Brain cell type proportion analysis using BRETIGEA

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1 Background for BRETIGEA

Several comprehensive RNA-seq experiments in different brain cell types have now been published in humans and mice. Some of these experiments have profiled gene expression of cell populations isolated through immunopanning procedures. Immunopanning involves immunoprecipitation of particular cell types in cell culture plates, based on selection for an antibody adsorbed to the plate surface. Others studies have performed RNA profiling of single cells with microfluidics devices and used clustering methods to identify cell types from the resulting RNA expression profiles. The devices used for single cell RNA sequencing (scRNA-seq) often select cells based on size or via encapsulation in a droplet and involve the creation of a cDNA library from the transcriptome from a theoretical maximum of one cell.

Existing studies have been mainly based on individual datasets, and are therefore subject to systematic noise, including sampling bias due to sample collection or preparation technique, as well as stochasticity in gene expression. As an increasing number of RNA-seq cell type-specific transcriptomic experiments have become available for both human and mouse, we set out to conduct a comprehensive meta-analysis of brain cell type gene signatures, which is now published in McKenzie et al (2018), doi:10.1038/s41598-018-27293-5. We created cell type-specific (i.e. marker) gene signatures for six cell types: astrocytes (ast), endothelial cells (end), microglia (mic), neurons (neu), oligodendrocytes (oli), and oligodendrocyte precursor cells (opc). The goal of our cell type specifity measure, which is fully described in our manuscript, is to measure whether a gene is expressed in only one cell type relative to the others.

The five data sets used in the creation of the cell type marker signatures can be found in the manuscript.

2 Introduction to BRETIGEA

A major goal of **BRETIGEA** (BRain cEll Type specIfic Gene Expression Analysis) is to simplify the process of defining your own set of brain cell type marker genes by using a well-validated set of cell type-specific marker genes derived from both immunopanning and single cell microfluidic experiments, as described in McKenzie et al (2018), doi:10.1038/s41598-018-27293-5. There are brain cell type markers available that have been developed from human data, mouse data,, and combinations using data from both species (the default). Notably, if you use your own marker data, the functions in **BRETIGEA** are applicable to bulk gene expression data from any tissue. This vignette shows how you can perform cell type proportion estimation and adjustment on your own bulk gene expression data.

3 Data loading and input format

First, we will load the package and read in example bulk RNA-sequencing data from four brain regions (frontal white matter, temporal cortex, parietal cortex, and hippocampus), which was generated by the Allen Brain Atlas ("Allen Institute for Cell Science. Aging, Dementia and TBI," n.d.) and filtered to contain primarily brain marker genes. We also will load a data frame with additional immunohistochemistry quantification measurements from each brain sample, to use as a validation of the method.

```
library(BRETIGEA, quietly = TRUE)
library(knitr) #only used for vignette creation
```

Here is the format of the inputs:

```
str(aba_marker_expression, list.len = 5)
```

```
## 'data.frame':    395 obs. of  377 variables:
##  $ X488395315: num  0.6557 4.5264 0 0 0.0397 ...
##  $ X496100277: num  0.0951 8.8558 0 0 0.0165 ...
##  $ X496100278: num  0 4.87 0 0 0 ...
##  $ X496100279: num  0 4.85 0 0 0.17 ...
##  $ X496100281: num  0 3.6 0 0 0 ...
##   [list output truncated]
```

```
str(aba_pheno_data, list.len = 5)
```

```
## 'data.frame':    377 obs. of  4 variables:
##  $ structure_acronym.x: chr  "TCx" "FWM" "FWM" "TCx" ...
##  $ ihc_iba1_ffpe      : num  0.0371 0.044 0.0465 0.074 0.1124 ...
##  $ ihc_gfap_ffpe      : num  0.0218 NA 0.0664 0.0181 0.0756 ...
##  $ id                 : chr  "X488395315" "X496100277" "X496100278" "X496100279" ...
```

4 Relative cell type proportion estimation

To run the brain cell type proportion estimation analysis and extract the matrix of surrogate proportion variables for each of the major six brain cell types (astrocytes, endothelial cells, microglia, neurons, oligodendrocytes, and OPCs), run this:

```
ct_res = brainCells(aba_marker_expression, nMarker = 50)
```

```
##     markers cell
## 1      AQP4  ast
## 2   ALDH1L1  ast
```

```
## 3    BMPR1B  ast
## 4   SLC14A1  ast
## 5      MLC1  ast
## 6     FGFR3  ast
## 7  SLC25A18  ast
## 8      GLI3  ast
## 9      GFAP  ast
## 10   ACSBG1  ast
## 11   SLC4A4  ast
## 12     GJA1  ast
## 13     GJB6  ast
## 14 SLC39A12  ast
## 15      AGT  ast
## 16   CHRDL1  ast
## 17   SLC1A2  ast
## 18   CLDN10  ast
## 19     SOX9  ast
## 20  PPP1R3C  ast
##  [1] "AQP4"     "ALDH1L1"  "BMPR1B"   "SLC14A1"  "MLC1"     "FGFR3"
##  [7] "SLC25A18" "GLI3"     "GFAP"     "ACSBG1"   "SLC4A4"   "GJA1"
## [13] "GJB6"     "SLC39A12" "AGT"      "CHRDL1"   "SLC1A2"   "CLDN10"
## [19] "SOX9"     "PPP1R3C"  "CLU"      "SLC7A10"  "ID4"      "DIO2"
## [25] "SFXN5"    "SLC6A11"  "ATP13A4"  "ACOT11"   "SCARA3"   "ALDOC"
## [31] "PLCD4"    "ATP1B2"   "NTSR2"    "RGS20"    "ELOVL2"   "PAX6"
## [37] "ENTPD2"   "NCAN"     "KIAA1161" "ETNPPL"   "PPAP2B"   "LGR6"
## [43] "GPAM"     "NWD1"     "F3"       "TTPA"     "CBS"      "LIX1"
## [49] "GRIN2C"   "PHKG1"
##  [1] "APOLD1"  "EMCN"    "SDPR"    "PTPRB"   "CDH5"    "SLC38A5" "TM4SF1"
##  [8] "NOSTRIN" "CYYR1"   "MECOM"   "MYCT1"   "CLDN5"   "ERG"     "ABCB1"
## [15] "ICAM2"   "FN1"     "ESAM"    "ATP10A"  "VWF"     "CD34"    "PODXL"
## [22] "SLC19A3" "FLT1"    "TBX3"    "HMCN1"   "ITM2A"   "TEK"     "ITGA1"
## [29] "TIE1"    "ADCY4"   "CLIC5"   "ANXA1"   "OCLN"    "PALMD"   "SEMA3G"
## [36] "ABCG2"   "ROBO4"   "SLC16A4" "SLC52A3" "SOX7"    "SHE"     "CA4"
## [43] "EBF1"    "CD93"    "KDR"     "SLC2A1"  "PTRF"    "LEF1"    "HIGD1B"
## [50] "FOXF2"
##  [1] "CCL3"    "CCL4"    "CD14"    "C1QB"    "IL1A"    "TREM2"   "GPR183"
##  [8] "CD83"    "SLC2A5"  "C1QC"    "NCKAP1L" "CSF1R"   "CD300A"  "FCGR2A"
## [15] "LAPTM5"  "HAVCR2"  "C3AR1"   "CX3CR1"  "PTAFR"   "C1QA"    "FCGR1A"
## [22] "SELPLG"  "PLEK"    "CTSS"    "CSF3R"   "TYROBP"  "SLA"     "PTPN6"
## [29] "TLR2"    "CD86"    "GPR84"   "LYZ"     "MPEG1"   "BCL2A1"  "ITGAM"
## [36] "CD53"    "IRF8"    "IL10RA"  "GPR34"   "AIF1"    "CD74"    "PTPRC"
## [43] "RHOH"    "BLNK"    "TLR1"    "C5AR1"   "FCER1G"  "DOCK2"   "RGS1"
## [50] "ALOX5AP"
##  [1] "RELN"     "VIP"      "GAD2"     "TAC3"     "DLX1"     "PENK"
##  [7] "SYT1"     "TMEM130"  "GAD1"     "SYNPR"    "STMN2"    "GABRG2"
## [13] "GPR83"    "SST"      "ZMAT4"    "SNAP25"   "RAB3C"    "NELL1"
## [19] "SCG2"     "SYT4"     "CNR1"     "CLSTN2"   "SPHKAP"   "KCNQ5"
## [25] "PNOC"     "ROBO2"    "KCNC2"    "GALNTL6"  "VSNL1"    "GRIN2A"
## [31] "GABRA1"   "CHGB"     "SRRM4"    "ZNF804A"  "KIAA1324" "BCL11A"
## [37] "SV2B"     "HTR3A"    "NPY"      "PRMT8"    "CNTNAP2"  "GLRA2"
## [43] "SLC12A5"  "SLC17A6"  "CRH"      "GRIA1"    "GDA"      "INA"
## [49] "RGS8"     "CELF4"
##  [1] "PLP1"     "CLDN11"   "ERMN"     "UGT8"     "MOG"      "MOBP"
##  [7] "MAG"      "MBP"      "OPALIN"   "GJB1"     "MYRF"     "KLK6"
```

```
## [13] "FA2H"     "CNP"      "ENPP6"    "LPAR1"    "ERBB3"    "TMEM125"
## [19] "ANLN"     "ASPA"     "QDPR"     "S1PR5"    "ENPP2"    "NIPAL4"
## [25] "MAL"      "BCAS1"    "CRYAB"    "LGI3"     "SGK2"     "GPR37"
## [31] "HHIP"     "SLAIN1"   "TMEM88B"  "CNTN2"    "NINJ2"    "ST18"
## [37] "MAP6D1"   "PLEKHH1"  "PRR18"    "TF"       "TRIM59"   "PEX5L"
## [43] "HAPLN2"   "GJC2"     "GJC3"     "SEPT4"    "PPP1R14A" "GPR62"
## [49] "SEC14L5"  "GAL3ST1"
##  [1] "PDGFRA"   "SHC4"     "MATN4"    "TNR"      "PNLIP"    "PCDH15"
##  [7] "FAM180A"  "NEU4"     "LHFPL3"   "CHST6"    "MEGF11"   "OLIG1"
## [13] "GPR17"    "RNF43"    "RBPJL"    "UGT8"     "PMEL"     "SOX10"
## [19] "GAL3ST1"  "SULF2"    "CCNB1"    "MYT1"     "ACAN"     "XYLT1"
## [25] "CSPG4"    "C1QL1"    "CKAP2"    "GJC3"     "TOP2A"    "PRKG2"
## [31] "BCAS1"    "SAPCD2"   "ZNF488"   "LRRN1"    "TMEM255B" "S100A3"
## [37] "PBK"      "SUSD5"    "STK32A"   "SULF1"    "PRKCQ"    "DPYD"
## [43] "GPSM2"    "LAD1"     "UGDH"     "CKAP2L"   "GJB1"     "EMID1"
## [49] "TGFA"     "ADAM12"
##            AQP4     ALDH1L1     BMPR1B    SLC14A1       MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##       SLC25A18       GLI3       GFAP     ACSBG1     SLC4A4       GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##        SLC39A12        AGT    CHRDL1    SLC1A2    CLDN10       SOX9    PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##             CLU  SLC7A10        ID4      DIO2     SFXN5   SLC6A11    ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11     SCARA3     ALDOC     PLCD4     ATP1B2      NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2       PAX6     ENTPD2        NCAN  KIAA1161     ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B       LGR6     GPAM      NWD1         F3       TTPA        CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##            LIX1     GRIN2C      PHKG1
## [1,] -0.8404202 -0.2054718 -0.7618352
##          APOLD1       EMCN       SDPR      PTPRB       CDH5    SLC38A5
## [1,] -0.6397974 -0.5150059 -0.5503207 -0.4286219 -0.7509274 -0.2792929
##          TM4SF1    NOSTRIN      CYYR1      MECOM      MYCT1      CLDN5
## [1,] -0.5732277 -0.5492278 -0.5233367 -0.6553751 -0.4798552 -0.6769395
##             ERG      ABCB1      ICAM2        FN1       ESAM    ATP10A
## [1,] -0.5483382 -0.5187547 -0.6892712 -0.6866703 -0.5985029 -0.386112
##             VWF       CD34      PODXL    SLC19A3      FLT1       TBX3
## [1,] -0.6532856 -0.4892499 -0.6865958 -0.3100597 -0.682325 -0.4185505
##           HMCN1     ITM2A        TEK      ITGA1       TIE1      ADCY4
## [1,] -0.4729641 -0.404837 -0.4247323 -0.6994108 -0.4460777 -0.5100022
##           CLIC5      ANXA1       OCLN      PALMD     SEMA3G      ABCG2
## [1,] -0.2212121 -0.4021003 -0.1725926 -0.4391917 -0.5039709 -0.4910518
##           ROBO4    SLC16A4    SLC52A3       SOX7        SHE       CA4
## [1,] -0.4063845 -0.2065062 -0.4868766 -0.3217972 -0.6208689 0.1057804
##            EBF1       CD93        KDR     SLC2A1       PTRF       LEF1
## [1,] -0.4929378 -0.4586119 -0.4572021 -0.6991769 -0.4608555 -0.1165776
##          HIGD1B      FOXF2
## [1,] -0.1667598 -0.1962837
##              CCL3       CCL4      CD14      C1QB     IL1A     TREM2    GPR183
## [1,] -0.009014479 0.02049567 0.6772439 0.9027497 0.147061 0.8121957 0.6689415
##            CD83   SLC2A5      C1QC  NCKAP1L     CSF1R    CD300A    FCGR2A
## [1,] -0.3230165 0.882668 0.9215579 0.924154 0.7685014 0.8795061 0.8366178
```

```
##         LAPTM5    HAVCR2     C3AR1    CX3CR1     PTAFR      C1QA    FCGR1A
## [1,] 0.9474317 0.8554602 0.8224433 0.3634809 0.7619302 0.8550013 0.6713506
##         SELPLG      PLEK      CTSS     CSF3R    TYROBP       SLA     PTPN6
## [1,] 0.5294624 0.6737376 0.8570066 0.7479062 0.9002925 0.8394877 0.8757021
##           TLR2      CD86     GPR84       LYZ     MPEG1    BCL2A1     ITGAM
## [1,] 0.8563525 0.8670868 0.3866831 0.5769851 0.3112844 0.5858728 0.8377073
##           CD53      IRF8    IL10RA     GPR34      AIF1      CD74     PTPRC
## [1,] 0.8110169 0.7524594 0.8152008 0.6202537 0.8964808 0.9569894 0.9488961
##           RHOH      BLNK      TLR1     C5AR1    FCER1G     DOCK2      RGS1
## [1,] 0.3987691 0.6580784 0.8748194 0.5982698 0.8581698 0.8865086 0.6465002
##        ALOX5AP
## [1,] 0.8643056
##            RELN       VIP      GAD2      TAC3      DLX1      PENK      SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##        TMEM130      GAD1     SYNPR    STMN2    GABRG2     GPR83       SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748
##          ZMAT4    SNAP25     RAB3C     NELL1     SCG2      SYT4      CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##         CLSTN2     SPHKAP     KCNQ5      PNOC     ROBO2     KCNC2   GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1    GRIN2A    GABRA1     CHGB     SRRM4   ZNF804A  KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##        BCL11A      SV2B     HTR3A       NPY   PRMT8   CNTNAP2     GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##        SLC12A5   SLC17A6       CRH      GRIA1       GDA       INA      RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##            PLP1     CLDN11       ERMN       UGT8        MOG       MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##             MAG        MBP     OPALIN       GJB1       MYRF       KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##            FA2H        CNP      ENPP6      LPAR1     ERBB3    TMEM125      ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##            ASPA       QDPR      S1PR5     ENPP2     NIPAL4        MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
##           BCAS1      CRYAB       LGI3       SGK2      GPR37       HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1    TMEM88B     CNTN2      NINJ2       ST18     MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##         PLEKHH1      PRR18         TF    TRIM59      PEX5L     HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##            GJC2      GJC3      SEPT4   PPP1R14A      GPR62    SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##         GAL3ST1
## [1,] -0.8845151
##          PDGFRA       SHC4        MATN4        TNR       PNLIP     PCDH15
## [1,] -0.6594077 -0.8876408 -0.009790091 -0.2148693 -0.04108205 -0.1075733
##         FAM180A       NEU4     LHFPL3      CHST6     MEGF11      OLIG1
## [1,] -0.2698467 -0.2856533 -0.5938882 -0.6238268 -0.1090868 -0.8296958
##           GPR17     RNF43     RBPJL       UGT8       PMEL      SOX10    GAL3ST1
## [1,] -0.5917444 0.435638 0.1101175 -0.8814859 0.05653651 -0.8517942 -0.8665949
##          SULF2     CCNB1       MYT1       ACAN     XYLT1      CSPG4     C1QL1
## [1,] 0.1274339 0.4931099 -0.6166283 -0.1083521 0.1532883 -0.7196438 -0.336823
```

```
##          CKAP2      GJC3     TOP2A     PRKG2      BCAS1     SAPCD2     ZNF488
## [1,] 0.6525218 0.1210485 0.0195238 0.4824663 -0.9974827 -0.6061126 -0.4965659
##         LRRN1    TMEM255B      S100A3        PBK     SUSD5     STK32A     SULF1
## [1,] 0.426307 -0.07905286 -0.09222221 0.01888503 0.3814492 -0.3316909 -0.291499
##           PRKCQ       DPYD      GPSM2        LAD1        UGDH      CKAP2L
## [1,] -0.8390872 -0.8863703 -0.9110727 -0.07256941 -0.06724674 -0.05768831
##          GJB1      EMID1       TGFA     ADAM12
## [1,] -0.83458 -0.1593035 -0.8341445 -0.4069115
```

```
kable(head(ct_res))
```

	ast	end	mic	neu	oli	opc
X488395315	-0.0409765	-0.0468875	-0.0249076	0.0226400	-0.0194737	-0.0287028
X496100277	0.0391782	0.0090563	-0.0012271	-0.1361360	0.1323645	0.1322346
X496100278	0.0742051	0.0864415	0.1158266	-0.1360790	0.1534334	0.1555192
X496100279	-0.0091306	-0.0055174	0.0103811	0.0680277	-0.0194953	-0.0216833
X496100281	0.1136897	-0.0070804	0.0825388	0.0116946	-0.0243035	-0.0278465
X496100283	-0.0440731	-0.0263346	-0.0356047	0.0449777	-0.0220543	-0.0188682

4.1 Selecting the nMarker parameter

Note that the above analysis uses $nMarker = 50$ marker genes. A notable trade-off in the selection of the number of marker genes to include in the analysis is that the more marker genes you use, the more likely you are to average out any cell type-specific expression changes that may occur across groups in your sample. On the other hand, the fewer marker genes you use, the higher-quality these marker genes will tend to be in terms of strength of cell type specificity. We have chose $nMarker = 50$ because it has been a reasonable number in our experince, but the goals of your analysis may differ and you may want to choose a different number of marker genes for each cell type.

Note that only marker genes which have been measured in your data set will be used by the cell type proportion estimates, so if your data set has fewer gene measurements (e.g., in a proteomics data set), that may be a reason to use fewer marker genes.

Comparing these cell type proportion estimates to the independent immunohistochemistry quantifications of two marker genes (IBA1 and GFAP), you can see that the correlation is strong.

```
cor_mic = cor.test(ct_res[, "mic"], as.numeric(aba_pheno_data$ihc_iba1_ffpe),
  method = "spearman")
print(cor_mic)
```

```
##
##  Spearman's rank correlation rho
##
## data:  ct_res[, "mic"] and as.numeric(aba_pheno_data$ihc_iba1_ffpe)
## S = 5350838, p-value = 1.729e-10
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## 0.328793
```

```
cor_ast = cor.test(ct_res[, "ast"], as.numeric(aba_pheno_data$ihc_gfap_ffpe),
  method = "spearman")
print(cor_ast)
```

```
##
```

```
##  Spearman's rank correlation rho
##
## data:  ct_res[, "ast"] and as.numeric(aba_pheno_data$ihc_gfap_ffpe)
## S = 3591868, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.4751708
```

The default cell type proportion estimation method is singular value decomposition, but if you want to use PCA, that is an option as well.

```
ct_res = brainCells(aba_marker_expression, nMarker = 50, species = "combined",
  method = "PCA")
```

```
##     markers cell
## 1      AQP4  ast
## 2   ALDH1L1  ast
## 3    BMPR1B  ast
## 4   SLC14A1  ast
## 5      MLC1  ast
## 6     FGFR3  ast
## 7  SLC25A18  ast
## 8      GLI3  ast
## 9      GFAP  ast
## 10   ACSBG1  ast
## 11   SLC4A4  ast
## 12     GJA1  ast
## 13     GJB6  ast
## 14 SLC39A12  ast
## 15      AGT  ast
## 16   CHRDL1  ast
## 17   SLC1A2  ast
## 18   CLDN10  ast
## 19     SOX9  ast
## 20  PPP1R3C  ast
##  [1] "AQP4"     "ALDH1L1"  "BMPR1B"   "SLC14A1"  "MLC1"     "FGFR3"
##  [7] "SLC25A18" "GLI3"     "GFAP"     "ACSBG1"   "SLC4A4"   "GJA1"
## [13] "GJB6"     "SLC39A12" "AGT"      "CHRDL1"   "SLC1A2"   "CLDN10"
## [19] "SOX9"     "PPP1R3C"  "CLU"      "SLC7A10"  "ID4"      "DIO2"
## [25] "SFXN5"    "SLC6A11"  "ATP13A4"  "ACOT11"   "SCARA3"   "ALDOC"
## [31] "PLCD4"    "ATP1B2"   "NTSR2"    "RGS20"    "ELOVL2"   "PAX6"
## [37] "ENTPD2"   "NCAN"     "KIAA1161" "ETNPPL"   "PPAP2B"   "LGR6"
## [43] "GPAM"     "NWD1"     "F3"       "TTPA"     "CBS"      "LIX1"
## [49] "GRIN2C"   "PHKG1"
##  [1] "APOLD1"  "EMCN"    "SDPR"    "PTPRB"   "CDH5"    "SLC38A5" "TM4SF1"
##  [8] "NOSTRIN" "CYYR1"   "MECOM"   "MYCT1"   "CLDN5"   "ERG"     "ABCB1"
## [15] "ICAM2"   "FN1"     "ESAM"    "ATP10A"  "VWF"     "CD34"    "PODXL"
## [22] "SLC19A3" "FLT1"    "TBX3"    "HMCN1"   "ITM2A"   "TEK"     "ITGA1"
## [29] "TIE1"    "ADCY4"   "CLIC5"   "ANXA1"   "OCLN"    "PALMD"   "SEMA3G"
## [36] "ABCG2"   "ROBO4"   "SLC16A4" "SLC52A3" "SOX7"    "SHE"     "CA4"
## [43] "EBF1"    "CD93"    "KDR"     "SLC2A1"  "PTRF"    "LEF1"    "HIGD1B"
## [50] "FOXF2"
##  [1] "CCL3"    "CCL4"    "CD14"    "C1QB"    "IL1A"    "TREM2"   "GPR183"
##  [8] "CD83"    "SLC2A5"  "C1QC"    "NCKAP1L" "CSF1R"   "CD300A"  "FCGR2A"
```

```
## [15] "LAPTM5"  "HAVCR2"  "C3AR1"   "CX3CR1"  "PTAFR"   "C1QA"    "FCGR1A"
## [22] "SELPLG"  "PLEK"    "CTSS"    "CSF3R"   "TYROBP"  "SLA"     "PTPN6"
## [29] "TLR2"    "CD86"    "GPR84"   "LYZ"     "MPEG1"   "BCL2A1"  "ITGAM"
## [36] "CD53"    "IRF8"    "IL10RA"  "GPR34"   "AIF1"    "CD74"    "PTPRC"
## [43] "RHOH"    "BLNK"    "TLR1"    "C5AR1"   "FCER1G"  "DOCK2"   "RGS1"
## [50] "ALOX5AP"
##  [1] "RELN"     "VIP"      "GAD2"     "TAC3"     "DLX1"     "PENK"
##  [7] "SYT1"     "TMEM130"  "GAD1"     "SYNPR"    "STMN2"    "GABRG2"
## [13] "GPR83"    "SST"      "ZMAT4"    "SNAP25"   "RAB3C"    "NELL1"
## [19] "SCG2"     "SYT4"     "CNR1"     "CLSTN2"   "SPHKAP"   "KCNQ5"
## [25] "PNOC"     "ROBO2"    "KCNC2"    "GALNTL6"  "VSNL1"    "GRIN2A"
## [31] "GABRA1"   "CHGB"     "SRRM4"    "ZNF804A"  "KIAA1324" "BCL11A"
## [37] "SV2B"     "HTR3A"    "NPY"      "PRMT8"    "CNTNAP2"  "GLRA2"
## [43] "SLC12A5"  "SLC17A6"  "CRH"      "GRIA1"    "GDA"      "INA"
## [49] "RGS8"     "CELF4"
##  [1] "PLP1"     "CLDN11"   "ERMN"     "UGT8"     "MOG"      "MOBP"
##  [7] "MAG"      "MBP"      "OPALIN"   "GJB1"     "MYRF"     "KLK6"
## [13] "FA2H"     "CNP"      "ENPP6"    "LPAR1"    "ERBB3"    "TMEM125"
## [19] "ANLN"     "ASPA"     "QDPR"     "S1PR5"    "ENPP2"    "NIPAL4"
## [25] "MAL"      "BCAS1"    "CRYAB"    "LGI3"     "SGK2"     "GPR37"
## [31] "HHIP"     "SLAIN1"   "TMEM88B"  "CNTN2"    "NINJ2"    "ST18"
## [37] "MAP6D1"   "PLEKHH1"  "PRR18"    "TF"       "TRIM59"   "PEX5L"
## [43] "HAPLN2"   "GJC2"     "GJC3"     "SEPT4"    "PPP1R14A" "GPR62"
## [49] "SEC14L5"  "GAL3ST1"
##  [1] "PDGFRA"   "SHC4"     "MATN4"    "TNR"      "PNLIP"    "PCDH15"
##  [7] "FAM180A"  "NEU4"     "LHFPL3"   "CHST6"    "MEGF11"   "OLIG1"
## [13] "GPR17"    "RNF43"    "RBPJL"    "UGT8"     "PMEL"     "SOX10"
## [19] "GAL3ST1"  "SULF2"    "CCNB1"    "MYT1"     "ACAN"     "XYLT1"
## [25] "CSPG4"    "C1QL1"    "CKAP2"    "GJC3"     "TOP2A"    "PRKG2"
## [31] "BCAS1"    "SAPCD2"   "ZNF488"   "LRRN1"    "TMEM255B" "S100A3"
## [37] "PBK"      "SUSD5"    "STK32A"   "SULF1"    "PRKCQ"    "DPYD"
## [43] "GPSM2"    "LAD1"     "UGDH"     "CKAP2L"   "GJB1"     "EMID1"
## [49] "TGFA"     "ADAM12"
##           AQP4    ALDH1L1    BMPR1B   SLC14A1      MLC1     FGFR3 SLC25A18
## [1,] 0.7958953 0.07419527 0.4061147 0.6875915 0.7476287 0.2868527 0.302239
##           GLI3      GFAP    ACSBG1      SLC4A4      GJA1       GJB6  SLC39A12
## [1,] 0.4204516 0.9999001 0.2077684 -0.09074864 0.5208035 -0.5028409 0.1784168
##            AGT     CHRDL1     SLC1A2     CLDN10      SOX9   PPP1R3C       CLU
## [1,] 0.7350907 -0.6087144 -0.3359356 -0.3455259 0.5681326 0.1791119 0.5938866
##        SLC7A10       ID4       DIO2      SFXN5    SLC6A11   ATP13A4    ACOT11
## [1,] -0.110352 0.6952727 -0.2188643 -0.1894126 -0.5592311 0.3663146 0.1992575
##         SCARA3      ALDOC      PLCD4    ATP1B2     NTSR2     RGS20    ELOVL2
## [1,] 0.2338075 -0.1107247 -0.5112359 0.1778165 0.4740656 0.1526715 0.1147339
##           PAX6    ENTPD2       NCAN   KIAA1161    ETNPPL    PPAP2B      LGR6
## [1,] 0.5797094 0.7823284 0.05518203 -0.1721708 0.3264465 0.5024131 0.0444335
##           GPAM     NWD1        F3      TTPA       CBS      LIX1    GRIN2C
## [1,] -0.159156 0.430843 0.1665845 0.3924951 0.2509145 0.8404202 0.2054718
##          PHKG1
## [1,] 0.7618352
##         APOLD1      EMCN      SDPR     PTPRB      CDH5   SLC38A5    TM4SF1
## [1,] 0.6397974 0.5150059 0.5503207 0.4286219 0.7509274 0.2792929 0.5732277
##        NOSTRIN     CYYR1     MECOM     MYCT1     CLDN5       ERG     ABCB1
## [1,] 0.5492278 0.5233367 0.6553751 0.4798552 0.6769395 0.5483382 0.5187547
##           ICAM2       FN1      ESAM   ATP10A       VWF      CD34     PODXL
```

```
## [1,] 0.6892712 0.6866703 0.5985029 0.386112 0.6532856 0.4892499 0.6865958
##        SLC19A3     FLT1      TBX3     HMCN1    ITM2A       TEK     ITGA1
## [1,] 0.3100597 0.682325 0.4185505 0.4729641 0.404837 0.4247323 0.6994108
##           TIE1     ADCY4     CLIC5     ANXA1      OCLN     PALMD    SEMA3G
## [1,] 0.4460777 0.5100022 0.2212121 0.4021003 0.1725926 0.4391917 0.5039709
##          ABCG2     ROBO4   SLC16A4   SLC52A3      SOX7       SHE        CA4
## [1,] 0.4910518 0.4063845 0.2065062 0.4868766 0.3217972 0.6208689 -0.1057804
##           EBF1      CD93       KDR    SLC2A1      PTRF      LEF1    HIGD1B
## [1,] 0.4929378 0.4586119 0.4572021 0.6991769 0.4608555 0.1165776 0.1667598
##          FOXF2
## [1,] 0.1962837
##             CCL3        CCL4       CD14       C1QB      IL1A      TREM2
## [1,] 0.009014479 -0.02049567 -0.6772439 -0.9027497 -0.147061 -0.8121957
##          GPR183      CD83    SLC2A5       C1QC   NCKAP1L      CSF1R     CD300A
## [1,] -0.6689415 0.3230165 -0.882668 -0.9215579 -0.924154 -0.7685014 -0.8795061
##          FCGR2A     LAPTM5     HAVCR2      C3AR1     CX3CR1      PTAFR
## [1,] -0.8366178 -0.9474317 -0.8554602 -0.8224433 -0.3634809 -0.7619302
##            C1QA     FCGR1A     SELPLG       PLEK       CTSS      CSF3R
## [1,] -0.8550013 -0.6713506 -0.5294624 -0.6737376 -0.8570066 -0.7479062
##          TYROBP        SLA      PTPN6       TLR2       CD86      GPR84
## [1,] -0.9002925 -0.8394877 -0.8757021 -0.8563525 -0.8670868 -0.3866831
##             LYZ      MPEG1     BCL2A1      ITGAM       CD53       IRF8
## [1,] -0.5769851 -0.3112844 -0.5858728 -0.8377073 -0.8110169 -0.7524594
##          IL10RA      GPR34       AIF1       CD74      PTPRC       RHOH
## [1,] -0.8152008 -0.6202537 -0.8964808 -0.9569894 -0.9488961 -0.3987691
##            BLNK       TLR1      C5AR1     FCER1G      DOCK2       RGS1
## [1,] -0.6580784 -0.8748194 -0.5982698 -0.8581698 -0.8865086 -0.6465002
##         ALOX5AP
## [1,] -0.8643056
##           RELN        VIP       GAD2       TAC3       DLX1       PENK
## [1,] 0.1166803 -0.6135118 -0.8276635 -0.7295642 -0.7836934 -0.4386146
##            SYT1    TMEM130       GAD1      SYNPR     STMN2     GABRG2
## [1,] -0.9587805 -0.6442915 -0.8571033 -0.5407849 -0.954468 -0.9428849
##           GPR83        SST      ZMAT4     SNAP25      RAB3C      NELL1
## [1,] -0.4040754 -0.1924748 -0.8855612 -0.9937954 -0.7968844 -0.8839205
##            SCG2       SYT4       CNR1     CLSTN2    SPHKAP      KCNQ5       PNOC
## [1,] -0.579349 -0.9400202 -0.4062468 -0.3223093 0.1236097 -0.9203101 -0.4488496
##           ROBO2      KCNC2    GALNTL6      VSNL1     GRIN2A     GABRA1
## [1,] -0.8036322 -0.8932601 -0.7152115 -0.8592326 -0.8891878 -0.9103732
##            CHGB      SRRM4    ZNF804A   KIAA1324    BCL11A       SV2B      HTR3A
## [1,] -0.141477 -0.8110747 -0.3509051 -0.6024863 -0.742308 -0.9386318 -0.1299354
##             NPY     PRMT8     CNTNAP2      GLRA2    SLC12A5    SLC17A6        CRH
## [1,] 0.2984589 -0.80817 -0.9295066 -0.6637972 -0.9034275 -0.7684521 -0.4350317
##             GRIA1        GDA        INA       RGS8      CELF4
## [1,] -0.05161995 -0.7713854 -0.8972024 -0.1695003 -0.8067627
##            PLP1    CLDN11      ERMN      UGT8       MOG      MOBP       MAG
## [1,] 0.9305459 0.8798909 0.9359872 0.8949407 0.9124765 0.9624925 0.9200603
##             MBP    OPALIN      GJB1      MYRF      KLK6      FA2H       CNP
## [1,] 0.9924521 0.7476423 0.8302352 0.9282941 0.9099573 0.9222307 0.9139697
##          ENPP6     LPAR1    ERBB3   TMEM125     ANLN      ASPA      QDPR
## [1,] 0.8174142 0.9629297 0.920759 0.8009576 0.884949 0.9246854 0.8106579
##          S1PR5    ENPP2    NIPAL4       MAL     BCAS1     CRYAB      LGI3
## [1,] 0.9338734 0.931507 0.8928996 0.9135844 0.9744962 0.7663222 0.5304539
##            SGK2     GPR37      HHIP    SLAIN1   TMEM88B    CNTN2     NINJ2
```

```
## [1,] 0.8293518 0.8947933 0.8194185 0.8955728 0.6271867 0.932188 0.8435802
##           ST18    MAP6D1   PLEKHH1     PRR18        TF   TRIM59     PEX5L
## [1,] 0.9443919 0.8858248 0.9312008 0.8960713 0.9043357 0.875323 0.7511829
##         HAPLN2      GJC2       GJC3     SEPT4  PPP1R14A     GPR62   SEC14L5
## [1,] 0.8260379 0.8721555 -0.1293849 0.9596247 0.8221449 0.8587124 0.8569685
##        GAL3ST1
## [1,] 0.8845151
##         PDGFRA      SHC4       MATN4       TNR      PNLIP    PCDH15   FAM180A
## [1,] 0.6594077 0.8876408 0.009790091 0.2148693 0.04108205 0.1075733 0.2698467
##           NEU4    LHFPL3     CHST6    MEGF11     OLIG1     GPR17     RNF43
## [1,] 0.2856533 0.5938882 0.6238268 0.1090868 0.8296958 0.5917444 -0.435638
##           RBPJL      UGT8        PMEL     SOX10   GAL3ST1      SULF2      CCNB1
## [1,] -0.1101175 0.8814859 -0.05653651 0.8517942 0.8665949 -0.1274339 -0.4931099
##           MYT1      ACAN      XYLT1     CSPG4    C1QL1      CKAP2       GJC3
## [1,] 0.6166283 0.1083521 -0.1532883 0.7196438 0.336823 -0.6525218 -0.1210485
##           TOP2A      PRKG2     BCAS1    SAPCD2    ZNF488     LRRN1   TMEM255B
## [1,] -0.0195238 -0.4824663 0.9974827 0.6061126 0.4965659 -0.426307 0.07905286
##          S100A3         PBK      SUSD5    STK32A    SULF1     PRKCQ      DPYD
## [1,] 0.09222221 -0.01888503 -0.3814492 0.3316909 0.291499 0.8390872 0.8863703
##          GPSM2       LAD1       UGDH     CKAP2L    GJB1     EMID1      TGFA
## [1,] 0.9110727 0.07256941 0.06724674 0.05768831 0.83458 0.1593035 0.8341445
##         ADAM12
## [1,] 0.4069115
```

```
kable(head(ct_res))
```

	ast	end	mic	neu	oli	opc
X488395315	-772.2007	-11.216558	-27.520538	117.72323	-652.7520	-52.75793
X496100277	738.3115	2.166464	-1.355803	-707.87803	4436.8175	243.05687
X496100278	1398.3931	20.678778	127.977252	-707.58137	5143.0376	285.85561
X496100279	-172.0668	-1.319885	11.470150	353.72941	-653.4776	-39.85540
X496100281	2142.4780	-1.693788	91.197438	60.80918	-814.6443	-51.18396
X496100283	-830.5568	-6.299840	-39.339784	233.87439	-739.2522	-34.68110

The *species* argument controls which species the marker genes are derived from, and can be set to "human" and "mouse" for data specific to those species.

If you want to only estimate the proportion of particular cell types, you can do so by setting the *celltypes* argument. Here, we only estimate the proportions of astrocytes, neurons, and oligodendrocytes. Note that the estimates of each cell type is done independently, so choosing to estimate the proportions of one cell type or not will not affect the estimates of the other cell types.

```
ct_res = brainCells(aba_marker_expression, nMarker = 50, species = "combined",
  celltypes = c("ast", "neu", "oli"))
```

```
##     markers cell
## 1      AQP4  ast
## 2   ALDH1L1  ast
## 3    BMPR1B  ast
## 4   SLC14A1  ast
## 5      MLC1  ast
## 6     FGFR3  ast
## 7  SLC25A18  ast
## 8      GLI3  ast
```

```
## 9      GFAP  ast
## 10   ACSBG1  ast
## 11   SLC4A4  ast
## 12     GJA1  ast
## 13     GJB6  ast
## 14 SLC39A12  ast
## 15      AGT  ast
## 16   CHRDL1  ast
## 17   SLC1A2  ast
## 18   CLDN10  ast
## 19     SOX9  ast
## 20  PPP1R3C  ast
##  [1] "AQP4"     "ALDH1L1"  "BMPR1B"   "SLC14A1"  "MLC1"     "FGFR3"
##  [7] "SLC25A18" "GLI3"     "GFAP"     "ACSBG1"   "SLC4A4"   "GJA1"
## [13] "GJB6"     "SLC39A12" "AGT"      "CHRDL1"   "SLC1A2"   "CLDN10"
## [19] "SOX9"     "PPP1R3C"  "CLU"      "SLC7A10"  "ID4"      "DIO2"
## [25] "SFXN5"    "SLC6A11"  "ATP13A4"  "ACOT11"   "SCARA3"   "ALDOC"
## [31] "PLCD4"    "ATP1B2"   "NTSR2"    "RGS20"    "ELOVL2"   "PAX6"
## [37] "ENTPD2"   "NCAN"     "KIAA1161" "ETNPPL"   "PPAP2B"   "LGR6"
## [43] "GPAM"     "NWD1"     "F3"       "TTPA"     "CBS"      "LIX1"
## [49] "GRIN2C"   "PHKG1"
##  [1] "RELN"     "VIP"      "GAD2"     "TAC3"     "DLX1"     "PENK"
##  [7] "SYT1"     "TMEM130"  "GAD1"     "SYNPR"    "STMN2"    "GABRG2"
## [13] "GPR83"    "SST"      "ZMAT4"    "SNAP25"   "RAB3C"    "NELL1"
## [19] "SCG2"     "SYT4"     "CNR1"     "CLSTN2"   "SPHKAP"   "KCNQ5"
## [25] "PNOC"     "ROBO2"    "KCNC2"    "GALNTL6"  "VSNL1"    "GRIN2A"
## [31] "GABRA1"   "CHGB"     "SRRM4"    "ZNF804A"  "KIAA1324" "BCL11A"
## [37] "SV2B"     "HTR3A"    "NPY"      "PRMT8"    "CNTNAP2"  "GLRA2"
## [43] "SLC12A5"  "SLC17A6"  "CRH"      "GRIA1"    "GDA"      "INA"
## [49] "RGS8"     "CELF4"
##  [1] "PLP1"     "CLDN11"   "ERMN"     "UGT8"     "MOG"      "MOBP"
##  [7] "MAG"      "MBP"      "OPALIN"   "GJB1"     "MYRF"     "KLK6"
## [13] "FA2H"     "CNP"      "ENPP6"    "LPAR1"    "ERBB3"    "TMEM125"
## [19] "ANLN"     "ASPA"     "QDPR"     "S1PR5"    "ENPP2"    "NIPAL4"
## [25] "MAL"      "BCAS1"    "CRYAB"    "LGI3"     "SGK2"     "GPR37"
## [31] "HHIP"     "SLAIN1"   "TMEM88B"  "CNTN2"    "NINJ2"    "ST18"
## [37] "MAP6D1"   "PLEKHH1"  "PRR18"    "TF"       "TRIM59"   "PEX5L"
## [43] "HAPLN2"   "GJC2"     "GJC3"     "SEPT4"    "PPP1R14A" "GPR62"
## [49] "SEC14L5"  "GAL3ST1"
##            AQP4     ALDH1L1     BMPR1B    SLC14A1       MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##       SLC25A18       GLI3       GFAP     ACSBG1     SLC4A4       GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##        SLC39A12        AGT    CHRDL1    SLC1A2    CLDN10       SOX9    PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##             CLU  SLC7A10        ID4      DIO2     SFXN5   SLC6A11    ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11     SCARA3     ALDOC     PLCD4     ATP1B2      NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2       PAX6     ENTPD2        NCAN  KIAA1161     ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B       LGR6     GPAM      NWD1         F3       TTPA        CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##            LIX1     GRIN2C      PHKG1
```

```
## [1,] -0.8404202 -0.2054718 -0.7618352
##            RELN       VIP      GAD2      TAC3      DLX1      PENK      SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##        TMEM130      GAD1     SYNPR    STMN2    GABRG2     GPR83       SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748
##          ZMAT4    SNAP25     RAB3C     NELL1     SCG2      SYT4      CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##         CLSTN2     SPHKAP     KCNQ5      PNOC     ROBO2     KCNC2   GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1    GRIN2A    GABRA1     CHGB     SRRM4   ZNF804A  KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##        BCL11A      SV2B     HTR3A        NPY    PRMT8   CNTNAP2     GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##        SLC12A5   SLC17A6       CRH      GRIA1       GDA       INA      RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##            PLP1     CLDN11       ERMN       UGT8        MOG       MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##             MAG        MBP     OPALIN       GJB1       MYRF       KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##            FA2H        CNP      ENPP6      LPAR1     ERBB3    TMEM125      ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##            ASPA       QDPR      S1PR5     ENPP2     NIPAL4        MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
##           BCAS1      CRYAB       LGI3       SGK2      GPR37       HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1    TMEM88B     CNTN2      NINJ2       ST18     MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##         PLEKHH1      PRR18         TF    TRIM59      PEX5L     HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##            GJC2      GJC3      SEPT4   PPP1R14A      GPR62    SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##         GAL3ST1
## [1,] -0.8845151
```

```
kable(head(ct_res))
```

	ast	neu	oli
X488395315	-0.0409765	0.0226400	-0.0194737
X496100277	0.0391782	-0.1361360	0.1323645
X496100278	0.0742051	-0.1360790	0.1534334
X496100279	-0.0091306	0.0680277	-0.0194953
X496100281	0.1136897	0.0116946	-0.0243035
X496100283	-0.0440731	0.0449777	-0.0220543

5 Using alternative cell type marker genes from Kelley *et al.*

In addition to the default data set built from a meta-analysis across cell type-specific gene expression data, BRETIGEA also offers access to cell type markers based on leveraging variation across intact tissue samples. The cell types for which markers are available based on this data set are astrocytes, neurons, microglia, and oligodendrocytes.

To use this, change the *data_set* parameter to "kelley" (referring to Kelley *et al.*, 2018, PMID: 30154505) when you call brainCells(). Note that the *species* argument will be ignored if *data_set* is set to "kelley".

```
ct_res = brainCells(aba_marker_expression, nMarker = 50, data_set = "kelley")
```

```
##     markers cell
## 1     NTRK2  ast
## 2    NOTCH2  ast
## 3    SLC1A3  ast
## 4    ATP1A2  ast
## 5      PON2  ast
## 6    PDLIM5  ast
## 7   TP53BP2  ast
## 8      HEPH  ast
## 9    PPAP2B  ast
## 10     MLC1  ast
## 11    RAB31  ast
## 12   GPR125  ast
## 13  METTL7A  ast
## 14   SLC4A4  ast
## 15    BBOX1  ast
## 16   BMPR1B  ast
## 17   ETNPPL  ast
## 18 ARHGEF26  ast
## 19     GJA1  ast
## 20   SLC1A2  ast
##  [1] "PPAP2B"   "MLC1"     "SLC4A4"   "BMPR1B"   "ETNPPL"   "GJA1"
##  [7] "SLC1A2"   "GPAM"     "AQP4"     "FGFR3"    "AGT"      "SLC25A18"
## [13] "ATP13A4"  "CLDN10"   "SOX9"     "GJB6"     "PPP1R3C"  "NTSR2"
## [19] "ACSBG1"   "SLC39A12" "LIX1"     "SLC7A10"  "GLI3"     "ALDH1L1"
## [25] "ATP1B2"   "F3"       "ID4"      "ELOVL2"   "SFXN5"    "RGS20"
## [31] "NCAN"     "SLC14A1"  "DIO2"     "TTPA"     "ACOT11"   "NWD1"
## [37] "PAX6"     "PDGFRA"   "GRIN2C"   "SCARA3"   "KIAA1161" "CHRDL1"
## [43] "CBS"      "EMID1"    "CLU"      "GFAP"     "GPSM2"    "RNF43"
## [49] "MXRA8"    "MECOM"
##  [1] "MOG"      "FA2H"     "CNP"      "ERBB3"    "GPR37"    "CNTN2"
##  [7] "MAG"      "ENPP2"    "UGT8"     "TMEM125"  "PLP1"     "TF"
## [13] "GJB1"     "ASPA"     "SLAIN1"   "KLK6"     "ANLN"     "MYRF"
## [19] "MAL"      "ERMN"     "SGK2"     "ST18"     "HHIP"     "OPALIN"
## [25] "CLDN11"   "NIPAL4"   "MOBP"     "SHC4"     "CRYAB"    "PPP1R14A"
## [31] "MAP6D1"   "SOX10"    "GAL3ST1"  "NINJ2"    "PRR18"    "TRIM59"
## [37] "GJC2"     "QDPR"     "ENPP6"    "SEPT4"    "HAPLN2"   "S1PR5"
## [43] "PLEKHH1"  "ZNF488"   "GPR62"    "SEC14L5"  "LPAR1"    "OLIG1"
## [49] "PRKCQ"    "CHST6"
##  [1] "AIF1"    "TYROBP"  "CD74"    "C1QB"    "LAPTM5"  "ALOX5AP" "CSF1R"
##  [8] "C1QA"    "HAVCR2"  "CX3CR1"  "SLC2A5"  "SELPLG"  "TREM2"   "GPR34"
## [15] "ITGAM"   "CD53"    "CD86"    "PTAFR"   "FCGR1A"  "C1QC"    "PTPRC"
## [22] "BLNK"    "CTSS"    "FCER1G"  "TLR1"    "NCKAP1L" "PTPN6"   "MPEG1"
## [29] "IL10RA"  "CD14"    "IRF8"    "CD300A"  "FCGR2A"  "TLR2"    "PLEK"
## [36] "C3AR1"   "SLA"     "DOCK2"   "GPR183"  "CNTN2"   "CNP"     "MAG"
## [43] "CCL3"    "NINJ2"   "MAL"     "CLDN11"  "QDPR"    "CSF3R"   "KLK6"
## [50] "TF"
##  [1] "SNAP25"   "CNR1"     "GABRA1"   "GABRG2"   "SV2B"     "SLC12A5"
##  [7] "RAB3C"    "GAD1"     "CNTNAP2"  "GAD2"     "SYT1"     "PRMT8"
## [13] "KCNQ5"    "GRIN2A"   "ZMAT4"    "SYT4"     "GRIA1"    "INA"
```

```
## [19] "BCL11A"   "SLC17A6"  "CELF4"    "KIAA1324" "RGS8"     "ROBO2"
##          PPAP2B       MLC1     SLC4A4     BMPR1B    ETNPPL       GJA1    SLC1A2
## [1,] -0.5025541 -0.7477438 0.09048259 -0.4063123 -0.326647 -0.5208349 0.3356524
##           GPAM       AQP4      FGFR3        AGT   SLC25A18    ATP13A4    CLDN10
## [1,] 0.1590143 -0.7959551 -0.2870478 -0.7351957 -0.3024247 -0.3664846 0.3453167
##           SOX9      GJB6    PPP1R3C      NTSR2     ACSBG1   SLC39A12
## [1,] -0.5681646 0.5026505 -0.1792838 -0.4742672 -0.2080146 -0.1785399
##           LIX1   SLC7A10      GLI3     ALDH1L1     ATP1B2         F3
## [1,] -0.8404701 0.1101243 -0.420511 -0.07441655 -0.1779509 -0.1667923
##            ID4     ELOVL2     SFXN5      RGS20        NCAN    SLC14A1     DIO2
## [1,] -0.6953497 -0.1149166 0.1891457 -0.1528931 -0.05527618 -0.6875852 0.218628
##           TTPA     ACOT11       NWD1       PAX6    PDGFRA     GRIN2C
## [1,] -0.3925443 -0.1993598 -0.4308381 -0.5797566 -0.427459 -0.2055993
##          SCARA3  KIAA1161    CHRDL1        CBS      EMID1        CLU       GFAP
## [1,] -0.2339306 0.1721085 0.6085179 -0.2509234 -0.3614802 -0.5940632 -0.9998986
##         GPSM2     RNF43      MXRA8       MECOM
## [1,] -0.33791 0.2061761 -0.6480445 -0.09320791
##             MOG       FA2H        CNP      ERBB3      GPR37     CNTN2
## [1,] -0.9553868 -0.9374078 -0.9570886 -0.9470527 -0.9563399 -0.936811
##             MAG      ENPP2       UGT8    TMEM125     PLP1         TF       GJB1
## [1,] -0.9337397 -0.9917416 -0.9661407 -0.8633007 -0.99921 -0.9465401 -0.8960731
##            ASPA     SLAIN1       KLK6       ANLN       MYRF        MAL
## [1,] -0.9527922 -0.9339612 -0.9648252 -0.9343073 -0.9200252 -0.9465757
##            ERMN       SGK2       ST18       HHIP     OPALIN     CLDN11
## [1,] -0.9774926 -0.8833653 -0.9669427 -0.8792891 -0.7946807 -0.9485021
##          NIPAL4       MOBP       SHC4      CRYAB   PPP1R14A     MAP6D1
## [1,] -0.9355339 -0.9262692 -0.9307934 -0.7704165 -0.8341845 -0.9422173
##          SOX10    GAL3ST1      NINJ2      PRR18     TRIM59       GJC2
## [1,] -0.889713 -0.8625225 -0.9005809 -0.9079648 -0.9344645 -0.8996056
##            QDPR      ENPP6      SEPT4     HAPLN2      S1PR5    PLEKHH1
## [1,] -0.8591096 -0.8742807 -0.9309558 -0.8274583 -0.9459345 -0.9366046
##          ZNF488      GPR62    SEC14L5      LPAR1      OLIG1      PRKCQ
## [1,] -0.5983907 -0.9024721 -0.8754486 -0.9132296 -0.8161764 -0.8763089
##          CHST6
## [1,] -0.684862
##            AIF1     TYROBP       CD74       C1QB     LAPTM5    ALOX5AP
## [1,] -0.3667772 -0.4549482 -0.4369198 -0.2800804 -0.4879601 -0.4901835
##           CSF1R       C1QA    HAVCR2     CX3CR1     SLC2A5     SELPLG
## [1,] -0.3691395 -0.1929456 -0.644708 -0.3615215 -0.3424207 -0.4273749
##           TREM2      GPR34      ITGAM       CD53       CD86      PTAFR
## [1,] -0.5285649 -0.3000078 -0.4559793 -0.2683018 -0.4235582 -0.5261217
##          FCGR1A       C1QC      PTPRC       BLNK       CTSS     FCER1G
## [1,] -0.2301161 -0.3175702 -0.4665704 -0.3460233 -0.4004204 -0.3696705
##            TLR1    NCKAP1L      PTPN6      MPEG1     IL10RA       CD14
## [1,] -0.3978289 -0.4454142 -0.4332804 -0.2814146 -0.3509839 -0.1336975
##            IRF8     CD300A     FCGR2A       TLR2       PLEK      C3AR1
## [1,] -0.3603299 -0.3983796 -0.3730523 -0.331365 -0.3125135 -0.3919277
##             SLA      DOCK2     GPR183      CNTN2        CNP        MAG
## [1,] -0.1708626 -0.5143557 -0.3278701 -0.9397309 -0.9768923 -0.9562714
##              CCL3      NINJ2        MAL    CLDN11       QDPR      CSF3R
## [1,] 0.0009828922 -0.9443308 -0.9428705 -0.927282 -0.8680864 -0.5755449
##            KLK6         TF
## [1,] -0.9416907 -0.9922734
##          SNAP25       CNR1     GABRA1    GABRG2       SV2B    SLC12A5
```

```
## [1,] -0.9994439 -0.4711826 -0.8826786 -0.929699 -0.9306014 -0.8922213
##           RAB3C       GAD1    CNTNAP2       GAD2       SYT1      PRMT8
## [1,] -0.8324769 -0.8455382 -0.9100061 -0.8047595 -0.9539956 -0.7734852
##           KCNQ5     GRIN2A      ZMAT4       SYT4      GRIA1        INA
## [1,] -0.9077714 -0.9091246 -0.8637406 -0.9389565 -0.1366514 -0.8630253
##          BCL11A    SLC17A6      CELF4   KIAA1324       RGS8      ROBO2
## [1,] -0.7639501 -0.7188173 -0.8249301 -0.6574843 -0.2404888 -0.8230147
```

```
kable(head(ct_res))
```

	ast	oli	mic	neu
X488395315	-0.0409743	-0.0166393	-0.0291033	0.0218630
X496100277	0.0391691	0.1090432	0.1821966	-0.1393577
X496100278	0.0741579	0.1770217	0.1403979	-0.1393649
X496100279	-0.0091355	-0.0206609	-0.0237831	0.0673423
X496100281	0.1137161	-0.0139311	-0.0160118	0.0245435
X496100283	-0.0440718	-0.0203663	-0.0219785	0.0430816

In the Allen Brain Atlas RNA-seq data, the estimated proportions are overall very similar between the "mckenzie" and "kelley" data sets.

```
ct_res_mckenzie = brainCells(aba_marker_expression, nMarker = 50, data_set = "mckenzie", species = "huma
```

```
##       markers cell
## 1        GPR98  ast
## 2         AQP4  ast
## 3       BMPR1B  ast
## 4       ETNPPL  ast
## 5         GJB6  ast
## 6         GJA1  ast
## 7        FGFR3  ast
## 8     SLC25A18  ast
## 9       SLC1A2  ast
## 10        SDC4  ast
## 11        GFAP  ast
## 12       EDNRB  ast
## 13 RNF219-AS1  ast
## 14  LINC00499  ast
## 15    ALDH1L1  ast
## 16     CHI3L1  ast
## 17     CLDN10  ast
## 18        AGT  ast
## 19    SLCO1C1  ast
## 20     SLC4A4  ast
##  [1] "AQP4"     "BMPR1B"   "ETNPPL"   "GJB6"     "GJA1"     "FGFR3"
##  [7] "SLC25A18" "SLC1A2"   "GFAP"     "ALDH1L1"  "CLDN10"   "AGT"
## [13] "SLC4A4"   "GPAM"     "SLC14A1"  "ID4"      "ACSBG1"   "MLC1"
## [19] "SLC39A12" "NCAN"     "ATP1B2"   "CLU"      "RGS20"    "GLI3"
## [25] "SOX9"     "ACOT11"   "SFXN5"    "ELOVL2"   "SLC7A10"  "SCARA3"
## [31] "PAX6"     "SLC6A11"  "F3"       "DIO2"     "ALDOC"    "ATP13A4"
## [37] "PPAP2B"   "LIX1"     "PPP1R3C"  "CHRDL1"   "GRIN2C"   "RNF43"
## [43] "NTSR2"    "NWD1"     "KIAA1161" "TTPA"     "LGR6"     "EMID1"
## [49] "ENTPD2"   "PLCD4"
##  [1] "APOLD1"  "SDPR"    "CD34"    "TM4SF1"  "MECOM"   "VWF"     "ITGA1"
```

```
##  [8] "ABCB1"   "ABCG2"   "ATP10A"  "ERG"     "HIGD1B"  "PODXL"   "MYCT1"
## [15] "EBF1"    "EMCN"    "CLDN5"   "NOSTRIN" "ESAM"    "PTPRB"   "TBX3"
## [22] "PALMD"   "LEF1"    "CDH5"    "SEMA3G"  "FN1"     "CYYR1"   "ADCY4"
## [29] "ANXA1"   "SLC38A5" "SLC2A1"  "TIE1"    "ROBO4"   "CLIC5"   "SOX7"
## [36] "CA4"     "ICAM2"   "PTRF"    "HMCN1"   "SLC52A3" "FOXF2"   "SLC16A4"
## [43] "ITM2A"   "SLC19A3" "OCLN"    "SHE"     "KDR"     "ISG15"   "FLT1"
## [50] "AGRN"
##  [1] "CCL3"    "CCL4"    "CD74"    "C1QB"    "TLR1"    "SLA"     "IL1A"
##  [8] "HAVCR2"  "PLEK"    "C3AR1"   "TREM2"   "CD14"    "CD300A"  "PTPRC"
## [15] "PTAFR"   "TLR2"    "CD83"    "PTPN6"   "SLC2A5"  "BCL2A1"  "GPR183"
## [22] "MPEG1"   "IL10RA"  "RHOH"    "GPR34"   "CD53"    "BLNK"    "TYROBP"
## [29] "CX3CR1"  "C5AR1"   "C1QA"    "SELPLG"  "LAPTM5"  "CSF3R"   "FCER1G"
## [36] "C1QC"    "CSF1R"   "NCKAP1L" "AIF1"    "ALOX5AP" "DOCK2"   "ITGAM"
## [43] "LYZ"     "FCGR1A"  "CD86"    "CTSS"    "IRF8"    "FCGR2A"  "RGS1"
## [50] "GPR84"
##  [1] "SYNPR"    "RELN"     "CNR1"     "GAD2"     "RAB3C"    "SYT1"
##  [7] "KCNC2"    "ZMAT4"    "CHGB"     "GABRA1"   "GAD1"     "TAC3"
## [13] "SCG2"     "GALNTL6"  "STMN2"    "SNAP25"   "INA"      "SRRM4"
## [19] "DLX1"     "GDA"      "SYT4"     "GPR83"    "KCNQ5"    "GABRG2"
## [25] "ZNF804A"  "SPHKAP"   "VSNL1"    "VIP"      "ROBO2"    "GRIA1"
## [31] "CLSTN2"   "PRMT8"    "GRIN2A"   "SLC12A5"  "TMEM130"  "GLRA2"
## [37] "BCL11A"   "SV2B"     "CNTNAP2"  "KIAA1324" "CELF4"    "PNOC"
## [43] "RGS8"     "NELL1"    "PENK"     "CRH"      "SST"      "SULF1"
## [49] "SLC17A6"
##  [1] "UGT8"     "PLP1"     "ERMN"     "CLDN11"   "MAG"      "TF"
##  [7] "KLK6"     "CNTN2"    "MOBP"     "ST18"     "ERBB3"    "MYRF"
## [13] "MOG"      "SLAIN1"   "OPALIN"   "CNP"      "ENPP2"    "HHIP"
## [19] "QDPR"     "ANLN"     "GJB1"     "LPAR1"    "BCAS1"    "MBP"
## [25] "ZNF488"   "SEPT4"    "NINJ2"    "FA2H"     "TRIM59"   "PLEKHH1"
## [31] "GPR37"    "MAP6D1"   "SGK2"     "PEX5L"    "TGFA"     "LHFPL3"
## [37] "ASPA"     "S1PR5"    "CRYAB"    "HAPLN2"   "OLIG1"    "PPP1R14A"
## [43] "MAL"      "LGI3"     "TMEM125"  "SEC14L5"  "SHC4"     "PRR18"
## [49] "GPR62"    "XYLT1"
##  [1] "TGFA"   "XYLT1"  "TNR"    "MEGF11" "PDGFRA" "GPSM2"  "LRRN1"  "PCDH15"
##  [9] "SHC4"   "LHFPL3" "STK32A"
##            AQP4     BMPR1B     ETNPPL      GJB6       GJA1      FGFR3
## [1,] -0.7958953 -0.4061145 -0.3264466 0.5028413 -0.5208029 -0.2868519
##        SLC25A18    SLC1A2       GFAP     ALDH1L1    CLDN10        AGT
## [1,] -0.3022388 0.3359357 -0.9999002 -0.07419478 0.3455264 -0.7350902
##          SLC4A4      GPAM    SLC14A1        ID4     ACSBG1       MLC1
## [1,] 0.09074835 0.1591568 -0.6875913 -0.6952725 -0.2077688 -0.7476283
##        SLC39A12        NCAN     ATP1B2        CLU     RGS20       GLI3
## [1,] -0.1784169 -0.05518123 -0.1778163 -0.5938856 -0.152671 -0.4204512
##            SOX9     ACOT11     SFXN5     ELOVL2  SLC7A10     SCARA3      PAX6
## [1,] -0.5681311 -0.1992568 0.1894125 -0.1147346 0.110352 -0.2338064 -0.579708
##        SLC6A11         F3      DIO2    ALDOC    ATP13A4     PPAP2B       LIX1
## [1,] 0.5592315 -0.1665847 0.2188641 0.110725 -0.3663146 -0.5024126 -0.8404205
##         PPP1R3C    CHRDL1     GRIN2C     RNF43      NTSR2       NWD1  KIAA1161
## [1,] -0.1791112 0.6087142 -0.2054701 0.2063764 -0.4740655 -0.4308429 0.1721714
##            TTPA        LGR6     EMID1     ENTPD2     PLCD4
## [1,] -0.3924953 -0.04443324 -0.361383 -0.7823283 0.5112364
##          APOLD1       SDPR       CD34     TM4SF1      MECOM        VWF
## [1,] -0.6399815 -0.5520798 -0.4907274 -0.5695515 -0.6550512 -0.6524641
##           ITGA1      ABCB1      ABCG2     ATP10A        ERG     HIGD1B
```

```
## [1,] -0.6972485 -0.5203408 -0.4937788 -0.3887715 -0.5470173 -0.1689564
##          PODXL      MYCT1       EBF1       EMCN      CLDN5    NOSTRIN
## [1,] -0.686035 -0.4810083 -0.4940037 -0.5164972 -0.6762312 -0.5489817
##            ESAM      PTPRB       TBX3      PALMD       LEF1       CDH5
## [1,] -0.5982823 -0.4305522 -0.4197295 -0.4402406 -0.1165449 -0.7478238
##         SEMA3G        FN1      CYYR1      ADCY4      ANXA1    SLC38A5
## [1,] -0.504194 -0.6877241 -0.5232659 -0.5090985 -0.4017235 -0.2817508
##          SLC2A1       TIE1      ROBO4      CLIC5       SOX7       CA4
## [1,] -0.6995822 -0.4477667 -0.4056899 -0.2223977 -0.3214358 0.1048609
##           ICAM2       PTRF      HMCN1    SLC52A3      FOXF2    SLC16A4
## [1,] -0.6872572 -0.4610223 -0.4746686 -0.4871699 -0.1964257 -0.2073382
##           ITM2A   SLC19A3       OCLN       SHE        KDR       ISG15
## [1,] -0.4047572 -0.309978 -0.1732357 -0.619215 -0.4551206 -0.09500632
##           FLT1       AGRN
## [1,] -0.6822437 0.05437876
##              CCL3       CCL4      CD74      C1QB      TLR1       SLA      IL1A
## [1,] -0.009014479 0.02049567 0.9569894 0.9027497 0.8748194 0.8394877 0.147061
##         HAVCR2      PLEK     C3AR1     TREM2      CD14    CD300A     PTPRC
## [1,] 0.8554602 0.6737376 0.8224433 0.8121957 0.6772439 0.8795061 0.9488961
##          PTAFR      TLR2       CD83     PTPN6   SLC2A5    BCL2A1    GPR183
## [1,] 0.7619302 0.8563525 -0.3230165 0.8757021 0.882668 0.5858728 0.6689415
##          MPEG1    IL10RA      RHOH     GPR34      CD53      BLNK    TYROBP
## [1,] 0.3112844 0.8152008 0.3987691 0.6202537 0.8110169 0.6580784 0.9002925
##         CX3CR1     C5AR1      C1QA    SELPLG    LAPTM5     CSF3R    FCER1G
## [1,] 0.3634809 0.5982698 0.8550013 0.5294624 0.9474317 0.7479062 0.8581698
##           C1QC     CSF1R  NCKAP1L      AIF1   ALOX5AP     DOCK2     ITGAM
## [1,] 0.9215579 0.7685014 0.924154 0.8964808 0.8643056 0.8865086 0.8377073
##           LYZ    FCGR1A      CD86      CTSS      IRF8    FCGR2A      RGS1
## [1,] 0.5769851 0.6713506 0.8670868 0.8570066 0.7524594 0.8366178 0.6465002
##          GPR84
## [1,] 0.3866831
##           SYNPR    RELN       CNR1       GAD2      RAB3C       SYT1      KCNC2
## [1,] -0.5407689 0.11676 -0.4061398 -0.8276954 -0.7968191 -0.9588116 -0.8932509
##           ZMAT4       CHGB     GABRA1       GAD1      TAC3       SCG2
## [1,] -0.8855258 -0.1413789 -0.9103821 -0.8571014 -0.729535 -0.5793877
##          GALNTL6    STMN2     SNAP25        INA     SRRM4       DLX1        GDA
## [1,] -0.7152189 -0.95448 -0.9937844 -0.8971981 -0.811072 -0.7836811 -0.7714656
##            SYT4      GPR83      KCNQ5     GABRG2    ZNF804A    SPHKAP     VSNL1
## [1,] -0.9400441 -0.4039511 -0.9202798 -0.9428785 -0.3507682 0.1237171 -0.859272
##              VIP      ROBO2       GRIA1     CLSTN2      PRMT8     GRIN2A
## [1,] -0.6134488 -0.8036823 -0.05150754 -0.3222614 -0.8081944 -0.8891158
##        SLC12A5    TMEM130      GLRA2    BCL11A       SV2B    CNTNAP2   KIAA1324
## [1,] -0.903364 -0.6441962 -0.6638931 -0.742246 -0.9386706 -0.9294711 -0.6023963
##           CELF4       PNOC       RGS8      NELL1       PENK        CRH
## [1,] -0.8067308 -0.4488567 -0.1693912 -0.8839522 -0.4386024 -0.4350206
##              SST      SULF1    SLC17A6
## [1,] -0.1926701 0.08911178 -0.7684385
##           UGT8      PLP1       ERMN     CLDN11        MAG        TF       KLK6
## [1,] -0.8949423 -0.930547 -0.9359886 -0.8798922 -0.9200623 -0.904338 -0.9099586
##           CNTN2       MOBP       ST18      ERBB3       MYRF        MOG
## [1,] -0.9321899 -0.9624937 -0.9443937 -0.9207618 -0.9282964 -0.9124786
##          SLAIN1     OPALIN       CNP      ENPP2      HHIP       QDPR      ANLN
## [1,] -0.8955747 -0.7476443 -0.913972 -0.9315086 -0.819422 -0.8106599 -0.884951
##            GJB1     LPAR1      BCAS1        MBP     ZNF488      SEPT4
```

```
## [1,] -0.8302383 -0.962931 -0.9744962 -0.9924517 -0.5290359 -0.9596253
##           NINJ2       FA2H     TRIM59    PLEKHH1      GPR37     MAP6D1
## [1,] -0.8435832 -0.9222321 -0.8753261 -0.9312029 -0.8947963 -0.8858273
##            SGK2      PEX5L       TGFA     LHFPL3       ASPA      S1PR5
## [1,] -0.8293538 -0.7511845 -0.8519515 -0.5616319 -0.9246865 -0.9338739
##           CRYAB     HAPLN2      OLIG1   PPP1R14A        MAL       LGI3
## [1,] -0.7663217 -0.8260412 -0.8329667 -0.8221472 -0.9135859 -0.5304531
##         TMEM125    SEC14L5       SHC4      PRR18      GPR62     XYLT1
## [1,] -0.8009608 -0.8569698 -0.9115929 -0.8960737 -0.8587162 0.1569451
##            TGFA     XYLT1        TNR     MEGF11     PDGFRA      GPSM2
## [1,] -0.7243984 -0.506883 -0.8940025 -0.7164912 -0.8635213 -0.5814406
##           LRRN1     PCDH15       SHC4     LHFPL3     STK32A
## [1,] -0.2153496 -0.7722088 -0.5199548 -0.6963018 -0.7288558
```

```
ct_res_kelley = brainCells(aba_marker_expression, nMarker = 50, data_set = "kelley")
```

```
##     markers cell
## 1     NTRK2  ast
## 2    NOTCH2  ast
## 3    SLC1A3  ast
## 4    ATP1A2  ast
## 5      PON2  ast
## 6    PDLIM5  ast
## 7   TP53BP2  ast
## 8      HEPH  ast
## 9    PPAP2B  ast
## 10     MLC1  ast
## 11    RAB31  ast
## 12   GPR125  ast
## 13  METTL7A  ast
## 14   SLC4A4  ast
## 15    BBOX1  ast
## 16   BMPR1B  ast
## 17   ETNPPL  ast
## 18 ARHGEF26  ast
## 19     GJA1  ast
## 20   SLC1A2  ast
##  [1] "PPAP2B"   "MLC1"     "SLC4A4"   "BMPR1B"   "ETNPPL"   "GJA1"
##  [7] "SLC1A2"   "GPAM"     "AQP4"     "FGFR3"    "AGT"      "SLC25A18"
## [13] "ATP13A4"  "CLDN10"   "SOX9"     "GJB6"     "PPP1R3C"  "NTSR2"
## [19] "ACSBG1"   "SLC39A12" "LIX1"     "SLC7A10"  "GLI3"     "ALDH1L1"
## [25] "ATP1B2"   "F3"       "ID4"      "ELOVL2"   "SFXN5"    "RGS20"
## [31] "NCAN"     "SLC14A1"  "DIO2"     "TTPA"     "ACOT11"   "NWD1"
## [37] "PAX6"     "PDGFRA"   "GRIN2C"   "SCARA3"   "KIAA1161" "CHRDL1"
## [43] "CBS"      "EMID1"    "CLU"      "GFAP"     "GPSM2"    "RNF43"
## [49] "MXRA8"    "MECOM"
##  [1] "MOG"      "FA2H"     "CNP"      "ERBB3"    "GPR37"    "CNTN2"
##  [7] "MAG"      "ENPP2"    "UGT8"     "TMEM125"  "PLP1"     "TF"
## [13] "GJB1"     "ASPA"     "SLAIN1"   "KLK6"     "ANLN"     "MYRF"
## [19] "MAL"      "ERMN"     "SGK2"     "ST18"     "HHIP"     "OPALIN"
## [25] "CLDN11"   "NIPAL4"   "MOBP"     "SHC4"     "CRYAB"    "PPP1R14A"
## [31] "MAP6D1"   "SOX10"    "GAL3ST1"  "NINJ2"    "PRR18"    "TRIM59"
## [37] "GJC2"     "QDPR"     "ENPP6"    "SEPT4"    "HAPLN2"   "S1PR5"
## [43] "PLEKHH1"  "ZNF488"   "GPR62"    "SEC14L5"  "LPAR1"    "OLIG1"
## [49] "PRKCQ"    "CHST6"
```

```
##  [1] "AIF1"    "TYROBP"  "CD74"    "C1QB"    "LAPTM5"  "ALOX5AP" "CSF1R"
##  [8] "C1QA"    "HAVCR2"  "CX3CR1"  "SLC2A5"  "SELPLG"  "TREM2"   "GPR34"
## [15] "ITGAM"   "CD53"    "CD86"    "PTAFR"   "FCGR1A"  "C1QC"    "PTPRC"
## [22] "BLNK"    "CTSS"    "FCER1G"  "TLR1"    "NCKAP1L" "PTPN6"   "MPEG1"
## [29] "IL10RA"  "CD14"    "IRF8"    "CD300A"  "FCGR2A"  "TLR2"    "PLEK"
## [36] "C3AR1"   "SLA"     "DOCK2"   "GPR183"  "CNTN2"   "CNP"     "MAG"
## [43] "CCL3"    "NINJ2"   "MAL"     "CLDN11"  "QDPR"    "CSF3R"   "KLK6"
## [50] "TF"
##  [1] "SNAP25"   "CNR1"     "GABRA1"   "GABRG2"   "SV2B"     "SLC12A5"
##  [7] "RAB3C"    "GAD1"     "CNTNAP2"  "GAD2"     "SYT1"     "PRMT8"
## [13] "KCNQ5"    "GRIN2A"   "ZMAT4"    "SYT4"     "GRIA1"    "INA"
## [19] "BCL11A"   "SLC17A6"  "CELF4"    "KIAA1324" "RGS8"     "ROBO2"
##          PPAP2B       MLC1     SLC4A4     BMPR1B    ETNPPL       GJA1    SLC1A2
## [1,] -0.5025541 -0.7477438 0.09048259 -0.4063123 -0.326647 -0.5208349 0.3356524
##           GPAM       AQP4      FGFR3        AGT   SLC25A18    ATP13A4    CLDN10
## [1,] 0.1590143 -0.7959551 -0.2870478 -0.7351957 -0.3024247 -0.3664846 0.3453167
##            SOX9      GJB6    PPP1R3C      NTSR2     ACSBG1   SLC39A12
## [1,] -0.5681646 0.5026505 -0.1792838 -0.4742672 -0.2080146 -0.1785399
##            LIX1   SLC7A10      GLI3     ALDH1L1     ATP1B2         F3
## [1,] -0.8404701 0.1101243 -0.420511 -0.07441655 -0.1779509 -0.1667923
##             ID4     ELOVL2     SFXN5      RGS20        NCAN    SLC14A1     DIO2
## [1,] -0.6953497 -0.1149166 0.1891457 -0.1528931 -0.05527618 -0.6875852 0.218628
##            TTPA     ACOT11       NWD1       PAX6    PDGFRA     GRIN2C
## [1,] -0.3925443 -0.1993598 -0.4308381 -0.5797566 -0.427459 -0.2055993
##          SCARA3  KIAA1161    CHRDL1        CBS      EMID1        CLU       GFAP
## [1,] -0.2339306 0.1721085 0.6085179 -0.2509234 -0.3614802 -0.5940632 -0.9998986
##         GPSM2     RNF43      MXRA8       MECOM
## [1,] -0.33791 0.2061761 -0.6480445 -0.09320791
##             MOG       FA2H        CNP      ERBB3      GPR37     CNTN2
## [1,] -0.9553868 -0.9374078 -0.9570886 -0.9470527 -0.9563399 -0.936811
##             MAG      ENPP2       UGT8    TMEM125     PLP1         TF       GJB1
## [1,] -0.9337397 -0.9917416 -0.9661407 -0.8633007 -0.99921 -0.9465401 -0.8960731
##            ASPA     SLAIN1       KLK6       ANLN       MYRF        MAL
## [1,] -0.9527922 -0.9339612 -0.9648252 -0.9343073 -0.9200252 -0.9465757
##            ERMN       SGK2       ST18       HHIP     OPALIN     CLDN11
## [1,] -0.9774926 -0.8833653 -0.9669427 -0.8792891 -0.7946807 -0.9485021
##          NIPAL4       MOBP       SHC4      CRYAB   PPP1R14A     MAP6D1
## [1,] -0.9355339 -0.9262692 -0.9307934 -0.7704165 -0.8341845 -0.9422173
##          SOX10    GAL3ST1      NINJ2      PRR18     TRIM59       GJC2
## [1,] -0.889713 -0.8625225 -0.9005809 -0.9079648 -0.9344645 -0.8996056
##            QDPR      ENPP6      SEPT4     HAPLN2      S1PR5    PLEKHH1
## [1,] -0.8591096 -0.8742807 -0.9309558 -0.8274583 -0.9459345 -0.9366046
##          ZNF488      GPR62    SEC14L5      LPAR1      OLIG1      PRKCQ
## [1,] -0.5983907 -0.9024721 -0.8754486 -0.9132296 -0.8161764 -0.8763089
##          CHST6
## [1,] -0.684862
##            AIF1     TYROBP       CD74       C1QB     LAPTM5    ALOX5AP
## [1,] -0.3667772 -0.4549482 -0.4369198 -0.2800804 -0.4879601 -0.4901835
##          CSF1R       C1QA    HAVCR2     CX3CR1     SLC2A5     SELPLG
## [1,] -0.3691395 -0.1929456 -0.644708 -0.3615215 -0.3424207 -0.4273749
##           TREM2      GPR34      ITGAM       CD53       CD86      PTAFR
## [1,] -0.5285649 -0.3000078 -0.4559793 -0.2683018 -0.4235582 -0.5261217
##          FCGR1A       C1QC      PTPRC       BLNK       CTSS     FCER1G
## [1,] -0.2301161 -0.3175702 -0.4665704 -0.3460233 -0.4004204 -0.3696705
```

```
##            TLR1    NCKAP1L      PTPN6      MPEG1     IL10RA       CD14
## [1,] -0.3978289 -0.4454142 -0.4332804 -0.2814146 -0.3509839 -0.1336975
##            IRF8     CD300A     FCGR2A       TLR2       PLEK      C3AR1
## [1,] -0.3603299 -0.3983796 -0.3730523 -0.331365 -0.3125135 -0.3919277
##             SLA      DOCK2     GPR183      CNTN2        CNP        MAG
## [1,] -0.1708626 -0.5143557 -0.3278701 -0.9397309 -0.9768923 -0.9562714
##             CCL3      NINJ2        MAL    CLDN11       QDPR      CSF3R
## [1,] 0.0009828922 -0.9443308 -0.9428705 -0.927282 -0.8680864 -0.5755449
##            KLK6         TF
## [1,] -0.9416907 -0.9922734
##          SNAP25       CNR1     GABRA1    GABRG2       SV2B    SLC12A5
## [1,] -0.9994439 -0.4711826 -0.8826786 -0.929699 -0.9306014 -0.8922213
##           RAB3C       GAD1    CNTNAP2       GAD2       SYT1      PRMT8
## [1,] -0.8324769 -0.8455382 -0.9100061 -0.8047595 -0.9539956 -0.7734852
##           KCNQ5     GRIN2A      ZMAT4       SYT4      GRIA1        INA
## [1,] -0.9077714 -0.9091246 -0.8637406 -0.9389565 -0.1366514 -0.8630253
##          BCL11A    SLC17A6      CELF4   KIAA1324       RGS8      ROBO2
## [1,] -0.7639501 -0.7188173 -0.8249301 -0.6574843 -0.2404888 -0.8230147
```

```
cell_types_compare = colnames(ct_res_kelley)
for(i in 1:length(cell_types_compare)){
  cor_res = cor.test(ct_res_mckenzie[ , cell_types_compare[i]], ct_res_kelley[ , cell_types_compare[i]]
df_compare_cor = data.frame(Cell = cell_types_compare[i], Rho = cor_res$estimate, PVal = cor_res$p.valu
  if(i ==1) df_compare_cor_tot = df_compare_cor
  if(i > 1) df_compare_cor_tot = rbind(df_compare_cor_tot, df_compare_cor)}
kable(df_compare_cor_tot)
```

	Cell	Rho	PVal
rho	ast	0.9999982	0
rho1	oli	0.9256712	0
rho2	mic	0.4774784	0
rho3	neu	0.9927047	0

This alternative data set also offers marker genes derived from several specific brain regions:

```
##  [1] "CTX" "AMY" "BF"  "CB"  "CLA" "DI"  "FCX" "GP"  "HIP" "IN"  "LIM" "MED"
## [13] "MID" "OCX" "PCX" "PON" "SC"  "STR" "TCX" "WM"
```

6 Using your own cell type marker genes

If you have access to your own marker genes, you can use the *findCells* function instead. This has the same functionality otherwise; *brainCells* is simply a wrapper function for users who want to use the brain cell type marker genes that are provided by **BRETIGEA**. Note the format of the *markers* data frame: you must have one column with the gene symbol, named *markers*, and one column with the corresponding cell type, named *cell*.

```
str(markers_df_brain)
```

```
## 'data.frame':    6000 obs. of  2 variables:
##  $ markers: chr  "AQP4" "ALDH1L1" "BMPR1B" "SLC14A1" ...
##  $ cell   : chr  "ast" "ast" "ast" "ast" ...
```

```
ct_res = findCells(aba_marker_expression, markers = markers_df_brain, nMarker = 50)
```

```
##  [1] "AQP4"     "ALDH1L1"  "BMPR1B"   "SLC14A1"  "MLC1"     "FGFR3"
##  [7] "SLC25A18" "GLI3"     "GFAP"     "ACSBG1"   "SLC4A4"   "GJA1"
## [13] "GJB6"     "SLC39A12" "AGT"      "CHRDL1"   "SLC1A2"   "CLDN10"
## [19] "SOX9"     "PPP1R3C"  "CLU"      "SLC7A10"  "ID4"      "DIO2"
## [25] "SFXN5"    "SLC6A11"  "ATP13A4"  "ACOT11"   "SCARA3"   "ALDOC"
## [31] "PLCD4"    "ATP1B2"   "NTSR2"    "RGS20"    "ELOVL2"   "PAX6"
## [37] "ENTPD2"   "NCAN"     "KIAA1161" "ETNPPL"   "PPAP2B"   "LGR6"
## [43] "GPAM"     "NWD1"     "F3"       "TTPA"     "CBS"      "LIX1"
## [49] "GRIN2C"   "PHKG1"
##  [1] "APOLD1"  "EMCN"    "SDPR"    "PTPRB"   "CDH5"    "SLC38A5" "TM4SF1"
##  [8] "NOSTRIN" "CYYR1"   "MECOM"   "MYCT1"   "CLDN5"   "ERG"     "ABCB1"
## [15] "ICAM2"   "FN1"     "ESAM"    "ATP10A"  "VWF"     "CD34"    "PODXL"
## [22] "SLC19A3" "FLT1"    "TBX3"    "HMCN1"   "ITM2A"   "TEK"     "ITGA1"
## [29] "TIE1"    "ADCY4"   "CLIC5"   "ANXA1"   "OCLN"    "PALMD"   "SEMA3G"
## [36] "ABCG2"   "ROBO4"   "SLC16A4" "SLC52A3" "SOX7"    "SHE"     "CA4"
## [43] "EBF1"    "CD93"    "KDR"     "SLC2A1"  "PTRF"    "LEF1"    "HIGD1B"
## [50] "FOXF2"
##  [1] "CCL3"    "CCL4"    "CD14"    "C1QB"    "IL1A"    "TREM2"   "GPR183"
##  [8] "CD83"    "SLC2A5"  "C1QC"    "NCKAP1L" "CSF1R"   "CD300A"  "FCGR2A"
## [15] "LAPTM5"  "HAVCR2"  "C3AR1"   "CX3CR1"  "PTAFR"   "C1QA"    "FCGR1A"
## [22] "SELPLG"  "PLEK"    "CTSS"    "CSF3R"   "TYROBP"  "SLA"     "PTPN6"
## [29] "TLR2"    "CD86"    "GPR84"   "LYZ"     "MPEG1"   "BCL2A1"  "ITGAM"
## [36] "CD53"    "IRF8"    "IL10RA"  "GPR34"   "AIF1"    "CD74"    "PTPRC"
## [43] "RHOH"    "BLNK"    "TLR1"    "C5AR1"   "FCER1G"  "DOCK2"   "RGS1"
## [50] "ALOX5AP"
##  [1] "RELN"     "VIP"      "GAD2"     "TAC3"     "DLX1"     "PENK"
##  [7] "SYT1"     "TMEM130"  "GAD1"     "SYNPR"    "STMN2"    "GABRG2"
## [13] "GPR83"    "SST"      "ZMAT4"    "SNAP25"   "RAB3C"    "NELL1"
## [19] "SCG2"     "SYT4"     "CNR1"     "CLSTN2"   "SPHKAP"   "KCNQ5"
## [25] "PNOC"     "ROBO2"    "KCNC2"    "GALNTL6"  "VSNL1"    "GRIN2A"
## [31] "GABRA1"   "CHGB"     "SRRM4"    "ZNF804A"  "KIAA1324" "BCL11A"
## [37] "SV2B"     "HTR3A"    "NPY"      "PRMT8"    "CNTNAP2"  "GLRA2"
## [43] "SLC12A5"  "SLC17A6"  "CRH"      "GRIA1"    "GDA"      "INA"
## [49] "RGS8"     "CELF4"
##  [1] "PLP1"     "CLDN11"   "ERMN"     "UGT8"     "MOG"      "MOBP"
##  [7] "MAG"      "MBP"      "OPALIN"   "GJB1"     "MYRF"     "KLK6"
## [13] "FA2H"     "CNP"      "ENPP6"    "LPAR1"    "ERBB3"    "TMEM125"
## [19] "ANLN"     "ASPA"     "QDPR"     "S1PR5"    "ENPP2"    "NIPAL4"
## [25] "MAL"      "BCAS1"    "CRYAB"    "LGI3"     "SGK2"     "GPR37"
## [31] "HHIP"     "SLAIN1"   "TMEM88B"  "CNTN2"    "NINJ2"    "ST18"
## [37] "MAP6D1"   "PLEKHH1"  "PRR18"    "TF"       "TRIM59"   "PEX5L"
## [43] "HAPLN2"   "GJC2"     "GJC3"     "SEPT4"    "PPP1R14A" "GPR62"
## [49] "SEC14L5"  "GAL3ST1"
##  [1] "PDGFRA"   "SHC4"     "MATN4"    "TNR"      "PNLIP"    "PCDH15"
##  [7] "FAM180A"  "NEU4"     "LHFPL3"   "CHST6"    "MEGF11"   "OLIG1"
## [13] "GPR17"    "RNF43"    "RBPJL"    "UGT8"     "PMEL"     "SOX10"
## [19] "GAL3ST1"  "SULF2"    "CCNB1"    "MYT1"     "ACAN"     "XYLT1"
## [25] "CSPG4"    "C1QL1"    "CKAP2"    "GJC3"     "TOP2A"    "PRKG2"
## [31] "BCAS1"    "SAPCD2"   "ZNF488"   "LRRN1"    "TMEM255B" "S100A3"
## [37] "PBK"      "SUSD5"    "STK32A"   "SULF1"    "PRKCQ"    "DPYD"
## [43] "GPSM2"    "LAD1"     "UGDH"     "CKAP2L"   "GJB1"     "EMID1"
## [49] "TGFA"     "ADAM12"
```

```
##            AQP4     ALDH1L1     BMPR1B    SLC14A1       MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##       SLC25A18       GLI3       GFAP     ACSBG1     SLC4A4       GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##        SLC39A12        AGT    CHRDL1    SLC1A2    CLDN10       SOX9    PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##             CLU  SLC7A10        ID4      DIO2     SFXN5   SLC6A11    ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11     SCARA3     ALDOC     PLCD4     ATP1B2      NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2       PAX6     ENTPD2        NCAN  KIAA1161     ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B       LGR6     GPAM      NWD1         F3       TTPA        CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##            LIX1     GRIN2C      PHKG1
## [1,] -0.8404202 -0.2054718 -0.7618352
##          APOLD1       EMCN       SDPR      PTPRB       CDH5    SLC38A5
## [1,] -0.6397974 -0.5150059 -0.5503207 -0.4286219 -0.7509274 -0.2792929
##          TM4SF1    NOSTRIN      CYYR1      MECOM      MYCT1      CLDN5
## [1,] -0.5732277 -0.5492278 -0.5233367 -0.6553751 -0.4798552 -0.6769395
##             ERG      ABCB1      ICAM2        FN1       ESAM    ATP10A
## [1,] -0.5483382 -0.5187547 -0.6892712 -0.6866703 -0.5985029 -0.386112
##             VWF       CD34      PODXL    SLC19A3      FLT1       TBX3
## [1,] -0.6532856 -0.4892499 -0.6865958 -0.3100597 -0.682325 -0.4185505
##           HMCN1     ITM2A        TEK      ITGA1       TIE1      ADCY4
## [1,] -0.4729641 -0.404837 -0.4247323 -0.6994108 -0.4460777 -0.5100022
##           CLIC5      ANXA1       OCLN      PALMD     SEMA3G      ABCG2
## [1,] -0.2212121 -0.4021003 -0.1725926 -0.4391917 -0.5039709 -0.4910518
##           ROBO4    SLC16A4    SLC52A3       SOX7        SHE       CA4
## [1,] -0.4063845 -0.2065062 -0.4868766 -0.3217972 -0.6208689 0.1057804
##            EBF1       CD93        KDR     SLC2A1       PTRF       LEF1
## [1,] -0.4929378 -0.4586119 -0.4572021 -0.6991769 -0.4608555 -0.1165776
##          HIGD1B      FOXF2
## [1,] -0.1667598 -0.1962837
##              CCL3       CCL4      CD14      C1QB      IL1A     TREM2    GPR183
## [1,] -0.009014479 0.02049567 0.6772439 0.9027497 0.147061 0.8121957 0.6689415
##            CD83   SLC2A5      C1QC  NCKAP1L     CSF1R    CD300A    FCGR2A
## [1,] -0.3230165 0.882668 0.9215579 0.924154 0.7685014 0.8795061 0.8366178
##         LAPTM5    HAVCR2     C3AR1    CX3CR1     PTAFR      C1QA    FCGR1A
## [1,] 0.9474317 0.8554602 0.8224433 0.3634809 0.7619302 0.8550013 0.6713506
##         SELPLG      PLEK      CTSS     CSF3R    TYROBP       SLA     PTPN6
## [1,] 0.5294624 0.6737376 0.8570066 0.7479062 0.9002925 0.8394877 0.8757021
##           TLR2      CD86     GPR84       LYZ     MPEG1    BCL2A1     ITGAM
## [1,] 0.8563525 0.8670868 0.3866831 0.5769851 0.3112844 0.5858728 0.8377073
##           CD53      IRF8    IL10RA     GPR34      AIF1      CD74     PTPRC
## [1,] 0.8110169 0.7524594 0.8152008 0.6202537 0.8964808 0.9569894 0.9488961
##           RHOH      BLNK      TLR1     C5AR1    FCER1G     DOCK2      RGS1
## [1,] 0.3987691 0.6580784 0.8748194 0.5982698 0.8581698 0.8865086 0.6465002
##         ALOX5AP
## [1,] 0.8643056
##            RELN       VIP      GAD2      TAC3      DLX1      PENK      SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##         TMEM130      GAD1     SYNPR    STMN2    GABRG2     GPR83       SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748
```

```
##          ZMAT4    SNAP25     RAB3C     NELL1     SCG2      SYT4      CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##         CLSTN2     SPHKAP     KCNQ5      PNOC     ROBO2     KCNC2   GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1    GRIN2A    GABRA1     CHGB     SRRM4   ZNF804A  KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##        BCL11A      SV2B     HTR3A        NPY   PRMT8   CNTNAP2     GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##        SLC12A5   SLC17A6       CRH      GRIA1       GDA       INA      RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##           PLP1     CLDN11       ERMN       UGT8        MOG       MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##             MAG        MBP     OPALIN       GJB1       MYRF       KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##           FA2H        CNP      ENPP6      LPAR1     ERBB3    TMEM125      ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##           ASPA       QDPR      S1PR5     ENPP2     NIPAL4        MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
##          BCAS1      CRYAB       LGI3       SGK2      GPR37       HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1    TMEM88B     CNTN2      NINJ2       ST18     MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##         PLEKHH1      PRR18         TF    TRIM59      PEX5L     HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##           GJC2      GJC3      SEPT4   PPP1R14A      GPR62    SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##         GAL3ST1
## [1,] -0.8845151
##          PDGFRA       SHC4        MATN4        TNR       PNLIP     PCDH15
## [1,] -0.6594077 -0.8876408 -0.009790091 -0.2148693 -0.04108205 -0.1075733
##         FAM180A       NEU4     LHFPL3      CHST6     MEGF11      OLIG1
## [1,] -0.2698467 -0.2856533 -0.5938882 -0.6238268 -0.1090868 -0.8296958
##           GPR17    RNF43     RBPJL       UGT8       PMEL      SOX10    GAL3ST1
## [1,] -0.5917444 0.435638 0.1101175 -0.8814859 0.05653651 -0.8517942 -0.8665949
##          SULF2     CCNB1       MYT1       ACAN     XYLT1      CSPG4     C1QL1
## [1,] 0.1274339 0.4931099 -0.6166283 -0.1083521 0.1532883 -0.7196438 -0.336823
##          CKAP2      GJC3     TOP2A     PRKG2      BCAS1     SAPCD2     ZNF488
## [1,] 0.6525218 0.1210485 0.0195238 0.4824663 -0.9974827 -0.6061126 -0.4965659
##         LRRN1    TMEM255B      S100A3        PBK     SUSD5     STK32A     SULF1
## [1,] 0.426307 -0.07905286 -0.09222221 0.01888503 0.3814492 -0.3316909 -0.291499
##           PRKCQ       DPYD      GPSM2        LAD1        UGDH      CKAP2L
## [1,] -0.8390872 -0.8863703 -0.9110727 -0.07256941 -0.06724674 -0.05768831
##          GJB1      EMID1       TGFA     ADAM12
## [1,] -0.83458 -0.1593035 -0.8341445 -0.4069115
```

```
kable(head(ct_res))
```

	ast	end	mic	neu	oli	opc
X488395315	-0.0409765	-0.0468875	-0.0249076	0.0226400	-0.0194737	-0.0287028
X496100277	0.0391782	0.0090563	-0.0012271	-0.1361360	0.1323645	0.1322346
X496100278	0.0742051	0.0864415	0.1158266	-0.1360790	0.1534334	0.1555192
X496100279	-0.0091306	-0.0055174	0.0103811	0.0680277	-0.0194953	-0.0216833

	ast	end	mic	neu	oli	opc
X496100281	0.1136897	-0.0070804	0.0825388	0.0116946	-0.0243035	-0.0278465
X496100283	-0.0440731	-0.0263346	-0.0356047	0.0449777	-0.0220543	-0.0188682

7 Adjusting bulk gene expression data for estimated cell type proportions

BRETIGEA also offers users the ability to adjust their original gene expression matrices for the estimated cell type proportion estimates, in order to deconvolute the signal.

```
brain_cells_adjusted = adjustBrainCells(aba_marker_expression,
    nMarker = 50, species = "combined")
```

```
##     markers cell
## 1      AQP4  ast
## 2   ALDH1L1  ast
## 3    BMPR1B  ast
## 4   SLC14A1  ast
## 5      MLC1  ast
## 6     FGFR3  ast
## 7  SLC25A18  ast
## 8      GLI3  ast
## 9      GFAP  ast
## 10   ACSBG1  ast
## 11   SLC4A4  ast
## 12     GJA1  ast
## 13     GJB6  ast
## 14 SLC39A12  ast
## 15      AGT  ast
## 16   CHRDL1  ast
## 17   SLC1A2  ast
## 18   CLDN10  ast
## 19     SOX9  ast
## 20  PPP1R3C  ast
##  [1] "AQP4"     "ALDH1L1"  "BMPR1B"   "SLC14A1"  "MLC1"     "FGFR3"
##  [7] "SLC25A18" "GLI3"     "GFAP"     "ACSBG1"   "SLC4A4"   "GJA1"
## [13] "GJB6"     "SLC39A12" "AGT"      "CHRDL1"   "SLC1A2"   "CLDN10"
## [19] "SOX9"     "PPP1R3C"  "CLU"      "SLC7A10"  "ID4"      "DIO2"
## [25] "SFXN5"    "SLC6A11"  "ATP13A4"  "ACOT11"   "SCARA3"   "ALDOC"
## [31] "PLCD4"    "ATP1B2"   "NTSR2"    "RGS20"    "ELOVL2"   "PAX6"
## [37] "ENTPD2"   "NCAN"     "KIAA1161" "ETNPPL"   "PPAP2B"   "LGR6"
## [43] "GPAM"     "NWD1"     "F3"       "TTPA"     "CBS"      "LIX1"
## [49] "GRIN2C"   "PHKG1"
##  [1] "APOLD1"  "EMCN"    "SDPR"    "PTPRB"   "CDH5"    "SLC38A5" "TM4SF1"
##  [8] "NOSTRIN" "CYYR1"   "MECOM"   "MYCT1"   "CLDN5"   "ERG"     "ABCB1"
## [15] "ICAM2"   "FN1"     "ESAM"    "ATP10A"  "VWF"     "CD34"    "PODXL"
## [22] "SLC19A3" "FLT1"    "TBX3"    "HMCN1"   "ITM2A"   "TEK"     "ITGA1"
## [29] "TIE1"    "ADCY4"   "CLIC5"   "ANXA1"   "OCLN"    "PALMD"   "SEMA3G"
## [36] "ABCG2"   "ROBO4"   "SLC16A4" "SLC52A3" "SOX7"    "SHE"     "CA4"
## [43] "EBF1"    "CD93"    "KDR"     "SLC2A1"  "PTRF"    "LEF1"    "HIGD1B"
## [50] "FOXF2"
##  [1] "CCL3"    "CCL4"    "CD14"    "C1QB"    "IL1A"    "TREM2"   "GPR183"
```

```
##  [8] "CD83"    "SLC2A5"  "C1QC"    "NCKAP1L" "CSF1R"   "CD300A"  "FCGR2A"
## [15] "LAPTM5"  "HAVCR2"  "C3AR1"   "CX3CR1"  "PTAFR"   "C1QA"    "FCGR1A"
## [22] "SELPLG"  "PLEK"    "CTSS"    "CSF3R"   "TYROBP"  "SLA"     "PTPN6"
## [29] "TLR2"    "CD86"    "GPR84"   "LYZ"     "MPEG1"   "BCL2A1"  "ITGAM"
## [36] "CD53"    "IRF8"    "IL10RA"  "GPR34"   "AIF1"    "CD74"    "PTPRC"
## [43] "RHOH"    "BLNK"    "TLR1"    "C5AR1"   "FCER1G"  "DOCK2"   "RGS1"
## [50] "ALOX5AP"
##  [1] "RELN"     "VIP"      "GAD2"     "TAC3"     "DLX1"     "PENK"
##  [7] "SYT1"     "TMEM130"  "GAD1"     "SYNPR"    "STMN2"    "GABRG2"
## [13] "GPR83"    "SST"      "ZMAT4"    "SNAP25"   "RAB3C"    "NELL1"
## [19] "SCG2"     "SYT4"     "CNR1"     "CLSTN2"   "SPHKAP"   "KCNQ5"
## [25] "PNOC"     "ROBO2"    "KCNC2"    "GALNTL6"  "VSNL1"    "GRIN2A"
## [31] "GABRA1"   "CHGB"     "SRRM4"    "ZNF804A"  "KIAA1324" "BCL11A"
## [37] "SV2B"     "HTR3A"    "NPY"      "PRMT8"    "CNTNAP2"  "GLRA2"
## [43] "SLC12A5"  "SLC17A6"  "CRH"      "GRIA1"    "GDA"      "INA"
## [49] "RGS8"     "CELF4"
##  [1] "PLP1"     "CLDN11"   "ERMN"     "UGT8"     "MOG"      "MOBP"
##  [7] "MAG"      "MBP"      "OPALIN"   "GJB1"     "MYRF"     "KLK6"
## [13] "FA2H"     "CNP"      "ENPP6"    "LPAR1"    "ERBB3"    "TMEM125"
## [19] "ANLN"     "ASPA"     "QDPR"     "S1PR5"    "ENPP2"    "NIPAL4"
## [25] "MAL"      "BCAS1"    "CRYAB"    "LGI3"     "SGK2"     "GPR37"
## [31] "HHIP"     "SLAIN1"   "TMEM88B"  "CNTN2"    "NINJ2"    "ST18"
## [37] "MAP6D1"   "PLEKHH1"  "PRR18"    "TF"       "TRIM59"   "PEX5L"
## [43] "HAPLN2"   "GJC2"     "GJC3"     "SEPT4"    "PPP1R14A" "GPR62"
## [49] "SEC14L5"  "GAL3ST1"
##  [1] "PDGFRA"   "SHC4"     "MATN4"    "TNR"      "PNLIP"    "PCDH15"
##  [7] "FAM180A"  "NEU4"     "LHFPL3"   "CHST6"    "MEGF11"   "OLIG1"
## [13] "GPR17"    "RNF43"    "RBPJL"    "UGT8"     "PMEL"     "SOX10"
## [19] "GAL3ST1"  "SULF2"    "CCNB1"    "MYT1"     "ACAN"     "XYLT1"
## [25] "CSPG4"    "C1QL1"    "CKAP2"    "GJC3"     "TOP2A"    "PRKG2"
## [31] "BCAS1"    "SAPCD2"   "ZNF488"   "LRRN1"    "TMEM255B" "S100A3"
## [37] "PBK"      "SUSD5"    "STK32A"   "SULF1"    "PRKCQ"    "DPYD"
## [43] "GPSM2"    "LAD1"     "UGDH"     "CKAP2L"   "GJB1"     "EMID1"
## [49] "TGFA"     "ADAM12"
##            AQP4     ALDH1L1     BMPR1B    SLC14A1       MLC1      FGFR3
## [1,] -0.7958953 -0.07419527 -0.4061147 -0.6875915 -0.7476287 -0.2868527
##       SLC25A18       GLI3       GFAP     ACSBG1     SLC4A4       GJA1      GJB6
## [1,] -0.302239 -0.4204516 -0.9999001 -0.2077684 0.09074864 -0.5208035 0.5028409
##        SLC39A12        AGT    CHRDL1    SLC1A2    CLDN10       SOX9    PPP1R3C
## [1,] -0.1784168 -0.7350907 0.6087144 0.3359356 0.3455259 -0.5681326 -0.1791119
##             CLU  SLC7A10        ID4      DIO2     SFXN5   SLC6A11    ATP13A4
## [1,] -0.5938866 0.110352 -0.6952727 0.2188643 0.1894126 0.5592311 -0.3663146
##          ACOT11     SCARA3     ALDOC     PLCD4     ATP1B2      NTSR2      RGS20
## [1,] -0.1992575 -0.2338075 0.1107247 0.5112359 -0.1778165 -0.4740656 -0.1526715
##          ELOVL2       PAX6     ENTPD2        NCAN  KIAA1161     ETNPPL
## [1,] -0.1147339 -0.5797094 -0.7823284 -0.05518203 0.1721708 -0.3264465
##          PPAP2B       LGR6     GPAM      NWD1         F3       TTPA        CBS
## [1,] -0.5024131 -0.0444335 0.159156 -0.430843 -0.1665845 -0.3924951 -0.2509145
##            LIX1     GRIN2C      PHKG1
## [1,] -0.8404202 -0.2054718 -0.7618352
##          APOLD1       EMCN       SDPR      PTPRB       CDH5    SLC38A5
## [1,] -0.6397974 -0.5150059 -0.5503207 -0.4286219 -0.7509274 -0.2792929
##          TM4SF1    NOSTRIN      CYYR1      MECOM      MYCT1      CLDN5
## [1,] -0.5732277 -0.5492278 -0.5233367 -0.6553751 -0.4798552 -0.6769395
```

```
##             ERG      ABCB1      ICAM2        FN1       ESAM    ATP10A
## [1,] -0.5483382 -0.5187547 -0.6892712 -0.6866703 -0.5985029 -0.386112
##             VWF       CD34      PODXL    SLC19A3      FLT1       TBX3
## [1,] -0.6532856 -0.4892499 -0.6865958 -0.3100597 -0.682325 -0.4185505
##           HMCN1     ITM2A        TEK      ITGA1       TIE1      ADCY4
## [1,] -0.4729641 -0.404837 -0.4247323 -0.6994108 -0.4460777 -0.5100022
##           CLIC5      ANXA1       OCLN      PALMD     SEMA3G      ABCG2
## [1,] -0.2212121 -0.4021003 -0.1725926 -0.4391917 -0.5039709 -0.4910518
##           ROBO4    SLC16A4    SLC52A3       SOX7        SHE       CA4
## [1,] -0.4063845 -0.2065062 -0.4868766 -0.3217972 -0.6208689 0.1057804
##            EBF1       CD93        KDR     SLC2A1       PTRF       LEF1
## [1,] -0.4929378 -0.4586119 -0.4572021 -0.6991769 -0.4608555 -0.1165776
##          HIGD1B      FOXF2
## [1,] -0.1667598 -0.1962837
##              CCL3       CCL4      CD14      C1QB     IL1A     TREM2    GPR183
## [1,] -0.009014479 0.02049567 0.6772439 0.9027497 0.147061 0.8121957 0.6689415
##            CD83   SLC2A5      C1QC  NCKAP1L     CSF1R    CD300A    FCGR2A
## [1,] -0.3230165 0.882668 0.9215579 0.924154 0.7685014 0.8795061 0.8366178
##         LAPTM5    HAVCR2     C3AR1    CX3CR1     PTAFR      C1QA    FCGR1A
## [1,] 0.9474317 0.8554602 0.8224433 0.3634809 0.7619302 0.8550013 0.6713506
##         SELPLG      PLEK      CTSS     CSF3R    TYROBP       SLA     PTPN6
## [1,] 0.5294624 0.6737376 0.8570066 0.7479062 0.9002925 0.8394877 0.8757021
##           TLR2      CD86     GPR84       LYZ     MPEG1    BCL2A1     ITGAM
## [1,] 0.8563525 0.8670868 0.3866831 0.5769851 0.3112844 0.5858728 0.8377073
##           CD53      IRF8    IL10RA     GPR34      AIF1      CD74     PTPRC
## [1,] 0.8110169 0.7524594 0.8152008 0.6202537 0.8964808 0.9569894 0.9488961
##           RHOH      BLNK      TLR1     C5AR1    FCER1G     DOCK2      RGS1
## [1,] 0.3987691 0.6580784 0.8748194 0.5982698 0.8581698 0.8865086 0.6465002
##         ALOX5AP
## [1,] 0.8643056
##            RELN       VIP      GAD2      TAC3      DLX1      PENK      SYT1
## [1,] -0.1166803 0.6135118 0.8276635 0.7295642 0.7836934 0.4386146 0.9587805
##         TMEM130      GAD1     SYNPR    STMN2    GABRG2     GPR83       SST
## [1,] 0.6442915 0.8571033 0.5407849 0.954468 0.9428849 0.4040754 0.1924748
##          ZMAT4    SNAP25     RAB3C     NELL1     SCG2      SYT4      CNR1
## [1,] 0.8855612 0.9937954 0.7968844 0.8839205 0.579349 0.9400202 0.4062468
##         CLSTN2     SPHKAP     KCNQ5      PNOC     ROBO2     KCNC2   GALNTL6
## [1,] 0.3223093 -0.1236097 0.9203101 0.4488496 0.8036322 0.8932601 0.7152115
##          VSNL1    GRIN2A    GABRA1     CHGB     SRRM4   ZNF804A  KIAA1324
## [1,] 0.8592326 0.8891878 0.9103732 0.141477 0.8110747 0.3509051 0.6024863
##         BCL11A      SV2B     HTR3A       NPY    PRMT8   CNTNAP2     GLRA2
## [1,] 0.742308 0.9386318 0.1299354 -0.2984589 0.80817 0.9295066 0.6637972
##         SLC12A5   SLC17A6       CRH      GRIA1       GDA       INA      RGS8
## [1,] 0.9034275 0.7684521 0.4350317 0.05161995 0.7713854 0.8972024 0.1695003
##          CELF4
## [1,] 0.8067627
##            PLP1     CLDN11       ERMN       UGT8        MOG       MOBP
## [1,] -0.9305459 -0.8798909 -0.9359872 -0.8949407 -0.9124765 -0.9624925
##             MAG        MBP     OPALIN       GJB1       MYRF       KLK6
## [1,] -0.9200603 -0.9924521 -0.7476423 -0.8302352 -0.9282941 -0.9099573
##            FA2H        CNP      ENPP6      LPAR1     ERBB3    TMEM125      ANLN
## [1,] -0.9222307 -0.9139697 -0.8174142 -0.9629297 -0.920759 -0.8009576 -0.884949
##            ASPA       QDPR      S1PR5     ENPP2     NIPAL4        MAL
## [1,] -0.9246854 -0.8106579 -0.9338734 -0.931507 -0.8928996 -0.9135844
```

```
##           BCAS1      CRYAB       LGI3       SGK2      GPR37       HHIP
## [1,] -0.9744962 -0.7663222 -0.5304539 -0.8293518 -0.8947933 -0.8194185
##          SLAIN1    TMEM88B     CNTN2      NINJ2       ST18     MAP6D1
## [1,] -0.8955728 -0.6271867 -0.932188 -0.8435802 -0.9443919 -0.8858248
##         PLEKHH1      PRR18         TF    TRIM59      PEX5L     HAPLN2
## [1,] -0.9312008 -0.8960713 -0.9043357 -0.875323 -0.7511829 -0.8260379
##           GJC2      GJC3      SEPT4   PPP1R14A      GPR62    SEC14L5
## [1,] -0.8721555 0.1293849 -0.9596247 -0.8221449 -0.8587124 -0.8569685
##         GAL3ST1
## [1,] -0.8845151
##          PDGFRA       SHC4        MATN4        TNR       PNLIP     PCDH15
## [1,] -0.6594077 -0.8876408 -0.009790091 -0.2148693 -0.04108205 -0.1075733
##         FAM180A       NEU4     LHFPL3      CHST6     MEGF11      OLIG1
## [1,] -0.2698467 -0.2856533 -0.5938882 -0.6238268 -0.1090868 -0.8296958
##           GPR17    RNF43     RBPJL       UGT8       PMEL      SOX10    GAL3ST1
## [1,] -0.5917444 0.435638 0.1101175 -0.8814859 0.05653651 -0.8517942 -0.8665949
##          SULF2     CCNB1       MYT1       ACAN     XYLT1      CSPG4     C1QL1
## [1,] 0.1274339 0.4931099 -0.6166283 -0.1083521 0.1532883 -0.7196438 -0.336823
##          CKAP2      GJC3     TOP2A     PRKG2      BCAS1     SAPCD2     ZNF488
## [1,] 0.6525218 0.1210485 0.0195238 0.4824663 -0.9974827 -0.6061126 -0.4965659
##         LRRN1    TMEM255B      S100A3        PBK     SUSD5     STK32A     SULF1
## [1,] 0.426307 -0.07905286 -0.09222221 0.01888503 0.3814492 -0.3316909 -0.291499
##           PRKCQ       DPYD      GPSM2        LAD1        UGDH      CKAP2L
## [1,] -0.8390872 -0.8863703 -0.9110727 -0.07256941 -0.06724674 -0.05768831
##          GJB1      EMID1       TGFA     ADAM12
## [1,] -0.83458 -0.1593035 -0.8341445 -0.4069115
```

```
expression_data_adj = brain_cells_adjusted$expression
```

Note that *adjustBrainCells* is a wrapper function to *adjustCells* and if you have your own markers (e.g., for a non-brain data set), then you can use that interface instead for deconvolution of more general cell types.

As you can see, following adjustment, there is no longer a correlation between the RNA expression of the microglia marker gene AIF1 and its encoded protein IHC quantification (IBA1), nor between the RNA and protein expression of the astrocyte marker gene GFAP. (Note there *is* a non-significant trend towards a residual correlation here, which may be because GFAP is not a perfect marker of astrocyte proportion in this data set, but instead varies across samples based on disease state, region, and other factors).

```
cor.test(as.numeric(aba_marker_expression["AIF1", ]),
  as.numeric(aba_pheno_data$ihc_iba1_ffpe), method = "spearman")
```

```
##
##  Spearman's rank correlation rho
##
## data:  as.numeric(aba_marker_expression["AIF1", ]) and as.numeric(aba_pheno_data$ihc_iba1_ffpe)
## S = 5566784, p-value = 5.348e-09
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.3017048
```

```
cor.test(expression_data_adj["AIF1", ], as.numeric(aba_pheno_data$ihc_iba1_ffpe),
  method = "spearman")
```

```
##
##  Spearman's rank correlation rho
##
```

```
## data:  expression_data_adj["AIF1", ] and as.numeric(aba_pheno_data$ihc_iba1_ffpe)
## S = 7975568, p-value = 0.9931
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##           rho
## -0.0004520843
```

```
cor.test(as.numeric(aba_marker_expression["GFAP", ]), as.numeric(aba_pheno_data$ihc_gfap_ffpe),
  method = "spearman")
```

```
##
##  Spearman's rank correlation rho
##
## data:  as.numeric(aba_marker_expression["GFAP", ]) and as.numeric(aba_pheno_data$ihc_gfap_ffpe)
## S = 3582778, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##      rho
## 0.476499
```

```
cor.test(expression_data_adj["GFAP", ], as.numeric(aba_pheno_data$ihc_gfap_ffpe),
  method = "spearman")
```

```
##
##  Spearman's rank correlation rho
##
## data:  expression_data_adj["GFAP", ] and as.numeric(aba_pheno_data$ihc_gfap_ffpe)
## S = 6458042, p-value = 0.2962
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##        rho
## 0.05637708
```

8 Help and other resources

If you have any problems with or questions about using this package, please open an issue on Github or contact the package maintainer.

References

"Allen Institute for Cell Science. Aging, Dementia and TBI." n.d. http://aging.brain-map.org/.