | v-kit Hardy-Zuckerman 4 feline sarcoma viral oncogene homolog | AS,SS |
| KLHDC8A | 55220 | kelch domain containing 8A | AS |
| KLHL7 | 55975 | kelch-like 7 (Drosophila) | AS |
| KRCC1 | 51315 | lysine-rich coiled-coil 1 | AS |
| LAMB1 | 3912 | laminin, beta 1 | AS |
| LASP1 | 3927 | LIM and SH3 protein 1 | AS |
| LDHA | 3939 | lactate dehydrogenase A | AS |
| LHFPL3 | 375612 | lipoma HMGIC fusion partner-like 3 | AS |
| LIF | 3976 | leukemia inhibitory factor | AS,SG |
| LOC389831 | 389831 | uncharacterized LOC389831 | AS |
| LPL | 4023 | lipoprotein lipase | AS |
| LRRTM3 | 347731 | leucine rich repeat transmembrane neuronal 3 | AS |
| LRRTM4 | 80059 | leucine rich repeat transmembrane neuronal 4 | AS |
| MAP2K1 | 5604 | mitogen-activated protein kinase kinase 1 | AS |
| MAP2K4 | 6416 | mitogen-activated protein kinase kinase 4 | AS |
| MAP3K7 | 6885 | mitogen-activated protein kinase kinase kinase 7 | AS |
| MAPK3 | 5595 | mitogen-activated protein kinase 3 | AS,SS |
| MARK2 | 2011 | MAP/microtubule affinity-regulating kinase 2 | AS |
| MCM5 | 4174 | minichromosome maintenance complex component 5 | AS |
| MDM4 | 4194 | Mdm4 p53 binding protein homolog (mouse) | AS |
| MECOM ¹ | 2122 | MDS1 and EVI1 complex locus | AS,AG,SS,SR,SG |
| METTL21B | 25895 | methyltransferase like 21B | AS |
| MGMT | 4255 | O-6-methylguanine-DNA methyltransferase | AS |
| MLH1 | 4292 | mutL homolog 1, colon cancer, nonpolyposis type 2 (E. coli) | AS |
| MPLKIP | 136647 | M-phase specific PLK1 interacting protein | AS |
| MSH2 | 4436 | mutS homolog 2, colon cancer, nonpolyposis type 1 (E. coli) | AS |
| MSH6 | 2956 | mutS homolog 6 (E. coli) | AS |
| MYC | 4609 | v-myc myelocytomatosis viral oncogene homolog (avian) | AS,SS,SR |
| NBN | 4683 | nibrin | AS |

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|----------------------|--------|---|----------|
| NCAM1 | 4684 | neural cell adhesion molecule 1 | AS |
| NCAM2 | 4685 | neural cell adhesion molecule 2 | AS |
| NCF2 | 4688 | neutrophil cytosolic factor 2 | AS |
| NCL | 4691 | nucleolin | AS |
| NCOA3 | 8202 | nuclear receptor coactivator 3 | AS |
| NDRG2 | 57447 | NDRG family member 2 | AS |
| NF2 | 4771 | neurofibromin 2 (merlin) | AS |
| NOS3 | 4846 | nitric oxide synthase 3 (endothelial cell) | AS |
| NOTCH1 | 4851 | notch 1 | AS,SS |
| NRAS | 4893 | neuroblastoma RAS viral (v-ras) oncogene homolog | AS |
| NRXN3 | 9369 | neurexin 3 | AS |
| NSF | 4905 | N-ethylmaleimide-sensitive factor | AS |
| NTRK3 | 4916 | neurotrophic tyrosine kinase, receptor, type 3 | AS |
| OAS1 | 4938 | 2'-5'-oligoadenylate synthetase 1, 40/46kDa | AS |
| OLFML3 | 56944 | olfactomedin-like 3 | AS |
| OLIG2 | 10215 | oligodendrocyte lineage transcription factor 2 | AS,SS |
| OSBP | 5007 | oxysterol binding protein | AS |
| P2RX2 | 22953 | purinergic receptor P2X, ligand-gated ion channel, 2 | AS |
| PARVG | 64098 | parvin, gamma | AS |
| PCDHGA5 ^Z | 56110 | protocadherin gamma subfamily A, 5 | AS |
| PCDHGC3 | 5098 | protocadherin gamma subfamily C, 3 | AS |
| PDE1C | 5137 | phosphodiesterase 1C, calmodulin-dependent 70kDa | AS |
| PDGFA | 5154 | platelet-derived growth factor alpha polypeptide | AS |
| PDGFD | 80310 | platelet derived growth factor D | AS |
| PDGFRA | 5156 | platelet-derived growth factor receptor, alpha polypeptide | AS,SS,SR |
| PDGFRB | 5159 | platelet-derived growth factor receptor, beta polypeptide | AS |
| PDLIM4 | 8572 | PDZ and LIM domain 4 | AS |
| PDPN | 10630 | podoplanin | AS,SS,SR |
| PEG3 | 5178 | paternally expressed 3 | AS |
| PGAM2 | 5224 | phosphoglycerate mutase 2 (muscle) | AS |
| PGK1 | 5230 | phosphoglycerate kinase 1 | AS |
| PGK2 | 5232 | phosphoglycerate kinase 2 | AS |
| PGM3 | 5238 | phosphoglucomutase 3 | AS |
| PIK3CG | 5294 | phosphoinositide-3-kinase, catalytic, gamma polypeptide | AS |
| PIK3R1 | 5295 | phosphoinositide-3-kinase, regulatory subunit 1 (alpha) | AS |
| PKM | 5315 | pyruvate kinase, muscle | AS |
| PLCG1 | 5335 | phospholipase C, gamma 1 | AS |
| PLP2 | 5355 | proteolipid protein 2 (colonic epithelium-enriched) | AS |
| PLVAP | 83483 | plasmalemma vesicle associated protein | AS |
| PMCH | 5367 | pro-melanin-concentrating hormone | AS |
| PMS2 | 5395 | PMS2 postmeiotic segregation increased 2 (<i>S. cerevisiae</i>) | AS |
| PNPLA6 | 10908 | patatin-like phospholipase domain containing 6 | AS |
| PRRC1 | 133619 | proline-rich coiled-coil 1 | AS |
| PRUNE2 | 158471 | prune homolog 2 (<i>Drosophila</i>) | AS |
| PSD2 | 84249 | pleckstrin and Sec7 domain containing 2 | AS |
| PTEN | 5728 | phosphatase and tensin homolog | AS |

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|----------|--------|--|-------|
| RASL10A | 10633 | RAS-like, family 10, member A | AS |
| RASSF4 | 83937 | Ras association (RalGDS/AF-6) domain family member 4 | AS |
| RB1 | 5925 | retinoblastoma 1 | AS |
| RBM47 | 54502 | RNA binding motif protein 47 | AS |
| RET | 5979 | ret proto-oncogene | AS |
| RUNX1 | 861 | runt-related transcription factor 1 | AS,SG |
| S100A4 | 6275 | S100 calcium binding protein A4 | AS,SG |
| SAA2 | 6289 | serum amyloid A2 | AS |
| SAMD9 | 54809 | sterile alpha motif domain containing 9 | AS |
| SAMD9L | 219285 | sterile alpha motif domain containing 9-like | AS |
| SCG2 | 7857 | secretogranin II | AS |
| SCG3 | 29106 | secretogranin III | AS |
| SCN2A | 6326 | sodium channel, voltage-gated, type II, alpha subunit | AS |
| SCP2 | 6342 | sterol carrier protein 2 | AS |
| SDHA | 6389 | succinate dehydrogenase complex, subunit A, flavoprotein (Fp) | AS |
| SEPT9 | 10801 | septin 9 | AS |
| SERPINE1 | 5054 | serpin peptidase inhibitor, clade E (nexin, plasminogen activator inhibitor type 1), member 1 | AS |
| SERPINF1 | 5176 | serpin peptidase inhibitor, clade F(alpha-2 antiplasmin, pigment epithelium derived factor), member1 | AS |
| SFRP4 | 6424 | secreted frizzled-related protein 4 | AS |
| SKIL | 6498 | SKI-like oncogene | AS |
| SLC11A2 | 4891 | solute carrier family 11 (proton-coupled divalent metal ion transporters), member 2 | AS |
| SLC12A9 | 56996 | solute carrier family 12 (potassium/chloride transporters), member 9 | AS |
| SLC20A2 | 6575 | solute carrier family 20 (phosphate transporter), member 2 | AS |
| SLC25A3 | 5250 | solute carrier family 25 (mitochondrial carrier; phosphate carrier), member 3 | AS |
| SLC30A3 | 7781 | solute carrier family 30 (zinc transporter), member 3 | AS |
| SLC35F5 | 80255 | solute carrier family 35, member F5 | AS |
| SLC39A11 | 201266 | solute carrier family 39 (metal ion transporter), member 11 | AS |
| SLC3A2 | 6520 | solute carrier family 3 (activators of dibasic and neutral amino acid transport), member 2 | AS |
| SLC4A4 | 8671 | solute carrier family 4, sodium bicarbonate cotransporter, member 4 | AS |
| SLC9A6 | 10479 | solute carrier family 9, subfamily A (NHE6, cation proton antiporter 6), member 6 | AS |
| SLMO2 | 51012 | slowmo homolog 2 (Drosophila) | AS |
| SMAD2 | 4087 | SMAD family member 2 | AS |
| SMAD3 | 4088 | SMAD family member 3 | AS |
| SMAD4 | 4089 | SMAD family member 4 | AS |
| SMAD7 | 4092 | SMAD family member 7 | AS |
| SNAP25 | 6616 | synaptosomal-associated protein, 25kDa | AS |
| SNAP91 | 9892 | synaptosomal-associated protein, 91kDa homolog (mouse) | AS |
| SNRPN | 6638 | small nuclear ribonucleoprotein polypeptide N | AS |
| SOX8 | 30812 | SRY (sex determining region Y)-box 8 | AS |
| SPHK1 | 8877 | sphingosine kinase 1 | AS |
| SPTSSA | 171546 | serine palmitoyltransferase, small subunit A | AS |
| SRPX2 | 27286 | sushi-repeat containing protein, X-linked 2 | AS |
| SRRM2 | 23524 | serine/arginine repetitive matrix 2 | AS |
| STARD3 | 10948 | STAR-related lipid transfer (START) domain containing 3 | AS |
| STAT3 | 6774 | signal transducer and activator of transcription 3 (acute-phase response factor) | AS,SS |
| STK11 | 6794 | serine/threonine kinase 11 | AS |

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| STK17A | 9263 | serine/threonine kinase 17a | AS |
| SUCLA2 | 8803 | succinate-CoA ligase, ADP-forming, beta subunit | AS |
| SUN1 | 23353 | Sad1 and UNC84 domain containing 1 | AS |
| SYT3 | 84258 | synaptotagmin III | AS |
| SYTL4 | 94121 | synaptotagmin-like 4 | AS |
| TAB1 | 10454 | TGF-beta activated kinase 1/MAP3K7 binding protein 1 | AS |
| TAGLN | 6876 | transgelin | AS |
| TCF12 | 6938 | transcription factor 12 | AS |
| TCF3 | 6929 | transcription factor 3 (E2A immunoglobulin enhancer binding factors E12/E47) | AS |
| TCTN1 | 79600 | tectonic family member 1 | AS |
| TEX26 | 122046 | testis expressed 26 | AS |
| TGFB1 | 7040 | transforming growth factor, beta 1 | AS |
| TGFB3 | 7043 | transforming growth factor, beta 3 | AS |
| TGFBI | 7045 | transforming growth factor, beta-induced, 68kDa | AS,SG |
| TGFBR1 | 7046 | transforming growth factor, beta receptor 1 | AS |
| TGFBR2 | 7048 | transforming growth factor, beta receptor II (70/80kDa) | AS,SS,SR |
| THBS1 | 7057 | thrombospondin 1 | AS,SG |
| TIMP1 | 7076 | TIMP metalloproteinase inhibitor 1 | AS |
| TMEM248 | 55069 | transmembrane protein 248 | AS |
| TMEM45A | 55076 | transmembrane protein 45A | AS |
| TNFRSF12A | 51330 | tumor necrosis factor receptor superfamily, member 12A | AS |
| TOP2A | 7153 | topoisomerase (DNA) II alpha 170kDa | AS,SS |
| TP53 | 7157 | tumor protein p53 | AS |
| TRAPPC10 | 7109 | trafficking protein particle complex 10 | AS |
| TRIM28 | 10155 | tripartite motif containing 28 | AS |
| TRPV2 | 51393 | transient receptor potential cation channel, subfamily V, member 2 | AS |
| TRRAP | 8295 | transformation/transcription domain-associated protein | AS |
| TSC2 | 7249 | tuberous sclerosis 2 | AS |
| TSPAN6 | 7105 | tetraspanin 6 | AS |
| TSPO | 706 | translocator protein (18kDa) | AS |
| UQCRC1 | 7384 | ubiquinol-cytochrome c reductase core protein I | AS |
| UQCRH | 7388 | ubiquinol-cytochrome c reductase hinge protein | AS |
| VDAC1 | 7416 | voltage-dependent anion channel 1 | AS |
| VEGFA | 7422 | vascular endothelial growth factor A | AS |
| VHL | 7428 | von Hippel-Lindau tumor suppressor, E3 ubiquitin protein ligase | AS |

¹MECOM, not counted as one of 343 genes studied, was used for a tissue control in every ISH run, along with a no probe control slide.

²EGFR and PCDHGA were assessed with two probes each on independent slides.

Abbreviations of studies: AS (Anatomic Structures ISH Survey), AG (Anatomic Structures ISH for Enriched Genes), SS (Cancer Stem Cells ISH Survey), SR (Cancer Stem Cells RNA-Seq), and SG (Cancer Stem Cells ISH for Enriched Genes).

All probes were hybridized at 300ng/ml.

Table 2. 37 Genes Selected for Anatomic Structures ISH for Enriched Genes Study (AG)

| Gene Symbol | EntrezID | Name | Expected Specificity | Structures in Tissue for ISH | Studies Used |
|--------------------|----------|--|----------------------|---|-----------------|
| ARRDC3 | 57561 | arrestin domain containing 3 | PAN | CT, MVP, PAN | AG |
| ATF3 | 467 | activating transcription factor 3 | MVP/PAN | CT, MVP, PAN | AG,SG |
| BCAN | 63827 | brevican | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| BNIP3 | 664 | BCL2/adenovirus E1B 19kDa interacting protein 3 | PAN | CT, MVP, PAN | AG |
| BTG1 | 694 | B-cell translocation gene 1, anti-proliferative | MVP/PAN | LE, IT, CT, MVP, PAN | AG |
| CA9 | 768 | carbonic anhydrase IX | PAN | CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| CLEC2B | 9976 | C-type lectin domain family 2, member B | MVP/PAN | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| DDR1 | 780 | discoidin domain receptor tyrosine kinase 1 | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| DOK5 | 55816 | docking protein 5 | PAN | CT, MVP, PAN | AG |
| ELTD1 | 64123 | EGF, latrophilin and seven transmembrane domain containing 1 | MVP | CT, MVP, PAN | AG |
| ENPEP | 2028 | glutamyl aminopeptidase (aminopeptidase A) | MVP | CT, MVP, PAN | AG |
| ESM1 | 11082 | endothelial cell-specific molecule 1 | MVP | LE, IT, CT, MVP, PAN | AG |
| FAM162B | 221303 | family with sequence similarity 162, member B | MVP | CT, MVP, PAN | AG |
| FGFR3-TACC3 | NA | FGFR3-TACC3 fusion gene | N/A | FGFR3-TACC3 fusion blocks | AG |
| HIST1H1E | 3008 | histone cluster 1, H1e | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| ISG20 | 3669 | interferon stimulated exonuclease gene 20kDa | MVP/PAN | CT, MVP, PAN | AG |
| ITGA1 | 3672 | integrin, alpha 1 | MVP | CT, MVP, PAN | AG |
| KLF6 | 1316 | Kruppel-like factor 6 | MVP/PAN | CT, MVP, PAN | AG |
| LGALS3 | 3958 | lectin, galactoside-binding, soluble, 3 | MVP/PAN | CT, MVP, PAN | AG |
| MECOM ¹ | 2122 | MDS1 and EVI1 complex locus | N/A | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AS,AG,SS,S R,SG |
| MYADM | 91663 | myeloid-associated differentiation marker | MVP/PAN | CT, MVP, PAN | AG |
| MYL12B | 103910 | myosin, light chain 12B, regulatory | LE/IT | LE, IT | AG |
| NDRG1 | 10397 | N-myc downstream regulated 1 | PAN | CT, MVP, PAN | AG |
| NID2 | 22795 | nidogen 2 (osteonidogen) | MVP | CT, MVP, PAN | AG |
| NOVA1 | 4857 | neuro-oncological ventral antigen 1 | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| NREP | 9315 | neuronal regeneration related protein homolog (rat) | LE/IT | LE, IT, FGFR3-TACC3 fusion blocks | AG |
| NUSAP1 | 51203 | nucleolar and spindle associated protein 1 | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |

| | | | | | |
|---------|--------|---|---------|---|----|
| OR51E1 | 143503 | olfactory receptor, family 51, subfamily E, member 1 | MVP | CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| PTPRZ1 | 5803 | protein tyrosine phosphatase, receptor-type, Z polypeptide 1 | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| PYGL | 5836 | phosphorylase, glycogen, liver | PAN | CT, MVP, PAN | AG |
| SOCS3 | 9021 | suppressor of cytokine signaling 3 | MVP/PAN | CT, MVP, PAN | AG |
| STC1 | 6781 | stanniocalcin 1 | MVP/PAN | CT, MVP, PAN | AG |
| TAX1BP3 | 30851 | Tax1 (human T-cell leukemia virus type I) binding protein 3 | LE/IT | LE, IT, FGFR3-TACC3 fusion blocks | AG |
| TES | 26136 | testis derived transcript (3 LIM domains) | MVP | CT, MVP, PAN | AG |
| TNFAIP1 | 7126 | tumor necrosis factor, alpha-induced protein 1 (endothelial) | LE/IT | LE, IT | AG |
| TPX2 | 22974 | TPX2, microtubule-associated, homolog (<i>Xenopus laevis</i>) | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |
| TREM1 | 54210 | triggering receptor expressed on myeloid cells 1 | PAN | CT, MVP, PAN | AG |
| UHRF1 | 29128 | ubiquitin-like with PHD and ring finger domains 1 | CT | LE, IT, CT, MVP, PAN, FGFR3-TACC3 fusion blocks | AG |

¹MECOM, not counted as one of 37 genes studied, was used for a tissue control in every ISH run, along with a no probe control slide.

Abbreviations of structures: LE (Leading Edge), IT (Infiltrating Tumor), CT (Cellular Tumor), MVP (Microvascular Proliferation), PAN (Pseudopalisading Cells around Necrosis), and FGFR3-TACC3 fusion blocks (tissue blocks where a FGFR3-TACC3 fusion was detected by RNA-Seq).

Abbreviations of studies: AS (Anatomic Structures ISH Survey), AG (Anatomic Structures ISH for Enriched Genes), SS (Cancer Stem Cells ISH Survey), SR (Cancer Stem Cells RNA-Seq), and SG (Cancer Stem Cells ISH for Enriched Genes).

Probes hybridized at 300ng/ml were: BCAN, DDR1, LGALS3, MECOM (EVI1), MYL12B, NDRG1, NOVA1, PTPRZ1, PYGL, TAX1BP3, and TNFAIP1.

Probes hybridized at 600ng/ml were: ARRDC3, ATF3, BNIP3, BTG1, CA9, CLEC2B, DOK5, ELTD1, ENPEP, ESM1, FAM162B, FGFR3-TACC3, HIST1H1E, ISG20, ITGA1, KLF6, MYADM, NID2, NREP, NUSAP1, OR51E1, SOCS3, STC1, TES, TPX2, TREM1, and UHRF1.

Table 3. 55 Genes Selected for Pre-Survey Pilot of Cancer Stem Cells ISH Survey (SS)

| Gene Symbol | EntrezID | Name | Studies Used |
|------------------|----------|--|--------------|
| ABCB1 | 5243 | ATP-binding cassette, sub-family B (MDR/TAP), member 1 | SS |
| ABCG2 | 9429 | ATP-binding cassette, sub-family G (WHITE), member 2 | SS |
| AKT1 | 207 | v-akt murine thymoma viral oncogene homolog 1 | AS,SS |
| ALDH1A1 | 216 | aldehyde dehydrogenase 1 family, member A1 | SS |
| ASCL1 | 429 | achaete-scute complex homolog 1 (<i>Drosophila</i>) | SS |
| BAX ² | 581 | BCL2-associated X protein | AS,SS |
| BIRC5 | 332 | baculoviral IAP repeat containing 5 | SS |
| BMI1 | 648 | BMI1 polycomb ring finger oncogene | SS |
| CCDC88A | 55704 | coiled-coil domain containing 88A | SS |
| CCND2 | 894 | cyclin D2 | AS,SS |
| CD34 | 947 | CD34 molecule | SS |
| CD44 | 960 | CD44 molecule (Indian blood group) | AS,SS,SR |
| CSPG4 | 1464 | chondroitin sulfate proteoglycan 4 | SS |
| CTGF | 1490 | connective tissue growth factor | AS,SS |
| DANCR | 57291 | differentiation antagonizing non-protein coding RNA | SS,SR |

| | | | |
|---------------------|-------|--|----------------|
| DLX5 | 1749 | distal-less homeobox 5 | SS |
| EPAS1 | 2034 | endothelial PAS domain protein 1 | SS |
| ERBB2 | 2064 | v-erb-b2 erythroblastic leukemia viral oncogene homolog 2, neuro/glioblastoma derived oncogene homolog (avian) | AS,SS |
| ERBB3 | 2065 | v-erb-b2 erythroblastic leukemia viral oncogene homolog 3 (avian) | AS,SS |
| EZH2 | 2146 | enhancer of zeste homolog 2 (Drosophila) | SS |
| FOXO3 | 2309 | forkhead box O3 | AS,SS |
| FUT4 | 2526 | fucosyltransferase 4 (alpha (1,3) fucosyltransferase, myeloid-specific) | SS |
| HES6 | 55502 | hairy and enhancer of split 6 (Drosophila) | SS |
| HIF1A | 3091 | hypoxia inducible factor 1, alpha subunit (basic helix-loop-helix transcription factor) | AS,SS,SR |
| ID1 | 3397 | inhibitor of DNA binding 1, dominant negative helix-loop-helix protein | SS,SR |
| ID2 | 3398 | inhibitor of DNA binding 2, dominant negative helix-loop-helix protein | SS,SR |
| ID3 | 3399 | inhibitor of DNA binding 3, dominant negative helix-loop-helix protein | SS |
| IGFBP2 | 3485 | insulin-like growth factor binding protein 2, 36kDa | AS,SS,SR |
| ITGA6 | 3655 | integrin, alpha 6 | SS,SR |
| KIT | 3815 | v-kit Hardy-Zuckerman 4 feline sarcoma viral oncogene homolog | AS,SS |
| L1CAM ² | 3897 | L1 cell adhesion molecule | SS |
| LGR5 | 8549 | leucine-rich repeat containing G protein-coupled receptor 5 | SS |
| MAPK1 | 5594 | mitogen-activated protein kinase 1 | SS |
| MAPK3 ² | 5595 | mitogen-activated protein kinase 3 | AS,SS |
| MECOM ¹ | 2122 | MDS1 and EVI1 complex locus | AS,AG,SS,SR,SG |
| MET ² | 4233 | met proto-oncogene (hepatocyte growth factor receptor) | SS,SR |
| MIIP | 60672 | migration and invasion inhibitory protein | SS |
| MYC | 4609 | v-myc myelocytomatosis viral oncogene homolog (avian) | AS,SS,SR |
| NANOG | 79923 | Nanog homeobox | SS |
| NDRG4 | 65009 | NDRG family member 4 | SS |
| NES | 10763 | nestin | SS |
| NOS2 | 4843 | nitric oxide synthase 2, inducible | SS,SR |
| NOTCH1 | 4851 | notch 1 | AS,SS |
| NOTCH2 | 4853 | notch 2 | SS |
| OLIG2 | 10215 | oligodendrocyte lineage transcription factor 2 | AS,SS |
| PDGFRA | 5156 | platelet-derived growth factor receptor, alpha polypeptide | AS,SS,SR |
| PDPN | 10630 | podoplanin | AS,SS,SR |
| PI3 | 5266 | peptidase inhibitor 3, skin-derived | SS,SR |
| POSTN | 10631 | periostin, osteoblast specific factor | SS,SR |
| PROM1 | 8842 | prominin 1 | SS,SR |
| SOX2 | 6657 | SRY (sex determining region Y)-box 2 | SS |
| STAT3 | 6774 | signal transducer and activator of transcription 3 (acute-phase response factor) | AS,SS |
| TGFBR2 ² | 7048 | transforming growth factor, beta receptor II (70/80kDa) | AS,SS,SR |
| TNFAIP3 | 7128 | tumor necrosis factor, alpha-induced protein 3 | SS,SR |
| TOP2A | 7153 | topoisomerase (DNA) II alpha 170kDa | AS,SS |
| YBX1 | 4904 | Y box binding protein 1 | SS |

¹MECOM, not counted as one of the 55 genes studied, was used for a tissue control in every ISH run, along with a no probe control slide.

²BAX, L1CAM, MAPK3, MET, TGFBR2 were assessed with two probes each on independent slides.

Abbreviations of studies: AS (Anatomic Structures ISH Survey), AG (Anatomic Structures ISH for Enriched Genes), SS (Cancer Stem Cells ISH Survey), SR (Cancer Stem Cells RNA-Seq), and SG (Cancer Stem Cells ISH for Enriched Genes).

Probes hybridized at 300ng/ml were: AKT1, BAX, CD44, CTGF, HES6, HIF1A, ID2, ID3, IGFBP2, MAPK3, MECOM, NDRG4, NES, NOTCH2, PDPN, SOX2, STAT3, TOP2A, and YBX1.

Probes hybridized at 600ng/ml were: ABCB1, ABCG2, ALDH1A1, ASCL1, BIRC5, BMI1, CCDC88A, CCND2, CD34, CSPG4, DANCR, DLX5, EPAS1, ERBB2, ERBB3, EZH2, FOXO3, FUT4, ID1, ITGA6, KIT, L1CAM, LGR5, MAPK1, MET, MIIP, MYC, NANOG, NOS2, NOTCH1, OLIG2, PDGFRA, PI3, POSTN, PROM1, TGFB2, and TNFAIP3.

The final 20 probes used in the extensive survey were: BIRC5, CD44, DANCR, EZH2, HIF1A, ID1, ID2, IGFBP2, ITGA6, MET, MYC, NOS2, OLIG2, PDGFRA, PDPN, PI3, POSTN, PROM1, TGFB2, and TNFAIP3 (**Table 4**).

Table 4. 20 Genes Selected for Final Cancer Stem Cells ISH Survey (SS)

| Gene Symbol | EntrezID | Name | Gene Specificity ² | Studies Used |
|--------------------|----------|---|-------------------------------|----------------|
| BIRC5 | 332 | baculoviral IAP repeat containing 5 | BV | SS |
| CD44 | 960 | CD44 molecule (Indian blood group) | CT, PNZ | AS,SS,SR |
| DANCR | 57291 | differentiation antagonizing non-protein coding RNA | CT, HBV, PNZ | SS,SR |
| EZH2 | 2146 | enhancer of zeste homolog 2 (Drosophila) | UBIQUITOUS | SS |
| HIF1A | 3091 | hypoxia inducible factor 1, alpha subunit (basic helix-loop-helix transcription factor) | CT, HBV | AS,SS,SR |
| ID1 | 3397 | inhibitor of DNA binding 1, dominant negative helix-loop-helix protein | CT, PNZ | SS,SR |
| ID2 | 3398 | inhibitor of DNA binding 2, dominant negative helix-loop-helix protein | PAN | SS,SR |
| IGFBP2 | 3485 | insulin-like growth factor binding protein 2, 36kDa | HBV, CT, PNZ | AS,SS,SR |
| ITGA6 | 3655 | integrin, alpha 6 | MVP, HBV | SS,SR |
| MECOM ¹ | 2122 | MDS1 and EVI1 complex locus | N/A | AS,AG,SS,SR,SG |
| MET | 4233 | met proto-oncogene (hepatocyte growth factor receptor) | CT | SS,SR |
| MYC | 4609 | v-myc myelocytomatosis viral oncogene homolog (avian) | PAN, PNZ | AS,SS,SR |
| NOS2 | 4843 | nitric oxide synthase 2, inducible | CT | SS,SR |
| OLIG2 | 10215 | oligodendrocyte lineage transcription factor 2 | UBIQUITOUS | AS,SS |
| PDGFRA | 5156 | platelet-derived growth factor receptor, alpha polypeptide | CT | AS,SS,SR |
| PDPN | 10630 | podoplanin | PNZ, PAN, CT | AS,SS,SR |
| PI3 | 5266 | peptidase inhibitor 3, skin-derived | PNZ, PAN, CT | SS,SR |
| POSTN | 10631 | periostin, osteoblast specific factor | HBV, CT | SS,SR |
| PROM1 | 8842 | prominin 1 | PNZ, PAN | SS,SR |
| TGFB2 | 7048 | transforming growth factor, beta receptor II (70/80kDa) | HBV, MVP | AS,SS,SR |
| TNFAIP3 | 7128 | tumor necrosis factor, alpha-induced protein 3 | PNZ, PAN | SS,SR |

¹MECOM, not counted as one of the 20 genes studied, was used for a tissue control in every ISH run, along with a no probe control slide. The same set of 20 probes is presented in **Table 7**, which describes the results of the hybridizations on human visual cortex controls.

²Gene Specificity was determined in Pre-Survey Pilot of Cancer Stem Cells ISH Survey (**Table 3**).

Abbreviations of structures: CT (Cellular Tumor), HBV (Hyperplastic Blood Vessels), MVP (Microvascular Proliferation), PAN (Pseudopalisading Cells around Necrosis), and PNZ (Peri-Necrotic Zone).

Abbreviations of studies: AS (Anatomic Structures ISH Survey), AG (Anatomic Structures ISH for Enriched Genes), SS (Cancer Stem Cells ISH Survey), SR (Cancer Stem Cells RNA-Seq), and SG (Cancer Stem Cells ISH for Enriched Genes).

Probes hybridized at 300ng/ml were: CD44, HIF1A, ID2, IGFBP2, MECOM, and PDPN.

Probes hybridized at 600ng/ml were: BIRC5, DANCR, EZH2, ID1, ITGA6, MET, MYC, NOS2, OLIG2, PDGFRA, PI3, POSTN, PROM1, TGFB2, and TNFAIP3.

Table 5. 17 Laser Microdissection (LMD) Reference Genes Selected for Cancer Stem Cells RNA-Seq Study (SR)

| Gene Symbol | EntrezID | Name | Cell Clusters Isolated for Each Reference Gene | # Tumors for LMD | Studies Used |
|--------------------|----------|---|--|------------------|----------------|
| CD44 | 960 | CD44 molecule (Indian blood group) | CT, CT-control, CTpnz, CThbv | 5 | AS,SS,SR |
| DANCR | 57291 | differentiation antagonizing non-protein coding RNA | CT, CT-control, CTpnz, CThbv | 4 | SS,SR |
| HIF1A | 3091 | hypoxia inducible factor 1, alpha subunit (basic helix-loop-helix transcription factor) | CT, CT-control, CThbv | 3 | AS,SS,SR |
| ID1 | 3397 | inhibitor of DNA binding 1, dominant negative helix-loop-helix protein | CT, CT-control, CTpnz | 5 | SS,SR |
| ID2 | 3398 | inhibitor of DNA binding 2, dominant negative helix-loop-helix protein | CT-control, CTpan | 4 | SS,SR |
| IGFBP2 | 3485 | insulin-like growth factor binding protein 2, 36kDa | CT, CT-control, CTpnz, CThbv | 5 | AS,SS,SR |
| ITGA6 | 3655 | integrin, alpha 6 | CT-control, CThbv, CTmvp | 3 | SS,SR |
| MECOM ¹ | 2122 | MDS1 and EVI1 complex locus | N/A | NA | AS,AG,SS,SR,SG |
| MET | 4233 | met proto-oncogene (hepatocyte growth factor receptor) | CT, CT-control | 1 | SS,SR |
| MYC | 4609 | v-myc myelocytomatosis viral oncogene homolog (avian) | CT-control, CTpnz, CTpan | 3 | AS,SS,SR |
| NOS2 | 4843 | nitric oxide synthase 2, inducible | CT, CT-control | 2 | SS,SR |
| PDGFRA | 5156 | platelet-derived growth factor receptor, alpha polypeptide | CT, CT-control | 1 | AS,SS,SR |
| PDPN | 10630 | podoplanin | CT-control, CTpnz, CTpan | 9 | AS,SS,SR |
| PI3 | 5266 | peptidase inhibitor 3, skin-derived | CT-control, CTpnz, CTpan | 11 | SS,SR |
| POSTN | 10631 | periostin, osteoblast specific factor | CT, CT-control, CThbv | 11 | SS,SR |
| PROM1 | 8842 | prominin 1 | CT-control, CTpnz, CTpan | 6 | SS,SR |
| TGFBR2 | 7048 | transforming growth factor, beta receptor II (70/80kDa) | CT-control, CThbv, CTmvp | 12 | AS,SS,SR |
| TNFAIP3 | 7128 | tumor necrosis factor, alpha-induced protein 3 | CT-control, CTpnz, CTpan | 8 | SS,SR |

¹MECOM, not counted as one of the 17 genes studied, was used for a tissue control in every ISH run, along with a no probe control slide.

Abbreviations of structures for this study: CT (blood vessel-associated or sporadic gene expression in Cellular Tumor), CT-control (area of Cellular Tumor with low to undetectable expression of reference gene), CThbv or CTmvp (Hyperplastic Blood Vessels or Microvascular Proliferation in CT), and CTpan, CTpnn, or CTpnz (Pseudopalisading Cells around Necrosis, Pseudopalisading Cells but No visible Necrosis, or Peri-Necrotic Zone in CT)

Abbreviations of studies: AS (Anatomic Structures ISH Survey), AG (Anatomic Structures ISH for Enriched Genes), SS (Cancer Stem Cells ISH Survey), SR (Cancer Stem Cells RNA-Seq), and SG (Cancer Stem Cells ISH for Enriched Genes).

Probes hybridized at 300ng/ml were: CD44, HIF1A, ID2, IGFBP2, MECOM, and PDPN.

Probes hybridized at 600ng/ml were: DANCR, ID1, ITGA6, MET, MYC, NOS2, PDGFRA, PI3, POSTN, PROM1, TGFBR2, and TNFAIP3.

The 3 of 20 probes used in the ISH Survey but not in Cancer Stem Cells RNA-Seq Study were OLIG2, EZH2, and BIRC5.

Table 6. 76 Genes Selected Cancer Stem Cells ISH for Enriched Genes Study (SG)

| Gene Symbol | EntrezID | Name | Structures Likely to Have Enrichment | Structures in Tissue for ISH | Studies Used |
|-------------|----------|--|--------------------------------------|------------------------------|--------------|
| ADAM9 | 8754 | ADAM metallopeptidase domain 9 | CT | CT | SG |
| ARL4C | 10123 | ADP-ribosylation factor-like 4C | CT | CT | SG |
| ASS1 | 445 | argininosuccinate synthase 1 | MVP/PAN | CT, MVP/PAN, HBV, PAN | SG |
| ATF3 | 467 | activating transcription factor 3 | CT | CT, PAN | AG,SG |
| C12orf75 | 387882 | chromosome 12 open reading frame 75 | MVP | CT, MVP/PAN, HBV | SG |
| C15orf48 | 84419 | chromosome 15 open reading frame 48 | PAN | CT, PAN | SG |
| C8orf4 | 56892 | chromosome 8 open reading frame 4 | CT | CT, PAN | AS,SG |
| CAPG | 822 | capping protein (actin filament), gelsolin-like | PAN | CT, PAN | SG |
| CCL2 | 6347 | chemokine (C-C motif) ligand 2 | MVP/PAN | CT, MVP/PAN, HBV | SG |
| CD163 | 9332 | CD163 molecule | MVP | CT, MVP/PAN, HBV | AS,SG |
| CDCP1 | 64866 | CUB domain containing protein 1 | PAN | CT, MVP/PAN, HBV, PAN | SG |
| CNR1 | 1268 | cannabinoid receptor 1 (brain) | CT | CT | SG |
| CSF3 | 1440 | colony stimulating factor 3 (granulocyte) | PAN | CT, PAN | SG |
| CTSH | 1512 | cathepsin H | PAN | CT, MVP/PAN, HBV, PAN | SG |
| CTSL1 | 1514 | cathepsin L1 | CT | CT, PAN | SG |
| CYR61 | 3491 | cysteine-rich, angiogenic inducer, 61 | PAN | CT, PAN | SG |
| DAB2 | 1601 | disabled homolog 2, mitogen-responsive phosphoprotein (Drosophila) | PAN | CT, PAN | SG |
| DCN | 1634 | decorin | MVP/PAN | CT, MVP/PAN, HBV | SG |
| DIO2 | 1734 | deiodinase, iodothyronine, type II | MVP | CT, MVP/PAN, HBV | SG |
| DKK1 | 22943 | dickkopf 1 homolog (Xenopus laevis) | MVP/PAN | CT, MVP/PAN, HBV | AS,SG |
| EFEMP1 | 2202 | EGF containing fibulin-like extracellular matrix protein 1 | CT | CT | AS,SG |
| EMP1 | 2012 | epithelial membrane protein 1 | CT | CT | SG |
| FABP7 | 2173 | fatty acid binding protein 7, brain | CT | CT | SG |
| FAM129A | 116496 | family with sequence similarity 129, member A | CT | CT | AS,SG |
| FAM46A | 55603 | family with sequence similarity 46, member A | CT | CT | SG |
| FAP | 2191 | fibroblast activation protein, alpha | MVP | CT, MVP/PAN, HBV | SG |
| FAS | 355 | Fas (TNF receptor superfamily, member 6) | CT | CT | AS,SG |
| FILIP1L | 11259 | filamin A interacting protein 1-like | CT | CT, MVP/PAN, HBV | SG |
| FN1 | 2335 | fibronectin 1 | PAN | CT, PAN | SG |
| FNDC3B | 64778 | fibronectin type III domain containing 3B | CT | CT, PAN | SG |
| FZD7 | 8324 | frizzled family receptor 7 | CT | CT | SG |
| G0S2 | 50486 | G0/G1switch 2 | PAN | CT, PAN | SG |
| GLIPR1 | 11010 | GLI pathogenesis-related 1 | CT | CT | SG |
| GLRX | 2745 | glutaredoxin (thioltransferase) | CT | CT | SG |
| GNG12 | 55970 | guanine nucleotide binding protein (G protein), gamma 12 | CT | CT | SG |
| GPC4 | 2239 | glypican 4 | CT | CT, MVP/PAN, HBV | SG |
| GPC6 | 10082 | glypican 6 | MVP | CT, MVP/PAN, HBV | SG |
| ICAM1 | 3383 | intercellular adhesion molecule 1 | PAN | CT, PAN | SG |
| IER3 | 8870 | immediate early response 3 | PAN | CT, PAN | SG |
| IFI30 | 10437 | interferon, gamma-inducible protein 30 | PAN | CT, PAN | SG |
| IL13RA2 | 3598 | interleukin 13 receptor, alpha 2 | CT | CT, MVP/PAN, HBV, PAN | SG |
| IL6 | 3569 | interleukin 6 (interferon, beta 2) | PAN | CT, PAN | SG |

| | | | | | |
|--------------------|--------|---|-----|-----------------------|----------------|
| LAPTM5 | 7805 | lysosomal protein transmembrane 5 | PAN | CT, PAN | SG |
| LCP1 | 3936 | lymphocyte cytosolic protein 1 (L-plastin) | PAN | CT, PAN | SG |
| LIF | 3976 | leukemia inhibitory factor | PAN | CT, PAN | AS,SG |
| LPAR6 | 10161 | lysophosphatidic acid receptor 6 | CT | CT, MVP/PAN, HBV | SG |
| LYVE1 | 10894 | lymphatic vessel endothelial hyaluronan receptor 1 | MVP | CT, MVP/PAN, HBV | SG |
| MAP2K3 | 5606 | mitogen-activated protein kinase kinase 3 | PAN | CT, PAN | SG |
| MECOM ¹ | 2122 | MDS1 and EVI1 complex locus | N/A | CT, MVP/PAN, HBV, PAN | AS,AG,SS,SR,SG |
| NMRK1 | 54981 | nicotinamide riboside kinase 1 | CT | CT | SG |
| NRP2 | 8828 | neuropilin 2 | CT | CT, PAN | SG |
| NT5E | 4907 | 5'-nucleotidase, ecto (CD73) | PAN | CT, PAN | SG |
| OCIAD2 | 132299 | OCIA domain containing 2 | CT | CT | SG |
| PPAP2A | 8611 | phosphatidic acid phosphatase type 2A | MVP | CT, MVP/PAN, HBV | SG |
| PPP1R15A | 23645 | protein phosphatase 1, regulatory subunit 15A | PAN | CT, PAN | SG |
| PPP1R3B | 79660 | protein phosphatase 1, regulatory subunit 3B | CT | CT | SG |
| PRSS23 | 11098 | protease, serine, 23 | CT | CT, MVP/PAN, HBV | SG |
| RAC2 | 5880 | ras-related C3 botulinum toxin substrate 2 (rho family, small GTP binding protein Rac2) | PAN | CT, PAN | SG |
| RARRES2 | 5919 | retinoic acid receptor responder (tazarotene induced) 2 | PAN | CT, PAN | SG |
| RGS16 | 6004 | regulator of G-protein signaling 16 | PAN | CT, PAN | SG |
| RNA2.7 | 0 | RNA2.7 of human cytomegalovirus transcriptome | N/A | CT, PAN | SG |
| RUNX1 | 861 | runt-related transcription factor 1 | CT | CT, PAN | AS,SG |
| S100A4 | 6275 | S100 calcium binding protein A4 | CT | CT | AS,SG |
| SDC4 | 6385 | syndecan 4 | MVP | CT, MVP/PAN, HBV | SG |
| SEC24D | 9871 | SEC24 family, member D (S. cerevisiae) | CT | CT, PAN | SG |
| SERTAD1 | 29950 | SERTA domain containing 1 | CT | CT, PAN | SG |
| SHC1 | 6464 | SHC (Src homology 2 domain containing) transforming protein 1 | CT | CT, PAN | SG |
| SLC25A24 | 29957 | solute carrier family 25 (mitochondrial carrier; phosphate carrier), member 24 | CT | CT, MVP/PAN, HBV | SG |
| SLC4A7 | 9497 | solute carrier family 4, sodium bicarbonate cotransporter, member 7 | CT | CT, PAN | SG |
| SQRDL | 58472 | sulfide quinone reductase-like (yeast) | PAN | CT, PAN | SG |
| SRPX | 8406 | sushi-repeat containing protein, X-linked | CT | CT | SG |
| TAGLN2 | 8407 | transgelin 2 | CT | CT | SG |
| TGFBI | 7045 | transforming growth factor, beta-induced, 68kDa | PAN | CT, PAN | AS,SG |
| THBS1 | 7057 | thrombospondin 1 | PAN | CT, MVP/PAN, HBV, PAN | AS,SG |
| TNC | 3371 | tenascin C | CT | CT | SG |
| WNT5A | 7474 | wingless-type MMTV integration site family, member 5A | MVP | CT, MVP/PAN, HBV | SG |
| WWTR1 | 25937 | WW domain containing transcription regulator 1 | CT | CT | SG |

¹MECOM, not counted as one of the 76 genes studied, was used for a tissue control in every ISH run, along with a no probe control slide.

Abbreviations of structures: CT (Cellular Tumor), HBV (Hyperplastic Blood Vessels), MVP (Microvascular Proliferation), and PAN (Pseudopalisading Cells around Necrosis).

Abbreviations of studies: AS (Anatomic Structures ISH Survey), AG (Anatomic Structures ISH for Enriched Genes), SS (Cancer Stem Cells ISH Survey), SR (Cancer Stem Cells RNA-Seq), and SG (Cancer Stem Cells ISH for Enriched Genes).

Probes hybridized at 300ng/ml were: ADAM9, CAPG, CCL2, CD163, CTSH, CTSL1, CYR61, DCN, EFEMP1, EMP1, FABP7, FN1, GPC4, IFI30, LAPTM5, MECOM (EVI1), OCIAD2, PPAP2A, PPP1R15A, RARRES2, S100A4, TAGLN2, TGFBI, and TNC.

Probes hybridized at 600ng/ml were: ARL4C, ASS1, ATF3, C12orf75, C15orf48, C8orf4, CDCP1, CNR1, CSF3, DAB2, DIO2, DKK1, FAM129A, FAM46A, FAP, FAS, FILIP1L, FNDC3B, FZD7, G0S2, GLIPR1, GLRX, GNG12, GPC6, ICAM1, IER3, IL13RA2, IL6, LCP1, LIF, LPAR6, LYVE1, MAP2K3, NMRK1, NRP2, NT5E, PPP1R3B, PRSS23, RAC2, RGS16, RNA2.7, RUNX1, SDC4, SEC24D, SERTAD1, SHC1, SLC25A24, SLC4A7, SQRDL, SRPX, THBS1, WNT5A, and WWTR1.

Table 7. Expression of the Final Set of 20 Putative Cancer Stem Cell Genes in Human Cadaver Visual Cortex Controls

| Reference Gene | Description of Expression ¹ |
|----------------|--|
| BIRC5 | Very low scattered expression in selected layers and not detected in white matter |
| CD44 | Not detected |
| DANCR | Not detected |
| EZH2 | Very low scattered expression in selected layers and not detected in white matter |
| HIF1A | Low scattered expression throughout cortex and not detected in white matter |
| ID1 | Moderate expression in selected cells of small blood vessels scattered throughout cortex and white matter |
| ID2 | High expression in many cells of various types throughout cortex and scattered low expression in few cells of white matter |
| IGFBP2 | High expression in many cells of various types throughout cortex and scattered low expression in few cells of white matter |
| ITGA6 | Moderate expression in highly scattered cells in selected layer of cortex and not detected in white matter |
| MET | High expression in many cells of various types in selected layers of cortex and not detected in white matter |
| MYC | High expression in most cells throughout cortex and very scattered low expression in few cells of white matter |
| NOS2 | Low to moderate expression in many cells throughout cortex and very few cells of white matter |
| OLIG2 | Low to moderate expression in moderate number of cells throughout cortex and very few cells of white matter |
| PDGFRA | Low to moderate expression in few cells scattered throughout cortex and negligible numbers of cells in white matter |
| PDPN | Not detected |
| PI3 | Low expression in many cells throughout cortex and negligible numbers of cells in white matter |
| POSTN | Moderate to high expression in very limited number of cells scattered in selected layers and not detected in white matter |
| PROM1 | Not detected |
| TGFBR2 | Low to moderate expression in moderate number of cells scattered throughout cortex and not detected in white matter |
| TNFAIP3 | Not detected |

¹Description of expression is based on n=1 (each probe was hybridized to one tissue section on one slide in one experiment).

Probes hybridized at 300ng/ml were: CD44, HIF1A, ID2, IGFBP2, and PDPN.

Probes hybridized at 600ng/ml were: BIRC5, DANCR, EZH2, ID1, ITGA6, MET, MYC, NOS2, OLIG2, PDGFRA, PI3, POSTN, PROM1, TGFBR2, and TNFAIP3.