

ALLEN Mouse Brain Atlas

TECHNICAL WHITE PAPER: CROSS-PLATFORM VALIDATION

In order to validate the accuracy of the data generated by the Allen Brain Atlas, a systematic comparison was made with other publicly available ISH data sources. These sources included the Brain Gene Expression Map ([BGEM](http://www.stjudebgem.org/web/mainPage/mainPage.php), <http://www.stjudebgem.org/web/mainPage/mainPage.php>) and radioactive ISH data generated by Dr. Ed Lein and Dr. Fred Gage¹. BGEM is a publicly accessible database using high throughput radioactive ISH to map the expression pattern of selected genes in the C57Bl/6J mouse brain across multiple developmental time points including E11.5, E15.5, P7, and P42. Lein et al. (2004) analyzed the expression of more than 100 genes with unique expression patterns in the hippocampus in 10-11 week old C57Bl/6J mice. Expression patterns within the hippocampus were fully annotated and the full data set was available for review. These two sources provided an ideal data set with which to validate the Allen Mouse Brain Atlas data set.

A systematic comparison of the three data sets was performed. Expression patterns were annotated for all genes represented in Lein et al. (2004) for which coronal images were available in the Allen Mouse Brain Atlas database (72 genes). Of these genes, 25 had ISH data available in BGEM at the P42 (adult) time point. Annotation of gene expression in the hippocampal subregions was performed for the available data. A four-point scale was used to score intensity of expression relative to other brain regions. For each data set, an observer recorded a relative intensity score for the primary cell type within each hippocampal brain region including: CA1, CA2, and CA3, the dentate gyrus (DG), the hilus, the subiculum, the fimbria, and the choroid plexus. A general summary of the expression pattern within the hippocampus was then generated based on these scores. This analysis, in addition to a direct visual comparison of all available expression data, was used to form a conclusion as to whether the expression patterns of the different data sets match. These data are recorded in **Table 1**. Comparisons of plane-matched images from the Allen Mouse Brain Atlas and Lein et al. (2004) are presented in the accompanying figures (**Figures 1 and 2**).

Figure 1 shows matching coronal sections for *Calbindin 1 (Calb1)*, *Nephroblastoma overexpressed gene (Nov)*, *Connective tissue growth factor (Ctgf)* and *Parvalbumin (Pvalb)*. Darkfield-illuminated radioactive ISH data from Lein et al. (2004) is on the left, and DIG-based non-isotopic data from the Allen Mouse Brain Atlas is presented as the mirrored hemisphere. Probe lengths for each gene were approximately 500 nt for ³⁵S-based ISH, and approximately 900 nt for DIG-based ISH. The patterns and relative expression levels within a section between these two methodologies are, qualitatively, nearly identical for each of these genes. At this low magnification the autoradiographic signal is easier to visualize than the non-isotopic purple reaction product; however, at higher magnification the cellular morphology and ability to resolve individual cells in densely packed structures is superior in the non-isotopic methodology. [Figure 2](#) shows additional images of plane-matched coronal sections comparing ISH data from Lein et al. (2004) to data from the Allen Mouse

¹ Lein ES, Zhao X, Gage FH. (2004) Defining a molecular atlas of the hippocampus using DNA microarrays and high-throughput in situ hybridization. *J Neurosci* 24(15):3879-89.

Brain Atlas for all genes examined in the cross platform validation effort (http://brain-map.org/pdf/Cross_Platform_Validation_Figure2.pdf).

Overall there was very strong concordance across all three data sets. 71/72 genes available in the Allen Mouse Brain Atlas and Lein et al. (2004) have qualitatively matching expression patterns. 24/25 genes available in all 3 data sets show similar expression patterns. One gene (minichromosome maintenance deficient 6 [Mcm6]) for which the expression pattern of the Allen Mouse Brain Atlas data did not match that of the data from Lein et al. (2004), (BGEM data was not available), and one gene (Zinc finger protein 312 [Zfp312]) for which the expression pattern of the BGEM data did not match that from the Allen Mouse Brain Atlas or from Lein et al. (2004). Neither of these genes was represented in [GenePaint](http://genepaint.org) (<http://genepaint.org>), another database which includes ISH expression data for mouse brain. In order to better understand the cause of this discrepancy, we examined the probes that were used by the different databases for these genes. For Mcm6 the Allen Mouse Brain Atlas used an 839 nt probe spanning exons 7 through 12.

Lein et al. (2004) used a 1515 nt probe spanning exons 10-17. This suggests that alternate transcripts may account for the differences in expression pattern that were noted for this gene. In addition, the Allen Mouse Brain Atlas has generated three sets of ISH data for Mcm6 using the same probe sequence, making it unlikely that a processing error led to this discrepancy. For Zfp312, the probe used by the Allen Mouse Brain Atlas (830 nt) showed no overlap with the probe used by BGEM (382 nt). The probe used by Lein et al. (2004) spanned nearly the entire coding sequence of the gene (~2000 nt). This also leaves open the possibility that the distinct expression patterns that were observed may represent alternate transcripts. Overall the data generated for the Allen Mouse Brain Atlas showed strong concordance with these two independent sources of ISH data.

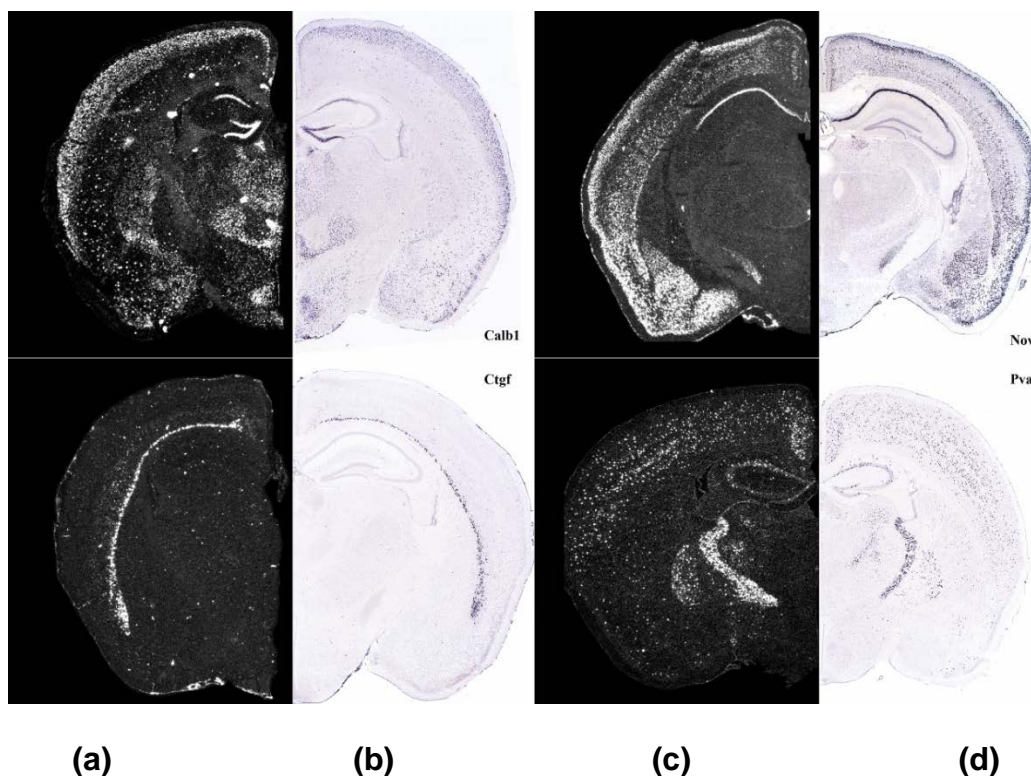


Figure 1 - Comparison of expression patterns in plane-matched coronal mouse brain sections processed for radioactive ISH (a,c) and non-isotopic DIG ISH (b,d).

ISH data is shown for Calbindin 1 (Calb1, upper panels in a,b), Nephroblastoma overexpressed gene (Nov, upper panels in c,d), Connective tissue growth factor (Ctgf, lower panels in a,b) and Parvalbumin (Pva, lower panels in c,d).

Table 1 - Cross-platform comparison of Allen Mouse Brain Atlas in situ hybridization (ISH) expression data with external data sources.

Standardized nomenclature from Mouse Genome Informatics (MGI) is used to describe each gene (aliases have been included in italics). The corresponding Genbank accession numbers are also shown. Data generated for the Allen Mouse Brain Atlas were compared with data presented in Lein et al., and with data generated by the Brain Gene Expression Map (BGEM). ISH data are summarized for the primary neuronal populations within each hippocampal subregion as well as in surrounding structures. Relative expression levels observed by in situ hybridization were scored by visual inspection of the in situ hybridization signal. A four-point scale was used to score relative labeling intensity in each region, taking into account labeling intensity in other brain regions. A final classification of the expression pattern within hippocampal regions is included. The last column indicates whether the data generated by the Allen Mouse Brain Atlas data matches the data from Lein et al, or BGEM. Instances where the data did not match are shaded in dark grey.

| MGI Gene Name | Genbank Number | Data Source | CA1 | CA2 | CA3 | DG Granule Cells | Hilus | Subiculum | Fimbria (Oligodendrocytes) | Choroid Plexus | Final Classification-Hippocampus | Patterns Match? |
|---|-------------------------------|-------------------|------|------|------|------------------|-------|-----------|----------------------------|----------------|---|---------------------------|
| Anxa11 annexin A11 | U65986 | ABA | ++ | +++ | +++ | ++++ | - | - | - | ++ | DG+CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | ++++ | - | - | - | ++ | DG+CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Atp1a1 ATPase, Na ⁺ /K ⁺ transporting, alpha 1 polypeptide <i>Atp1a1</i> | AA063844 (also W12919) | ABA | ++++ | ++++ | ++++ | ++++ | + | +++ | - | +++ | Highly expressed in all excitatory cells of the hippocampus | |
| | | Lein et al., 2004 | ++ | ++ | ++ | ++++ | + | + | - | ++ | DG enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Atp2a2 ATPase, Ca ⁺⁺ transporting, cardiac muscle, slow twitch 2 <i>SERC42a</i> | AA153484 | ABA | ++++ | ++++ | ++++ | +++ | +++ | +++ | - | ++ | CA1-CA3 enriched | |
| | | Lein et al., 2004 | +++ | ++++ | ++++ | ++ | ++ | ++ | - | - | CA1-CA3 enriched | yes |
| | | BGEM | ++ | +++ | +++ | + | N/A | N/A | - | - | CA2+CA3 enriched | Yes with lower expression |

| MGI Gene Name | Genbank Number | Data Source | CA1 | CA2 | CA3 | DG Granule Cells | Hilus | Subiculum | Fimbria (Oligodendrocytes) | Choroid Plexus | Final Classification-Hippocampus | Patterns Match? |
|---|----------------|-------------------|-----|------|------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Bok bcl-2-related ovarian killer protein <i>Mtd</i> | AA537500 | ABA | - | - | ++++ | - | ++ | + | - | - | CA3 restricted | |
| | | Lein et al., 2004 | - | - | ++++ | - | ++ | - | - | - | CA3 restricted | yes |
| | | BGEM | + | + | ++++ | + | ++ | - | - | + | CA3 enriched | yes |
| Big1 B-cell translocation gene 1, anti-proliferative | L16846 | ABA | ++ | - | - | ++++ | - | - | - | + | DG + CA1 restricted | |
| | | Lein et al., 2004 | ++ | - | - | ++++ | - | - | - | - | DG+CA1 restricted | yes |
| | | BGEM | + | - | - | ++ | - | - | - | - | DG+CA1 restricted | Yes |
| Cadps Ca2+dependent activator protein for secretion <i>Caps1</i> | D86214 | ABA | ++ | ++++ | ++++ | + | +++ | +++ | - | - | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | + | +++ | + | - | - | CA2+CA3 enriched | Yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Calb1 calbindin-28K <i>CB</i> | M21531 | ABA | +++ | - | - | ++++ | - | - | - | - | DG+CA1 restricted | |
| | | Lein et al., 2004 | +++ | - | - | ++++ | - | - | - | - | DG+CA1 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Calb2 calbindin 2 <i>calretinin (CR)</i> | X73985 | ABA | - | - | - | - | ++ | - | - | - | Dentate hilus restricted | |
| | | Lein et al., 2004 | - | - | - | - | +++ | - | - | - | Dentate hilus restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|--|----------------|-------------------|------|------|------|------------------|-------|-------------------------|----------------------------|----------------|----------------------------------|-----------------|
| Camk2g calcium/calmodulin-dependent protein kinase II gamma <i>Camk2g</i> | W12204 | ABA | ++++ | +++ | +++ | ++++ | ++ | +++ | - | + | DG+CA1 enriched | |
| | | Lein et al., 2004 | ++ | ++ | ++ | ++++ | ++ | ++ | - | - | DG enriched | yes |
| | | BGEM | ++ | + | + | +++ | + | ++ | - | + | DG+CA1 enriched | yes |
| Car4 carbonic anhydrase 4 | U37091 | ABA | +++ | ++ | ++++ | ++ | ++ | ++ | - | - | CA1+CA3 enriched | |
| | | Lein et al., 2004 | +++ | ++ | ++++ | ++ | + | + | - | - | CA1+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ccnd2 cyclin D2 | M83749 | ABA | + | ++ | ++++ | ++ | +++ | + | - | ++++ | CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | ++ | ++ | + | - | +++ | CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| D0H4S114 DNA segment, human D4S114 <i>P311, Sez17, Prx17</i> | X70398 | ABA | - | - | - | +++ | + | ++++ (pre-subiculum) | - | + | DG restricted | |
| | | Lein et al., 2004 | - | - | - | +++ | + | ++++ (pre-subiculum) | - | + | DG restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|---|----------------|-------------------|-----------------------|------|------|------------------|-------|--------------|----------------------------|----------------|----------------------------------|-----------------|
| Dcn Decorin Dspg2, Pg40, Pgs2, Slrr1b | X53929 | ABA | ++ (caudal CA1 only) | - | - | - | - | ++++ ventral | - | +++ | Caudal CA1+Subiculum only | |
| | | Lein et al., 2004 | +++ (caudal CA1 only) | - | - | - | - | ++++ ventral | - | +++ | Caudal CA1+Subiculum only | yes |
| | | BGEM | +++ (caudal CA1 only) | - | - | - | - | ++++ ventral | - | +++ | Caudal CA1+Subiculum only | yes |
| Darc Duffy blood group, chemokine receptor <i>Dfj, Cdkp1, CD234, Fy</i> | AF016697 | ABA | + | ++++ | ++++ | + | +++ | + | - | - | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | ++ | ++ | - | - | - | CA2+CA3 enriched | yes |
| | | BGEM | +++ | +++ | ++++ | +++ | ++ | ++ | - | - | CA2+CA3 enriched | yes |
| Dgat2 diacylglycerol O-acyltransferase 2 | W15862 | ABA | + | ++ | + | ++++ | + | ++ | - | - | DG enriched | |
| | | Lein et al., 2004 | + | + | + | ++++ | + | + | - | - | DG enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Dlat dihydrolipoamide S-acetyltransferase (E2 component of pyruvate dehydrogenase complex) <i>PDC-E2</i> | W29756 | ABA | +++ | ++++ | ++++ | +++ | ++ | ++ | - | + | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | +++ | ++ | ++ | +++ | - | - | CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|---|----------------|-------------------|------|------|------|------------------|-------|-----------|----------------------------|----------------|--|---------------------------|
| Dusp1 dual specificity phosphatase 1 <i>MKP-1, 3CH134, erp, Ptpn16</i> | X61940 | ABA | +++ | ++ | ++ | +/- | ++ | ++ | - | - | Slightly enriched in CA1 | |
| | | Lein et al., 2004 | ++++ | ++ | ++ | - | + | + | - | - | CA1 enriched | yes |
| | | BGEM | + | + | N/A | - | +/- | + | - | - | | Yes with lower expression |
| Elavl2 ELAV (embryonic lethal, abnormal vision, Drosophila)-like 2 (Hu antigen B) <i>Mei-N1, Hub</i> | U29088 | ABA | - | ++++ | ++++ | - | ++++ | ++ | - | - | CA2+CA3+Hilus restricted | |
| | | Lein et al., 2004 | - | ++++ | ++++ | - | +++ | ++ | - | - | CA2+CA3+Hilus restricted | yes |
| | | BGEM | - | ++++ | ++++ | - | +++ | + | - | - | CA2+CA3+Hilus restricted | yes |
| Enpp2 ectonucleotide pyrophosphatase/phosphodiesterase 2 | AA178190 | ABA | ++ | + | + | - | + | + | +++ | ++++ | Astrocytes, choroids, CA1 enriched | |
| | | Lein et al., 2004 | +/- | +/- | +/- | +/- | - | - | +++ | ++++ | Astrocytes, choroids, Low uniform expression in primary excitatory hippocampal neurons | Yes with lower expression |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| EST RIKEN cDNA 0610009A07 gene | AA212774 | ABA | - | - | +++ | + | + | - | - | - | CA3 enriched | |
| | | Lein et al., 2004 | - | - | ++++ | + | - | - | - | - | CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|---|----------------|-------------------|---------------------------------|------|----------------------------------|---------------------------------|-------------------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Etv1 ets variant gene 1 <i>ets-related protein 81 ER81, Etsrp81</i> | L10426 | ABA | ++ dorsal +++ ventral | + | +/- dorsal +++ ventral | - | - dorsal + | ++++ | - | - | CA1 enriched | |
| | | Lein et al., 2004 | +++ | ++ | ++ | + | - | ++++ | - | - | CA1 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Fbln1 fibulin 1 <i>BM-90</i> | X70854 | ABA | - | - | - | +++ (at ventral tip only) | - | - | - | - | DG restricted | |
| | | Lein et al., 2004 | +/- | +/- | +/- | ++ (++++ at ventral tip) | - | ++ | - | - | DG enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Fn1 fibronectin 1 | M18194 | ABA | - | - | - | - | - | ++++ | - | - | Subiculum | |
| | | Lein et al., | - | - | - | - | - | ++++ | - | - | Subiculum restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Frzb frizzled-related protein <i>frizzled, frizz, Frp, Frzb-1, Sfrp3</i> | U68058 | ABA | - | ++ | ++ | + | - | - | - | + | DG+CA2+CA3 restricted | |
| | | Lein et al., 2004 | - | ++++ | ++++ | ++ | - | + | - | - | DG+CA2+CA3 restricted | yes |
| | | BGEM | + | ++++ | ++++ | +++ | - | N/A | - | - | DG+CA2+CA3 enriched | yes |

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|--|----------------|-------------------|------|-----|--------------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Igfbp5 insulin-like growth factor binding protein 5 | I.12447 | ABA | - | - | - | ++++ | - | ++ | - | + | DG+Subiculum Restricted | |
| | | Lein et al., 2004 | - | - | - | ++++ | - | - | - | + | DG restricted | yes |
| | | BGEM | - | - | - | ++++ | - | + | - | + | DG+Subiculum Restricted | yes |
| Itp1l inositol 1,4,5-triphosphate receptor 1 <i>Itp3r, Pcp1, opt</i> | X15373 | ABA | ++++ | + | + | ++ | + | +++ | - | +++ | DG+CA1 enriched | |
| | | Lein et al., 2004 | ++++ | + | + | +++ | - | ++ | - | ++++ | DG+CA1 enriched | yes |
| | | BGEM | +++ | +/- | + | +++ | - | +++ | - | ++++ | DG+CA1 enriched | yes |
| Jun jun oncogene <i>Jun, c-jun</i> | X12761 | ABA | ++++ | +++ | +++ | ++++ | ++ | ++ | + | ++ | DG+CA1 enriched | |
| | | Lein et al., 2004 | + | - | ++ | ++++ | + | ++ | - | - | DG enriched | Yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Kcnj9 potassium inwardly-rectifying channel, subfamily J, member 9 <i>GIRK3, Kir3.3</i> | U11860 | ABA | ++ | + | + | ++++ | + | +++ | - | - | DG+CA1 enriched | |
| | | Lein et al., 2004 | +++ | + | + | ++++ | - | +++ | - | - | DG+CA1 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Kl klotho | AB005141 | ABA | +++ | ++ | +++ (distal) | ++ | + | ++ | - | ++++ | CA1 enriched | |
| | | Lein et al., 2004 | +++ | ++ | ++ | ++ | - | - | - | ++++ | CA1 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|--|----------------|-------------------|------|-----|------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Klk8 Kallikrein 8 <i>Prss19, BSP1</i> | D30785 | ABA | +++ | + | ++++ | - | + | + | - | - | CA1+CA3 enriched | |
| | | Lein et al., 2004 | ++++ | - | ++++ | - | - | - | - | - | CA1+CA3 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Lpl lipoprotein lipase | AA683731 | ABA | +++ | ++ | ++++ | - | + | + | - | + | CA1-CA3 enriched | |
| | | Lein et al., 2004 | +++ | ++ | +++ | - | + | ++ | - | - | CA1-CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Lxn latexin | D88769 | ABA | +++ | ++ | +++ | - | + | ++++ | - | - | CA1-CA3 restricted | |
| | | Lein et al., 2004 | ++ | + | + | - | + | ++++ | - | - | CA1-CA3 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Man1a mannosidase 1, alpha <i>Por1</i> | U04299 | ABA | ++++ | - | ++ | - | ++ | ++ | + | +++ | CA1+CA3 enriched | |
| | | Lein et al., 2004 | ++++ | - | + | - | - | - | - | + | CA1+CA3 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Mbp myelin basic protein <i>Hmbpr</i> | X67319 | ABA | - | - | + | +++ | + | - | ++++ | - | DG+Fimbria enriched | |
| | | Lein et al., 2004 | + | + | + | +++ | - | - | ++++ | - | DG+Fimbria enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|---|----------------|-------------------|------|------|------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|---------------------------|
| Mcm6 mini chromosome maintenance deficient 6 <i>Asp-1, Mcm6</i> | AA689977 | ABA | - | - | - | +++ | + | - | - | + | DG restricted | |
| | | Lein et al., 2004 | - | - | - | +++ | ++++ | +++ | - | - | DG Restricted | No |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Mrg1 myeloid ecotropic viral integration site-related gene 1 <i>Mrg1b, Meis2, Stra10</i> | AI323389 | ABA | +++ | ++ | ++ | - | - | - | - | - | CA1-CA3 restricted | |
| | | Lein et al., 2004 | ++++ | ++++ | ++++ | - | - | - | - | - | CA1-CA3 restricted | yes |
| | | BGEM | - | - | - | - | - | +/- | - | +/- | | Yes with lower expression |
| Myo5b myosin Vb | M55253 | ABA | +++ | ++ | ++++ | +++ | + | + | - | ++ | CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++ | ++++ | +++ | - | + | - | ++ | CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Nefl neurofilament, light polypeptide <i>Cmt2e, NF-L, NF68, Nfl</i> | M20480 | ABA | +++ | ++++ | ++++ | ++ | +++ | +++ | - | - | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | +++ | +++ | ++ | - | - | CA2+CA3 enriched | yes |
| | | BGEM | ++ | ++++ | ++++ | +++ | +++ | ++ | - | - | CA2+CA3 enriched | yes |
| Net1 neuroepithelial cell transforming gene 1 | AA691232 | ABA | ++ | ++ | + | ++++ | + | + | - | - | DG+CA1+CA2 enriched | |
| | | Lein et al., 2004 | ++ | + | + | ++++ | + | + | - | - | DG+CA1 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

| MGI Gene Name | Genbank Number | Data Source | CA1 | CA2 | CA3 | DG Granule Cells | Hilus | Subiculum | Fimbria (Oligodendrocytes) | Choroid Plexus | Final Classification-Hippocampus | Patterns Match? |
|---|----------------|-------------------|------|-----|-----|------------------|-------|-----------|----------------------------|----------------|--------------------------------------|----------------------------|
| Ngef neuronal guanine nucleotide exchange factor <i>ephecin, Timi2</i> | AA607353 | ABA | +++ | + | + | +++ | + | ++++ | - | - | DG+CA1 enriched | |
| | | Lein et al., 2004 | ++++ | - | - | +++ | - | ++ | - | - | DG+CA1 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Nov neuroblastoma overexpressed gene | Y09257 | ABA | ++++ | - | - | - | - | ++++ | - | - | CA1+ subiculum restricted | |
| | | Lein et al., 2004 | ++++ | - | - | - | - | ++++ | - | - | CA1+ subiculum restricted | yes |
| | | BGEM | ++++ | +/- | +/- | +/- | - | ++++ | - | - | CA1+ subiculum restricted | yes |
| Npnt Nephronectin | AA223007 | ABA | - | - | + | ++++ | + | + | - | + | DG enriched | |
| | | Lein et al., 2004 | + | + | + | ++++ | + | + | - | +++ | DG enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ntf3 neurotrophin 3 | X53257 | ABA | - | ++ | - | ++ | - | +++ | - | - | DG, CA2, subiculum restricted | |
| | | Lein et al., 2004 | - | +++ | - | ++++ | - | +++ | - | - | DG, CA2, subiculum restricted | yes |
| | | BGEM | - | +++ | - | ++ | - | +++ | - | - | DG, CA2, subiculum restricted | yes |
| Pbx3 pre B-cell leukemia transcription factor 3 | AF020200 | ABA | - | - | - | - | - | +/- | - | +/- | No staining in hippocampus | |
| | | Lein et al., 2004 | ++ | + | + | + | - | + | - | - | CA1 enriched | Yes with higher expression |
| | | BGEM | +/- | - | - | - | - | N/A | - | +/- | Little to no staining in hippocampus | yes |

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|---|---------------------------------|-------------------|-----|------|------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Pcp4 Purkinje cell protein 4 | X17320 | ABA | - | ++++ | - | ++++ | ++ | ++ | - | - | DG+CA2 restricted | |
| | | Lein et al., 2004 | - | ++++ | - | ++++ | +++ | ++ | - | - | DG+CA2 restricted | yes |
| | | BGEM | - | +++ | N/A | ++++ | N/A | ++ | - | + | DG+CA2 enriched | yes |
| Pfkfb phosphofructokinase, platelet | AA072252 | ABA | +++ | ++++ | ++++ | ++ | +++ | +++ | - | +++ | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | + | ++ | ++ | - | - | CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Pkia protein kinase inhibitor, alpha | M63554 | ABA | + | ++ | ++ | ++++ | + | ++ | - | + | DG+CA2+CA3 enriched | |
| | | Lein et al., 2004 | +/- | ++ | ++ | ++++ | + | ++ | - | - | DG+CA2+CA3 enriched | yes |
| | | BGEM | + | ++ | ++ | +++ | + | N/A | - | - | DG+CA2+CA3 enriched | yes |
| Prkcd protein kinase C, delta | X60304 | ABA | - | - | +++ | - | ++ | + | - | + | CA3 restricted | |
| | | Lein et al., 2004 | - | - | +++ | - | ++ | + | - | - | CA3 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Prss12 protease, serine, 12 neurotrypsin (motopsin) <i>Bsp-3</i> | AA063841 (also AA166254) | ABA | ++ | + | + | ++ | + | +++ | - | - | DG+CA1 enriched | |
| | | Lein et al., 2004 | + | + | + | ++ | + | ++++ | - | - | DG enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|---|----------------|-------------------|-----------------------------|-----------------------------|-----------------------------|------------------|--------------------------|-----------|----------------------------|----------------|---|-----------------|
| Ptpro protein tyrosine phosphatase, receptor type, O <i>PTPphi, Glepp1</i> | U37465 | ABA | + | ++ | + | +++ | ++++ | + | - | - | DG+Hilus enriched | |
| | | Lein et al., 2004 | ++ | ++ | ++ | ++++ | ++++ | - | - | - | DG+Hilus enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Pvalb Parvalbumin <i>PV, Pva</i> | X67141 | ABA | - +++ interneurons | - +++ interneurons | - +++ interneurons | - | - +++ interneurons | +++ | - | - | Not expressed in primary excitatory hippocampal neurons | |
| | | Lein et al., 2004 | - +++ interneurons | - +++ interneurons | - +++ interneurons | - | +++ | +++ | - | - | Not expressed in primary excitatory hippocampal neurons | yes |
| | | BGEM | - +++ interneurons | - +++ interneurons | - +++ interneurons | - | ++ | +++ | - | - | Not expressed in primary excitatory hippocampal neurons | yes |
| Rab3b RAB3B, member RAS oncogene family | AA166533 | ABA | +/- +++ in interneurons | +/- +++ in interneurons | +/- +++ in interneurons | +/- | ++ interneurons | +++ | - | - | Highly expressed in interneurons | |
| | | Lein et al., 2004 | + +++ in interneurons | + +++ in interneurons | + +++ in interneurons | + | +++ | ++++ | - | - | Highly expressed in interneurons | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|--|----------------|-------------------|------|------|------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Rab3ip RAB3A interacting protein <i>Gipat12, Rabin3</i> | AA444426 | ABA | ++ | +++ | +++ | ++ | + | + | - | ++ | CA2+CA3 enriched | |
| | | Lein et al., 2004 | +++ | ++++ | ++++ | +++ | - | + | - | ++ | CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Rbp4 retinol binding protein 4, plasma (also W11658) | AA049662 | ABA | - | - | - | - | - | +++ | - | - | Subiculum restricted | |
| | | Lein et al., 2004 | - | - | - | - | - | ++++ | - | - | Subiculum restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Satb1 special AT-rich sequence binding protein 1 | U05252 | ABA | +++ | + | ++ | + | ++++ | ++++ | - | + | Enriched in hilus and subiculum | |
| | | Lein et al., 2004 | + | - | +++ | ++ | ++++ | ++++ | - | - | Enriched in hilus and subiculum | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Sez6 seizure related gene 6 | D29763 | ABA | ++++ | +++ | ++ | + | +++ | +++ | - | - | CA1-CA3 enriched | |
| | | Lein et al., 2004 | ++++ | ++++ | +++ | + | +++ | +++ | - | - | CA1-CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Sh3gl2 SH3-domain GRB2-like 2 <i>endophilin 1</i> | U58886 | ABA | +++ | ++ | ++++ | ++ | + | ++ | - | - | CA3 enriched | |
| | | Lein et al., 2004 | ++ | + | ++++ | + | + | + | - | - | CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

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|---|----------------|-------------------|-----|------|------|------------------|-------|-----------|----------------------------|----------------|--|-----------------|
| Slc31a1 solute carrier family 31, member 1 <i>High affinity copper uptake protein 1</i> <i>Ctr1</i> | AA190119 | ABA | + | + | + | + | + | + | - | +++ | Uniform expression in primary excitatory hippocampal neurons | |
| | | Lein et al., 2004 | + | + | + | + | - | - | - | ++++ | Uniform expression in excitatory hippocampal neurons | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Slc39a6 solute carrier family 39 member 6 <i>Ermelin</i> | AA217411 | ABA | + | + | + | ++++ | + | + | - | - | DG enriched | |
| | | Lein et al., 2004 | + | + | + | ++++ | + | - | - | - | DG enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Sms spermine synthase | AF031486 | ABA | + | ++++ | +++ | + | + | + | - | - | CA2+CA3 enriched | |
| | | Lein et al., 2004 | + | ++++ | ++++ | ++ | + | + | - | - | CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Snap91 synaptosomal-associated protein 91 AP180 | M83985 | ABA | +++ | ++++ | ++++ | ++ | +++ | ++ | - | - | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | ++ | ++ | ++ | - | - | CA2+CA3 enriched | yes |
| | | BGEM | ++ | ++++ | ++++ | ++ | ++ | ++ | - | - | CA2+CA3 enriched | yes |
| Snca synuclein, alpha | W75614 | ABA | +++ | ++++ | ++++ | +++ | ++ | + | - | - | CA2+CA3 enriched | |
| | | Lein et al., 2004 | ++ | ++++ | ++++ | +++ | ++ | + | - | - | DG+CA2+CA3 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

| MGI Gene Name | Genbank Number | Data Source | CA1 | CA2 | CA3 | DG Granule Cells | Hilus | Subiculum | Fimbria (Oligodendrocytes) | Choroid Plexus | Final Classification-Hippocampus | Patterns Match? |
|--|------------------------|-------------------|------|------|------|------------------|-------|-----------|----------------------------|----------------|----------------------------------|-----------------|
| Spock1 sparc/osteonectin, cwcv and kazal-like domains proteoglycan 1 <i>testican, Tien1</i> | X92864 | ABA | - | ++++ | ++++ | - | +++ | ++ | - | - | CA2+CA3+hilus restricted | |
| | | Lein et al., 2004 | - | ++++ | ++++ | - | - | - | - | - | CA2+CA3 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| St8sia5 ST8 alpha-N-acetyl-neuraminide alpha-2,8-sialyltransferase 5 <i>Siat8e</i> | X98014 | ABA | +++ | ++ | +++ | - | ++ | ++ | - | - | CA1-CA3 restricted | |
| | | Lein et al., 2004 | ++++ | ++++ | ++++ | - | ++ | ++ | - | - | CA1-CA3 restricted | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Stmn1 stathmin 1 <i>Lag, Lap18, prosolin</i> | Z31235 (also AA117100) | ABA | + | + | + | + | +++ | +++ | + | - | Enriched in Hilus and subiculum | |
| | | Lein et al., 2004 | + | + | + | + | ++ | ++++ | - | - | Enriched in Hilus and subiculum | yes |
| | | BGEM | ++ | ++ | ++ | ++ | ++ | +++ | - | - | Enriched in subiculum | yes |
| Tgfb2 transforming growth factor, beta 2 | X57413 | ABA | + | +++ | ++++ | ++ | + | | - | +++ | DG+CA2+CA3 enriched | |
| | | Lein et al., 2004 | + | ++++ | ++++ | ++ | + | - | - | +++ | DG+CA2+CA3 enriched | yes |
| | | BGEM | + | ++++ | ++++ | ++ | + | - | - | ++ | DG+CA2+CA3 enriched | yes |
| Tiam1 T-cell lymphoma invasion and metastasis 1 | U05245 | ABA | + | + | - | ++++ | + | ++ | - | - | DG + CA2 enriched | |
| | | Lein et al., 2004 | - | ++ | - | ++++ | + | ++ | - | - | DG+CA2 restricted | yes |
| | | BGEM | + | + | - | ++++ | + | ++ | - | - | DG + CA2 enriched | yes |

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|---|----------------|-------------------|------|-----|------|------------------|-------|-----------|----------------------------|----------------|--|----------------------------|
| Tle1 transducin-like enhancer of split 1, homolog of Drosophila E(spl) <i>Grg1</i> | U61362 | ABA | +++ | ++ | ++ | +++ | + | + | - | + | DG+CA1 enriched | |
| | | Lein et al., 2004 | +++ | ++ | ++ | ++++ | ++ | N/A | - | + | DG+CA1 enriched | yes |
| | | BGEM | ++ | + | + | ++ | + | N/A | - | + | DG+CA1 enriched | yes |
| Tyro3 TYRO3 protein tyrosine kinase 3 <i>Brit, Dtk, Rae, Sky, Tjf</i> | U05683 | ABA | ++++ | - | ++ | - | + | ++ | + | + | CA1+CA3 restricted | |
| | | Lein et al., 2004 | ++++ | - | ++ | - | - | ++ | + | - | CA1+CA3 restricted | yes |
| | | BGEM | +++ | - | + | +/- | +/- | + | + | + | CA1+CA3 enriched | yes |
| Usp11 ubiquitin specific protease 11 | W87254 | ABA | ++++ | +++ | ++++ | ++++ | ++ | ++ | - | + | Uniform expression in primary excitatory hippocampal neurons | |
| | | Lein et al., 2004 | +++ | +++ | +++ | +++ | + | + | - | ++++ | Uniform expression in primary excitatory hippocampal neurons | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ybx1 Y- Box protein 1 <i>dtpB, Efta, Msy1, Nsep1, YB-1</i> | AA073584 | ABA | +++ | ++ | ++ | +++ | + | + | - | ++ | DG+CA1 enriched | |
| | | Lein et al., 2004 | ++ | + | + | ++++ | + | + | - | ++ | DG+CA1 enriched | yes |
| | | BGEM | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Zfp312 zinc finger protein 312 <i>fez-like</i> | W98265 | ABA | + | ++ | ++ | +/- | + | ++++ | - | + | CA2+CA3 enriched | |
| | | Lein et al., 2004 | +++ | +++ | +++ | - | ++ | ++++ | - | - | CA1-CA3 restricted | Yes with higher expression |
| | | BGEM | + | + | + | ++ | + | +/- | - | + | DG enriched | No |