R & OMICS

8/16/2022

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1 About this Resourse

This is a Quarto book to impress Jonathan.

This web resource covers basic R operations on gene expression tables such as data reading/writing, exploring wrangling and plotting. It is largely based on R *tidyverse* package and can be useful for Next Generation Sequencing functional data analysis.

The resource was created and is being maintained by Jordan RAMILOWSKI Associate Professor at the Bioinformatics Laboratory at Yokohama City University.

2 Required Data

- Download the data directory from Dropbox (link to come)

- setwd()

- Install and load all required R packages

```
setwd('/Users/jordan/R_in_OMICS/input') # example
library(data.table)
```

3 Reading and Writing files in *R*

3.1 data.table::fread

Simple and efficient way of reading R files:

```r
library(data.table)
data = fread(file = 'connectome_1in.tsv')
data = fread(file = 'connectome_1in.tsv', nThread = 4)  # can use many processors 'nThread
```

'fread' vs 'read.delim'(base) speed

```r
# 'fread':
t0 = Sys.time()
data = fread(file = 'connectome_1in.tsv')
t1 = Sys.time()-t0

# 'read.delim':
t0 = Sys.time()
data = read.delim2(file = 'connectome_1in.tsv')
t2 = Sys.time()-t0
```

```
[1] "fread: Time difference of 0.18643 secs"
```

```
[1] "read.delim: Time difference of 4.577949 secs"
```

3.2 data.table::fwrite

Simple and efficient way of writing R files:

```r
fwrite(data, file = 'connectome_1out.csv')                # csv file (default)
fwrite(data, file = 'connectome_1out.tsv', sep = '\t') # tab-delim file (own specification
```

4 Exploring data in R

```r
library(data.table)
```

Read in and look at first 10 columns of **connectome** data set:

```r
connectome_1=fread(file='connectome_1in.tsv', select = 1:10) # first 10 columns
```

```r
dim(connectome_1) # number of rows / columns
```

```
[1] 17263     10
```

```r
colnames(connectome_1) # names of data
```

```
 [1] "ApprovedSymbol"        "Localization"          "Taxon"
 [4] "F5_min"                "F5_med"                "F5_max"
 [7] "Adipocyte Breast"      "Adipocyte Omental"     "Adipocyte Perirenal"
[10] "Adipocyte Subcutaneous"
```

Closer look using specific R packages/functions:

4.1 using 'str'

```r
str(connectome_1)
```

```
Classes 'data.table' and 'data.frame':  17263 obs. of  10 variables:
 $ ApprovedSymbol      : chr  "A1BG" "A1CF" "A2M" "A2ML1" ...
 $ Localization        : chr  "secreted" "multiple" "multiple" "secreted" ...
 $ Taxon               : chr  "Eutheria" "Deuterostomia" "Euteleostomi" "Euteleostomi" ...
 $ F5_min              : num  0.264 0 0 0 0 ...
```

```
$ F5_med              : num  16.94 0 1.21 0 9.72 ...
$ F5_max              : num  2378 153 1515 206 80 ...
$ Adipocyte Breast    : num  36.8 0 90.3 0 24.4 ...
$ Adipocyte Omental   : num  35.2 0 121.4 0 10.8 ...
$ Adipocyte Perirenal : num  49.7 0 50.6 0 17.4 ...
$ Adipocyte Subcutaneous: num  41.1 0 63.4 0 27.7 ...
- attr(*, ".internal.selfref")=<externalptr>
```

4.2 using 'skimr::skim'

```
library(skimr)
skimr::skim(connectome_1)
```

Table 4.1: Data summary

Name	connectome_1
Number of rows	17263
Number of columns	10
Key	NULL
Column type frequency:	
character	3
numeric	7
Group variables	None

Variable type: character

skim_variable	n_missing	complete_rate	min	max	empty	n_unique	whitespace
ApprovedSymbol	0	1	1	10	0	17263	0
Localization	0	1	3	15	0	7	0
Taxon	0	1	0	16	614	17	0

Variable type: numeric

skim_variable	n_missing	complete_rate	mean	sd	p0	p25	p50	p75	p100	hist
F5_min	0	1	3.88	17.74	0	0.00	0.00	2.55	1451.39	
F5_med	0	1	32.14	154.02	0	0.03	5.94	22.71	6876.78	

skim_variable	n_missing	complete_rate	mean	sd	p0	p25	p50	p75	p100	hist
F5_max	0	1	476.92	4237.26	0	23.85	75.89	211.27	309580.87	
Adipocyte Breast	0	1	47.49	304.12	0	0.11	6.73	26.99	12064.67	
Adipocyte Omental	0	1	51.19	479.86	0	0.05	6.70	26.77	48575.26	
Adipocyte Perirenal	0	1	54.70	661.88	0	0.00	6.11	25.30	75911.77	
Adipocyte Subcutaneous	0	1	46.69	259.45	0	0.09	5.78	25.00	10252.56	

5 Basic dplyr operations on data columns

```
-- Attaching packages ------------------------------------- tidyverse 1.3.2 --
v ggplot2 3.3.6      v purrr   0.3.4
v tibble  3.1.8      v dplyr   1.0.9
v tidyr   1.2.0      v stringr 1.4.0
v readr   2.1.2      v forcats 0.5.1
-- Conflicts ------------------------------------- tidyverse_conflicts() --
x dplyr::between()   masks data.table::between()
x dplyr::filter()    masks stats::filter()
x dplyr::first()     masks data.table::first()
x dplyr::lag()       masks stats::lag()
x dplyr::last()      masks data.table::last()
x purrr::transpose() masks data.table::transpose()
```

```
        : 'magrittr'


    'package:purrr'         :

  set_names


    'package:tidyr'         :

  extract
```

```
  # the entire data has 17,263 rows and 150 columns
  data = fread(file = 'connectome_1in.tsv')
  dim(data)
```

```
[1] 17263    150
```

```
  # skim(data) #you can comment this out an run
```

5.1 'dplyr::select

```
# Simple
data %>% dplyr::select(ApprovedSymbol, F5_min, F5_med, F5_max) # selects columns by name
```

	ApprovedSymbol	F5_min	F5_med	F5_max
1:	A1BG	0.263767	16.943	2377.989
2:	A1CF	0.000000	0.000	153.024
3:	A2M	0.000000	1.212	1515.493
4:	A2ML1	0.000000	0.000	206.355
5:	A4GALT	0.000000	9.725	80.009

17259:	ZYG11A	0.000000	0.264	11.104
17260:	ZYG11B	4.388704	16.580	65.872
17261:	ZYX	20.467403	468.361	1826.202
17262:	ZZEF1	1.744677	9.323	93.429
17263:	ZZZ3	4.360941	20.657	68.401

```
data %>% dplyr::select(1:4, 50) # select columns by position
```

	ApprovedSymbol	Localization	Taxon	F5_min	Eosinophils
1:	A1BG	secreted	Eutheria	0.263767	2.636
2:	A1CF	multiple	Deuterostomia	0.000000	0.000
3:	A2M	multiple	Euteleostomi	0.000000	0.000
4:	A2ML1	secreted	Euteleostomi	0.000000	0.000
5:	A4GALT	multiple	Tetrapoda	0.000000	0.000

17259:	ZYG11A	nucleus	Euteleostomi	0.000000	0.000
17260:	ZYG11B	nucleus	Euteleostomi	4.388704	41.867
17261:	ZYX	multiple	Theria	20.467403	742.793
17262:	ZZEF1	other	Amniota	1.744677	93.429
17263:	ZZZ3	nucleus	Deuterostomia	4.360941	9.187

```
data %>% dplyr::select(CellCompartment=2, geneID=1, Minimum_expr=F5_min) ## dplyr::rename
```

	CellCompartment	geneID	Minimum_expr
1:	secreted	A1BG	0.263767
2:	multiple	A1CF	0.000000
3:	multiple	A2M	0.000000

```
    4:        secreted  A2ML1      0.000000
    5:        multiple A4GALT      0.000000
   ---
17259:         nucleus ZYG11A      0.000000
17260:         nucleus ZYG11B      4.388704
17261:        multiple    ZYX     20.467403
17262:           other  ZZEF1      1.744677
17263:         nucleus   ZZZ3      4.360941
```

```r
head(data)[1:2,1:3] # here are the original names and order
```

```
   ApprovedSymbol Localization        Taxon
1:          A1BG      secreted     Eutheria
2:          A1CF      multiple Deuterostomia
```

```r
data %>% dplyr::select(contains("Macrophage")) # selects columns by pattern
```

```
       Granulocyte Macrophage progenitor Macrophage Monocyte derived
    1:                          34.492                       17.923
    2:                           0.000                        0.000
    3:                           0.000                      208.304
    4:                           0.000                        0.000
    5:                           0.000                        0.000
   ---
17259:                           0.000                        0.000
17260:                          28.104                       29.538
17261:                         226.111                      544.167
17262:                          77.925                       21.500
17263:                          22.994                       24.682
```

```r
data %>% dplyr::select(starts_with("CD34+")) # selects columns by starting pattern
```

```
       CD34+ Haematopoietic stem cell CD34+ progenitor
    1:                          23.968           34.219
    2:                           0.000            0.000
    3:                           1.317            0.280
    4:                           0.000            0.000
    5:                           2.370            0.280
```

```
                                 ---
17259:                          0.527               0.000
17260:                         14.750               6.768
17261:                         91.394             128.700
17262:                         12.379              26.067
17263:                         21.861              28.870
```

```r
data %>% dplyr::select(ends_with("Endothelial")) # select columns by ending pattern
```

```
      Hepatic Sinusoidal Endothelial Renal Glomerular Endothelial
   1:                         11.219                          4.962
   2:                          0.000                          0.000
   3:                         36.612                         47.414
   4:                          0.000                          0.000
   5:                         13.360                         36.860
 ---
17259:                          1.070                          1.272
17260:                         10.445                          9.821
17261:                        894.871                        826.222
17262:                          9.780                         13.692
17263:                         13.323                         14.051
```

```r
data %>%  dplyr::select(where(is.character))# selects columns by data type
```

```
      ApprovedSymbol Localization         Taxon
   1:           A1BG     secreted       Eutheria
   2:           A1CF     multiple  Deuterostomia
   3:            A2M     multiple   Euteleostomi
   4:          A2ML1     secreted   Euteleostomi
   5:         A4GALT     multiple       Tetrapoda
 ---
17259:         ZYG11A      nucleus   Euteleostomi
17260:         ZYG11B      nucleus   Euteleostomi
17261:            ZYX     multiple          Theria
17262:          ZZEF1        other        Amniota
17263:           ZZZ3      nucleus  Deuterostomia
```

```r
# Same as above, but works by excluding columns
data %>%  dplyr::select(-c(6:150)) # excludes columns by position
```

```
       ApprovedSymbol Localization        Taxon     F5_min   F5_med
    1:           A1BG     secreted     Eutheria  0.263767   16.943
    2:           A1CF     multiple Deuterostomia  0.000000    0.000
    3:            A2M     multiple  Euteleostomi  0.000000    1.212
    4:          A2ML1     secreted  Euteleostomi  0.000000    0.000
    5:         A4GALT     multiple     Tetrapoda  0.000000    9.725
   ---
17259:         ZYG11A      nucleus  Euteleostomi  0.000000    0.264
17260:         ZYG11B      nucleus  Euteleostomi  4.388704   16.580
17261:            ZYX     multiple        Theria 20.467403  468.361
17262:          ZZEF1        other       Amniota  1.744677    9.323
17263:           ZZZ3      nucleus Deuterostomia  4.360941   20.657
```

```r
data %>%  dplyr::select(!where(is.numeric))# excludes columns by type using '!'
```

```
       ApprovedSymbol Localization        Taxon
    1:           A1BG     secreted     Eutheria
    2:           A1CF     multiple Deuterostomia
    3:            A2M     multiple  Euteleostomi
    4:          A2ML1     secreted  Euteleostomi
    5:         A4GALT     multiple     Tetrapoda
   ---
17259:         ZYG11A      nucleus  Euteleostomi
17260:         ZYG11B      nucleus  Euteleostomi
17261:            ZYX     multiple        Theria
17262:          ZZEF1        other       Amniota
17263:           ZZZ3      nucleus Deuterostomia
```

```r
# More complex

# Example:
# select and dplyr::rename column 1 and then,
# select all numeric columns starting with 'T' (character variable 'Taxon' will be exclude

data %>% dplyr::select(geneSymbol=1, starts_with("T") & where(is.numeric))
```

```
     geneSymbol Tenocyte Trabecular Meshwork Tracheal Epithelial
  1:       A1BG   18.775             30.337               10.808
  2:       A1CF    0.000              0.000                0.000
  3:        A2M    5.266              0.000                0.223
```

```
     4:      A2ML1    0.000              0.000                4.885
     5:     A4GALT   61.794              6.097               11.199
    ---
 17259:     ZYG11A    0.000              2.393                0.096
 17260:     ZYG11B   24.898             10.372                7.905
 17261:        ZYX  489.985           1313.519              616.760
 17262:      ZZEF1    6.676              8.898                6.903
 17263:       ZZZ3   22.721             19.108               11.410
```

```
#A few more 'select' arguments are: 'num_range()','matches()', 'any_of(), 'all_of()'
```

5.2 dplyr::rename / dplyr::rename_with

```
# renaming can also be done with 'select', but 'dplyr::rename' is easier

data=fread(file = 'connectome_1in.tsv', select = c(1,7:9))
data %>% dplyr::rename(geneSymbol = ApprovedSymbol)
```

```
        geneSymbol Adipocyte Breast Adipocyte Omental Adipocyte Perirenal
     1:       A1BG            36.847            35.174              49.723
     2:       A1CF             0.000             0.000               0.000
     3:        A2M            90.272           121.423              50.596
     4:      A2ML1             0.000             0.000               0.000
     5:     A4GALT            24.386            10.811              17.447
    ---
 17259:     ZYG11A             0.091             0.000               0.000
 17260:     ZYG11B            30.164            25.141              18.319
 17261:        ZYX           473.814           442.646             389.935
 17262:      ZZEF1             9.713             8.754               1.745
 17263:       ZZZ3            18.076            20.905              19.191
```

```
data %>% dplyr::rename_with(tolower)
```

```
        approvedsymbol adipocyte breast adipocyte omental adipocyte perirenal
     1:           A1BG            36.847            35.174              49.723
     2:           A1CF             0.000             0.000               0.000
     3:            A2M            90.272           121.423              50.596
     4:          A2ML1             0.000             0.000               0.000
```

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```
       5:       A4GALT        24.386        10.811        17.447
      ---
   17259:       ZYG11A         0.091         0.000         0.000
   17260:       ZYG11B        30.164        25.141        18.319
   17261:          ZYX       473.814       442.646       389.935
   17262:        ZZEF1         9.713         8.754         1.745
   17263:         ZZZ3        18.076        20.905        19.191
```

```
  data %>% dplyr::rename_with(toupper, where(is.numeric)) # dplyr::renames to upper - here,
```

```
        ApprovedSymbol ADIPOCYTE BREAST ADIPOCYTE OMENTAL ADIPOCYTE PERIRENAL
       1:        A1BG           36.847          35.174             49.723
       2:        A1CF            0.000           0.000              0.000
       3:         A2M           90.272         121.423             50.596
       4:       A2ML1            0.000           0.000              0.000
       5:       A4GALT          24.386          10.811             17.447
      ---
   17259:       ZYG11A           0.091           0.000              0.000
   17260:       ZYG11B          30.164          25.141             18.319
   17261:          ZYX         473.814         442.646            389.935
   17262:        ZZEF1           9.713           8.754              1.745
   17263:         ZZZ3          18.076          20.905             19.191
```

5.3 dplyr::relocate

```
  # moves columns to the front; this can also be done with 'select', but 'relocate' is easie
```

```
  data=fread(file = 'connectome_1in.tsv', select = c(1,7:9))
  data %>% relocate(starts_with('Adip'))
```

```
        Adipocyte Breast Adipocyte Omental Adipocyte Perirenal ApprovedSymbol
       1:          36.847            35.174             49.723           A1BG
       2:           0.000             0.000              0.000           A1CF
       3:          90.272           121.423             50.596            A2M
       4:           0.000             0.000              0.000          A2ML1
       5:          24.386            10.811             17.447         A4GALT
      ---
   17259:           0.091             0.000              0.000         ZYG11A
   17260:          30.164            25.141             18.319         ZYG11B
```

```
17261:           473.814           442.646           389.935           ZYX
17262:             9.713             8.754             1.745           ZZEF1
17263:            18.076            20.905            19.191           ZZZ3
```

```
data %>% relocate(where(is.numeric))
```

```
     Adipocyte Breast Adipocyte Omental Adipocyte Perirenal ApprovedSymbol
  1:           36.847           35.174           49.723           A1BG
  2:            0.000            0.000            0.000           A1CF
  3:           90.272          121.423           50.596           A2M
  4:            0.000            0.000            0.000           A2ML1
  5:           24.386           10.811           17.447           A4GALT
 ---
17259:            0.091            0.000            0.000          ZYG11A
17260:           30.164           25.141           18.319          ZYG11B
17261:          473.814          442.646          389.935           ZYX
17262:            9.713            8.754            1.745           ZZEF1
17263:           18.076           20.905           19.191           ZZZ3
```

```
# relocate can take other arguments '.before', '.after'
?relocate #check help
```

6 Basic dplyr operations on data rows

6.1 dplyr::filter

```r
# keeps rows based on desired criteria
# simple

data=fread(file = 'connectome_1in.tsv', select = c(1,5:8))
data %>% dplyr::filter(F5_max>5) #keeps rows using a numeric value
```

```
       ApprovedSymbol  F5_med    F5_max Adipocyte Breast Adipocyte Omental
    1:          A1BG  16.943  2377.989            36.847             35.174
    2:          A1CF   0.000   153.024             0.000              0.000
    3:           A2M   1.212  1515.493            90.272            121.423
    4:         A2ML1   0.000   206.355             0.000              0.000
    5:        A4GALT   9.725    80.009            24.386             10.811
   ---
15316:        ZYG11A   0.264    11.104             0.091              0.000
15317:        ZYG11B  16.580    65.872            30.164             25.141
15318:           ZYX 468.361  1826.202           473.814            442.646
15319:         ZZEF1   9.323    93.429             9.713              8.754
15320:          ZZZ3  20.657    68.401            18.076             20.905
```

```r
data=fread(file = 'connectome_1in.tsv', select = c(1:6))
my_genes=c('A1BG', 'CDKN3', 'ZPBP')
data %>% dplyr::filter(ApprovedSymbol %in% my_genes) #keeps rows based on custom string
```

```
   ApprovedSymbol Localization    Taxon    F5_min F5_med   F5_max
1:          A1BG     secreted Eutheria 0.263767 16.943 2377.989
2:         CDKN3     multiple  Amniota 0.000000 14.600  226.150
3:          ZPBP     secreted  Amniota 0.000000  0.000    0.651
```

```
# in conjunction with 'str_detect' from stringr package; (similar to 'grep')
data %>% dplyr::filter(str_detect(ApprovedSymbol, '^HIST2')) #keeps all HIST2 genes
```

```
    ApprovedSymbol Localization     Taxon      F5_min    F5_med     F5_max
 1:    HIST2H2AA3      nucleus Eukaryota    0.000000     0.431    671.790
 2:    HIST2H2AA4      nucleus Eukaryota    0.000000     0.431    671.790
 3:     HIST2H2AB      nucleus Eukaryota    9.958116    91.570   1240.587
 4:     HIST2H2BE     multiple Eukaryota   56.484107   416.034   2790.341
 5:     HIST2H2BF      nucleus Eukaryota    0.918399    21.239    457.095
 6:      HIST2H3A      nucleus Eukaryota    0.000000     0.174    797.346
 7:      HIST2H3C      nucleus Eukaryota    0.000000     0.174    797.346
 8:      HIST2H3D      nucleus Eukaryota    0.000000     0.174    797.346
 9:      HIST2H4A      nucleus Eukaryota  170.420082  1224.638  19898.334
10:      HIST2H4B      nucleus Eukaryota  170.420082  1224.638  19898.334
```

```
data %>% dplyr::filter(!str_detect(ApprovedSymbol, '^HIST2')) #removes (using '!') all HIS
```

```
        ApprovedSymbol Localization          Taxon    F5_min   F5_med     F5_max
     1:          A1BG      secreted       Eutheria  0.263767   16.943   2377.989
     2:          A1CF      multiple  Deuterostomia  0.000000    0.000    153.024
     3:           A2M      multiple   Euteleostomi  0.000000    1.212   1515.493
     4:         A2ML1      secreted   Euteleostomi  0.000000    0.000    206.355
     5:        A4GALT      multiple       Tetrapoda  0.000000    9.725     80.009
   ---
17249:        ZYG11A       nucleus   Euteleostomi  0.000000    0.264     11.104
17250:        ZYG11B       nucleus   Euteleostomi  4.388704   16.580     65.872
17251:           ZYX      multiple          Theria 20.467403  468.361   1826.202
17252:         ZZEF1         other        Amniota  1.744677    9.323     93.429
17253:          ZZZ3       nucleus  Deuterostomia  4.360941   20.657     68.401
```

```
# more complex
# example:
# filter all HIST2 genes with a median expression >10TPM and localized to nucleus

data %>% dplyr::filter(str_detect(ApprovedSymbol, '^HIST2') &
                  F5_med>=10 & Localization == 'nucleus')
```

```
   ApprovedSymbol Localization     Taxon    F5_min   F5_med     F5_max
1:     HIST2H2AB      nucleus Eukaryota  9.958116   91.570   1240.587
```

```
2:       HIST2H2BF      nucleus Eukaryota   0.918399   21.239   457.095
3:       HIST2H4A       nucleus Eukaryota 170.420082 1224.638 19898.334
4:       HIST2H4B       nucleus Eukaryota 170.420082 1224.638 19898.334
```

6.2 dplyr::arrange

```
# arranges row order
# descending - highest on top ; ascending highest at the bottom

data=fread(file = 'connectome_1in.tsv', select = 1:4)
data %>% dplyr::arrange(ApprovedSymbol) # arranges characters in descending order
```

```
       ApprovedSymbol Localization          Taxon    F5_min
    1:           A1BG     secreted       Eutheria  0.263767
    2:           A1CF     multiple Deuterostomia  0.000000
    3:            A2M     multiple  Euteleostomi  0.000000
    4:          A2ML1     secreted  Euteleostomi  0.000000
    5:         A4GALT     multiple      Tetrapoda  0.000000
   ---
17259:         ZYG11A      nucleus  Euteleostomi  0.000000
17260:         ZYG11B      nucleus  Euteleostomi  4.388704
17261:            ZYX     multiple         Theria 20.467403
17262:          ZZEF1        other        Amniota  1.744677
17263:           ZZZ3      nucleus Deuterostomia  4.360941
```

```
data %>% dplyr::arrange(desc(ApprovedSymbol)) # arranges characters in descending order
```

```
       ApprovedSymbol Localization          Taxon    F5_min
    1:           ZZZ3      nucleus Deuterostomia  4.360941
    2:          ZZEF1        other        Amniota  1.744677
    3:            ZYX     multiple         Theria 20.467403
    4:         ZYG11B      nucleus  Euteleostomi  4.388704
    5:         ZYG11A      nucleus  Euteleostomi  0.000000
   ---
17259:         A4GALT     multiple      Tetrapoda  0.000000
17260:          A2ML1     secreted  Euteleostomi  0.000000
17261:            A2M     multiple  Euteleostomi  0.000000
17262:           A1CF     multiple Deuterostomia  0.000000
17263:           A1BG     secreted       Eutheria  0.263767
```

```r
data %>% dplyr::arrange(F5_min) # arranges numbers in descending order
```

```
       ApprovedSymbol Localization        Taxon     F5_min
    1:           A1CF     multiple  Deuterostomia    0.0000
    2:            A2M     multiple    Euteleostomi    0.0000
    3:          A2ML1      secreted   Euteleostomi    0.0000
    4:         A4GALT     multiple       Tetrapoda    0.0000
    5:          A4GNT        other       Tetrapoda    0.0000
   ---
17259:          RPS24    cytoplasm       Eukaryota  331.8715
17260:          PCBP2     multiple   Opisthokonta  344.3184
17261:           CFL1     multiple       Eukaryota  390.6739
17262:         EIF4G2    cytoplasm  Deuterostomia  402.0313
17263:           ACTB     multiple       Eukaryota 1451.3885
```

```r
data %>% dplyr::arrange(-F5_min) # arranges numbers in ascending order
```

```
       ApprovedSymbol Localization        Taxon     F5_min
    1:           ACTB     multiple       Eukaryota 1451.3885
    2:         EIF4G2    cytoplasm  Deuterostomia  402.0313
    3:           CFL1     multiple       Eukaryota  390.6739
    4:          PCBP2     multiple   Opisthokonta  344.3184
    5:          RPS24    cytoplasm       Eukaryota  331.8715
   ---
17259:          ZUFSP      nucleus    Euteleostomi    0.0000
17260:          ZWINT     multiple        Eutheria    0.0000
17261:           ZXDA      nucleus    Euteleostomi    0.0000
17262:           ZXDB      nucleus    Euteleostomi    0.0000
17263:         ZYG11A      nucleus    Euteleostomi    0.0000
```

```r
data %>% dplyr::arrange(Localization, -F5_min) # can be combined; order matters
```

```
       ApprovedSymbol Localization        Taxon    F5_min
    1:         EIF4G2    cytoplasm  Deuterostomia 402.0313
    2:          RPS24    cytoplasm       Eukaryota 331.8715
    3:           EIF1    cytoplasm       Eukaryota 301.4819
    4:            FTL    cytoplasm          Theria 149.4635
    5:            UBC    cytoplasm       Eukaryota 139.8899
   ---
```

```
17259:            XYLT1     secreted     Bilateria   0.0000
17260:            ZG16B     secreted    Catarrhini   0.0000
17261:           ZNF365     secreted     Tetrapoda   0.0000
17262:             ZPBP     secreted       Amniota   0.0000
17263:            ZPBP2     secreted       Amniota   0.0000
```

6.3 dplyr::mutate / dplyr::case_when

```
# 'mutate': adds a new variable as a column

data=fread(file = 'connectome_1in.tsv', select = c(1,2,5))
data %>% dplyr::mutate(my_new_variable = 'FANTOM_5_data') # added as last column
```

```
       ApprovedSymbol Localization   F5_med my_new_variable
    1:           A1BG     secreted   16.943   FANTOM_5_data
    2:           A1CF     multiple    0.000   FANTOM_5_data
    3:            A2M     multiple    1.212   FANTOM_5_data
    4:           A2ML1     secreted    0.000   FANTOM_5_data
    5:          A4GALT     multiple    9.725   FANTOM_5_data
   ---
17259:          ZYG11A      nucleus    0.264   FANTOM_5_data
17260:          ZYG11B      nucleus   16.580   FANTOM_5_data
17261:             ZYX     multiple  468.361   FANTOM_5_data
17262:           ZZEF1        other    9.323   FANTOM_5_data
17263:            ZZZ3      nucleus   20.657   FANTOM_5_data
```

```
# 'case_when': now row values depend on the pattern

data %>% dplyr::mutate(expr_level = case_when(F5_med<10 ~'lowly-expressed gene',
                                     TRUE ~ 'highly-expressed gene'))
```

```
       ApprovedSymbol Localization  F5_med           expr_level
    1:           A1BG     secreted   16.943 highly-expressed gene
    2:           A1CF     multiple    0.000  lowly-expressed gene
    3:            A2M     multiple    1.212  lowly-expressed gene
    4:           A2ML1     secreted    0.000  lowly-expressed gene
    5:          A4GALT     multiple    9.725  lowly-expressed gene
   ---
17259:          ZYG11A      nucleus    0.264  lowly-expressed gene
```

```
17260:          ZYG11B       nucleus  16.580 highly-expressed gene
17261:             ZYX      multiple 468.361 highly-expressed gene
17262:            ZZEF1         other   9.323  lowly-expressed gene
17263:             ZZZ3       nucleus  20.657 highly-expressed gene
```

```r
data=fread(file = 'connectome_1in.tsv', select = c(1,2,4))
data %>% dplyr::mutate(expr_level =
                 case_when(F5_min>0 & Localization == 'secreted'~
                           'highly-expressed secreted protein',
                           TRUE ~ 'not so interesting')) %>%
     dplyr:: arrange(desc(Localization))
```

```
       ApprovedSymbol Localization   F5_min                        expr_level
    1:          A1BG     secreted 0.263767 highly-expressed secreted protein
    2:         A2ML1     secreted 0.000000                not so interesting
    3:        AADACL2     secreted 0.000000                not so interesting
    4:         ABHD12     secreted 5.284597 highly-expressed secreted protein
    5:        ABHD12B     secreted 0.000000                not so interesting
   ---
17259:         ZNF503    cytoplasm 0.000000                not so interesting
17260:         ZNF706    cytoplasm 6.065311                not so interesting
17261:          ZNFX1    cytoplasm 6.826872                not so interesting
17262:          ZNRF4    cytoplasm 0.000000                not so interesting
17263:         ZSWIM8    cytoplasm 1.970653                not so interesting
```

7 Combining 'dplyr' functions

Example:
1. find all highly expressed in CD14+ Monocytes (>10TPM) putative ligands (secreted genes)
2. order the genes from most highly expressed down, annotate them and save to a file
3. ApprovedSymbol (dplyr::rename to geneSymbol), Localization and the cell of interest
4. after excluding all 'orf' genes (ex: C1orf162, etc)

```r
data=fread(file = 'connectome_1in.tsv')
data %>% dplyr::filter(Localization=='secreted' & `CD14+ Monocytes` > 10) %>%
        dplyr::arrange(-`CD14+ Monocytes`) %>%
        dplyr::select(ApprovedSymbol, Localization, `CD14+ Monocytes`) %>%
        dplyr::rename(geneSymbol=ApprovedSymbol) %>%
        dplyr::mutate(Class='Monocyte Ligand') %>%
        dplyr::filter(!str_detect(geneSymbol, 'orf'))
```

```
      geneSymbol Localization CD14+ Monocytes            Class
  1:         LYZ     secreted      13533.670 Monocyte Ligand
  2:         IL8     secreted      12834.926 Monocyte Ligand
  3:         B2M     secreted       7159.262 Monocyte Ligand
  4:        CCL3     secreted       3027.740 Monocyte Ligand
  5:       CXCL2     secreted       2427.316 Monocyte Ligand
 ---
169:         PF4     secreted         10.554 Monocyte Ligand
170:        NID1     secreted         10.457 Monocyte Ligand
171:       TCTN3     secreted         10.359 Monocyte Ligand
172:       FOLR3     secreted         10.122 Monocyte Ligand
173:       THBS3     secreted         10.065 Monocyte Ligand
```

8 Working with groupped data

```
-- Attaching packages ------------------------------------- tidyverse 1.3.2 --
v ggplot2 3.3.6      v purrr   0.3.4
v tibble  3.1.8      v dplyr   1.0.9
v tidyr   1.2.0      v stringr 1.4.0
v readr   2.1.2      v forcats 0.5.1
-- Conflicts ----------------------------------------- tidyverse_conflicts() --
x dplyr::between()   masks data.table::between()
x dplyr::filter()    masks stats::filter()
x dplyr::first()     masks data.table::first()
x dplyr::lag()       masks stats::lag()
x dplyr::last()      masks data.table::last()
x purrr::transpose() masks data.table::transpose()


        : 'magrittr'


     'package:purrr'        :

  set_names


     'package:tidyr'        :

  extract
```

8.1 dplyr::add_count / dplyr::count

```r
data = fread(file = 'connectome_1in.tsv')
data %>% dplyr::add_count(ApprovedSymbol) %>% dplyr::arrange(-n)
```

```
     ApprovedSymbol Localization         Taxon    F5_min  F5_med   F5_max
  1:           A1BG     secreted      Eutheria  0.263767  16.943 2377.989
```

```
   2:        A1CF     multiple Deuterostomia 0.000000   0.000  153.024
   3:         A2M     multiple  Euteleostomi 0.000000   1.212 1515.493
   4:       A2ML1     secreted  Euteleostomi 0.000000   0.000  206.355
   5:      A4GALT     multiple      Tetrapoda 0.000000   9.725   80.009
  ---
17259:      ZYG11A     nucleus  Euteleostomi 0.000000   0.264   11.104
17260:      ZYG11B     nucleus  Euteleostomi 4.388704  16.580   65.872
17261:         ZYX    multiple         Theria 20.467403 468.361 1826.202
17262:       ZZEF1       other        Amniota 1.744677   9.323   93.429
17263:        ZZZ3     nucleus Deuterostomia 4.360941  20.657   68.401
      Adipocyte Breast Adipocyte Omental Adipocyte Perirenal
   1:         36.847           35.174              49.723
   2:          0.000            0.000               0.000
   3:         90.272          121.423              50.596
   4:          0.000            0.000               0.000
   5:         24.386           10.811              17.447
  ---
17259:          0.091            0.000               0.000
17260:         30.164           25.141              18.319
17261:        473.814          442.646             389.935
17262:          9.713            8.754               1.745
17263:         18.076           20.905              19.191
      Adipocyte Subcutaneous Alveolar Epithelial Amniotic Epithelial
   1:               41.076             4.143               0.264
   2:                0.000             0.000               0.000
   3:               63.397             0.000               0.000
   4:                0.000             0.000              21.168
   5:               27.730            11.608              19.070
  ---
17259:                0.000             0.123               1.733
17260:               18.911             4.978              15.027
17261:              663.910          1012.799             495.516
17262:                9.769             6.561              12.725
17263:               11.938            10.109               6.001
      Amniotic Membrane Annulus Pulposus Astrocyte Cerebellum
   1:            4.915           31.099                16.943
   2:            0.000            0.000                 0.000
   3:            0.819            0.000                 1.364
   4:          206.355            0.000                 0.000
   5:           30.631           42.725                 6.146
  ---
17259:            0.396            0.000                 1.195
17260:           21.576           17.402                 7.212
```

```
17261:              81.118           638.182               597.896
17262:              12.789             8.083                 9.124
17263:              25.542            26.437                10.307
       Astrocyte Cerebral Cortex Basophils Bronchial Epithelial
   1:                     7.498    17.908                 9.793
   2:                     0.000     0.103                 0.000
   3:                     8.824     0.128                 0.000
   4:                     0.000     0.619                 3.187
   5:                     0.655     0.334                16.745
   ---
17259:                     1.115     0.128                 0.100
17260:                    27.474    14.586                 6.326
17261:                   251.642   440.993               641.173
17262:                     8.411    33.169                 9.038
17263:                    27.943    17.550                13.487
       CD133+ Haematopoietic stem cell
   1:                              50.206
   2:                               0.000
   3:                               0.000
   4:                               0.000
   5:                               0.000
   ---
17259:                               0.000
17260:                               8.514
17261:                             116.266
17262:                              11.450
17263:                              31.122
       CD14+ Monocyte derived Endothelial progenitor CD14+ Monocytes
   1:                                          21.596          16.290
   2:                                           0.000           0.000
   3:                                         144.359           0.185
   4:                                           0.000           0.000
   5:                                           0.075           0.217
   ---
17259:                                           0.000           0.000
17260:                                          43.930          17.754
17261:                                         270.955         476.539
17262:                                          59.266          49.950
17263:                                          68.401          23.115
       CD14+CD16+ Monocytes CD14+CD16- Monocytes CD14-CD16+ Monocytes
   1:             16.181           23.447               10.928
   2:              0.000            0.000                0.000
   3:              0.141            0.050                0.127
```

```
   4:             0.000           0.000              0.000
   5:             0.000           0.037              0.000
   ---
17259:             0.000           0.000              0.000
17260:            15.776          20.266             16.119
17261:           359.648         580.106            329.579
17262:            19.920          23.946             30.071
17263:            15.776          17.156             13.928
      CD19+ B cells CD34+ Haematopoietic stem cell CD34+ progenitor
   1:        24.777                    23.968            34.219
   2:         0.000                     0.000             0.000
   3:         0.000                     1.317             0.280
   4:         0.000                     0.000             0.000
   5:         0.217                     2.370             0.280
   ---
17259:         1.290                     0.527             0.000
17260:        17.912                    14.750             6.768
17261:        26.779                    91.394           128.700
17262:        27.082                    12.379            26.067
17263:        35.293                    21.861            28.870
      CD4+ T cells CD4+CD25+CD45RA+ naive regulatory T cells
   1:        15.572                               13.057
   2:         0.000                                0.000
   3:         0.000                                0.000
   4:         0.000                                0.000
   5:         0.000                                0.000
   ---
17259:         0.262                                0.118
17260:        25.652                               16.660
17261:       156.419                               76.060
17262:        45.869                               23.929
17263:        51.262                               38.660
      CD4+CD25+CD45RA- memory regulatory T cells
   1:                                     15.473
   2:                                      0.000
   3:                                      0.000
   4:                                      0.000
   5:                                      0.341
   ---
17259:                                      0.062
17260:                                     15.991
17261:                                    154.997
17262:                                     20.953
```

```
17263:                                         31.162
         CD4+CD25-CD45RA+ naive conventional T cells
    1:                                         16.530
    2:                                          0.000
    3:                                          0.000
    4:                                          0.000
    5:                                          0.000
   ---
17259:                                          0.101
17260:                                         20.752
17261:                                        111.837
17262:                                         26.076
17263:                                         40.911
         CD4+CD25-CD45RA- memory conventional T cells CD8+ T cells
    1:                                         17.132       25.467
    2:                                          0.000        0.000
    3:                                          0.000        0.000
    4:                                          0.000        0.000
    5:                                          0.028        0.000
   ---
17259:                                          0.152        0.149
17260:                                         15.595       17.183
17261:                                        115.866      130.069
17262:                                         24.326       29.854
17263:                                         34.308       42.319
         Cardiac Myocyte Chondroblast Chondrocyte Chorionic Membrane
    1:          8.595        9.231      17.668               7.071
    2:          0.000        0.000       0.000               0.000
    3:         17.161        4.198      28.522              30.713
    4:          0.000        0.000       0.000              18.666
    5:         12.142       31.842      19.033              27.820
   ---
17259:          0.309        0.241       0.000               0.153
17260:         22.829       18.431      23.253              18.167
17261:        432.366      341.704     127.448             287.212
17262:         10.602        9.115       9.840              11.830
17263:         24.197       20.446      22.374              21.327
         Ciliary Epithelial Corneal Epithelial
    1:              5.169           10.818
    2:              0.000            0.000
    3:              1.474            0.000
    4:              0.029           16.614
    5:              3.882           62.267
```

```
        ---
17259:              1.246              1.103
17260:             22.091              5.705
17261:            425.145            416.233
17262:              9.560              6.434
17263:             26.001              4.983
        Dendritic Monocyte Immature derived Dendritic Plasmacytoid ES cells
    1:                             19.102                 93.768   10.198
    2:                              0.000                  0.000    0.000
    3:                            622.499                  0.966    0.044
    4:                              0.000                  0.000    0.125
    5:                              3.082                  1.999    5.704
    ---
17259:                              0.044                  0.000   11.104
17260:                             30.346                  4.601   18.448
17261:                            345.054                103.197  177.084
17262:                             22.906                 23.909    4.880
17263:                             17.190                 50.876   34.292
        Endothelial Aortic Endothelial Artery Endothelial Lymphatic
    1:             14.159             12.190                 2.268
    2:              0.000              0.000                 0.000
    3:              0.849              7.317               112.864
    4:              0.000              0.000                 0.000
    5:             16.708             22.830                17.733
    ---
17259:              0.514              0.737                 0.291
17260:             16.580             10.450                25.263
17261:            760.351            951.401               430.343
17262:             14.401             10.641                16.899
17263:             12.937             11.703                37.392
        Endothelial Microvascular Endothelial Thoracic
    1:                    15.821                   16.751
    2:                     0.000                    0.000
    3:                    22.919                    4.527
    4:                     0.000                    0.000
    5:                    48.154                   23.226
    ---
17259:                     0.760                    0.000
17260:                    14.217                   12.139
17261:                   678.548                  810.633
17262:                    12.125                   12.915
17263:                    12.092                   14.897
        Endothelial Umbilical Vein Endothelial Vein Eosinophils
```

```
     1:                         1.460              8.301         2.636
     2:                         0.000              0.000         0.000
     3:                         6.203              0.938         0.000
     4:                         0.000              0.000         0.000
     5:                         6.894              3.753         0.000
    ---
 17259:                         1.584              1.011         0.000
 17260:                        21.824             17.400        41.867
 17261:                       351.405            857.603       742.793
 17262:                        12.374             13.511        93.429
 17263:                        31.748             12.787         9.187
         Esophageal Epithelial Fibroblast Aortic Adventitial Fibroblast Cardiac
     1:                 8.286                        9.701                  24.256
     2:                 0.000                        0.000                   0.000
     3:                 0.436                        5.699                  10.457
     4:                17.008                        0.000                   0.000
     5:                18.752                       19.151                  15.473
    ---
 17259:                 0.872                        0.988                   0.465
 17260:                 7.414                       20.302                  21.306
 17261:               593.088                      515.496                 597.537
 17262:                 3.489                        8.258                  10.805
 17263:                 4.361                       20.657                  22.829
         Fibroblast Choroid Plexus Fibroblast Conjunctival Fibroblast Dermal
     1:                 35.255                      20.855                  22.007
     2:                  0.000                       0.000                   0.000
     3:                  7.497                       0.234                   1.313
     4:                  0.000                       0.000                   0.095
     5:                 44.240                       7.264                   6.952
    ---
 17259:                  0.378                       1.875                   0.965
 17260:                 14.575                       9.139                  14.446
 17261:                452.713                     698.512                 493.593
 17262:                 11.345                       6.561                   8.834
 17263:                 19.612                      19.917                  29.152
         Fibroblast Gingival Fibroblast Lymphatic Fibroblast Periodontal Ligament
     1:                 26.186                34.565                           20.547
     2:                  0.000                 0.000                            0.000
     3:                  0.465                 0.000                            1.168
     4:                  0.000                 0.000                            0.000
     5:                 21.772                28.743                           13.828
    ---
 17259:                  0.414                 0.000                            0.613
```

```
17260:              26.905                 5.509                           25.036
17261:             458.303              1757.244                          560.575
17262:              10.650                 4.431                            9.916
17263:              36.798                 8.407                           29.337
        Fibroblast Pulmonary Artery Fibroblast Skin Normal Gingival Epithelial
    1:                   15.881                 32.488                    5.443
    2:                    0.000                  0.000                    0.000
    3:                    0.340                 23.182                    0.064
    4:                    0.000                  0.000                   26.966
    5:                   12.364                 11.766                   11.276
   ---
17259:                    0.227                  0.235                    1.261
17260:                   14.860                 16.632                   17.275
17261:                  468.361                479.812                  359.155
17262:                    5.785                  8.612                    7.890
17263:                   12.931                 29.297                   17.675
        Granulocyte Macrophage progenitor Hair Follicle Dermal Papilla
    1:                           34.492                         35.204
    2:                            0.000                          0.000
    3:                            0.000                          9.592
    4:                            0.000                          0.000
    5:                            0.000                          6.254
   ---
17259:                            0.000                          0.460
17260:                           28.104                         13.679
17261:                          226.111                        941.256
17262:                           77.925                         13.769
17263:                           22.994                         26.221
        Hair Follicle Outer Root Sheath Hepatic Sinusoidal Endothelial
    1:                           50.829                         11.219
    2:                            0.000                          0.000
    3:                           69.227                         36.612
    4:                            0.000                          0.000
    5:                           26.718                         13.360
   ---
17259:                            0.000                          1.070
17260:                           18.619                         10.445
17261:                          492.240                        894.871
17262:                           10.575                          9.780
17263:                           21.046                         13.323
        Hepatic Stellate Hepatocyte Immature Langerhans
    1:             26.137  2377.989                 46.017
    2:              0.000   153.024                  0.000
```

```
    3:            1.235    1515.493              9.836
    4:            0.000       0.000             10.474
    5:            8.997       0.000              0.000
   ---
17259:            0.000       4.341              0.000
17260:           12.112      33.607              5.106
17261:         1114.881      94.638            161.451
17262:            8.467      16.168             20.296
17263:            7.909      42.797             27.800
     Intestinal Epithelial (polarized) Iris Pigment Epithelial
    1:                           0.984                    7.206
    2:                          53.254                    0.000
    3:                           9.593                    0.172
    4:                           0.000                    0.000
    5:                           6.026                    4.975
   ---
17259:                          1.599                    0.515
17260:                         16.111                   15.098
17261:                        118.807                  471.983
17262:                          7.379                    5.319
17263:                         15.988                   19.730
     Keratinocyte Epidermal Keratinocyte Oral Keratocytes Lens Epithelial
    1:                 4.995              1.852      31.620       12.195
    2:                 0.000              0.000       0.000        0.000
    3:                 0.034              0.000       0.000        0.663
    4:                20.528             13.148       0.000        0.000
    5:                 2.383             11.574       9.466        6.038
   ---
17259:                 0.488              1.204       1.497        0.676
17260:                 9.766             21.388       6.804       19.175
17261:               473.740            258.600     535.837      469.660
17262:                 9.513              5.185      10.281        8.082
17263:                16.939             29.165      12.492       20.688
     Macrophage Monocyte derived Mallassez derived Mammary Epithelial
    1:                 17.923             9.523                 4.266
    2:                  0.000             0.000                 0.000
    3:                208.304             0.000                 2.494
    4:                  0.000             5.063                 1.235
    5:                  0.000            14.173                 1.850
   ---
17259:                  0.000             0.794                 0.765
17260:                 29.538            11.063                11.799
17261:                544.167           391.202               360.113
```

```
17262:                        21.500            6.146           7.575
17263:                        24.682           19.728          27.103
        Mast cells Mast cells stimulated Mature Adipocyte Melanocyte Meningeal
    1:    21.826              11.824            1.629      24.663      6.175
    2:     0.000               0.000            0.000       0.000      0.000
    3:     1.178               0.000           85.879     423.667      2.797
    4:     0.496               0.000            0.000       0.209      0.000
    5:     0.883               0.000            5.599       0.575      7.811
   ---
17259:     0.119               0.000            0.300       0.554      1.516
17260:    23.254               8.868           38.571      15.233     14.621
17261:   130.957             205.441           75.078     176.569    725.339
17262:    24.955               4.434           17.865      11.846      8.827
17263:    26.307              38.920           14.656      16.781     16.446
        Mesenchymal precursor Adipose Mesenchymal precursor Bone Marrow
    1:               19.417                            15.766
    2:                0.000                             0.000
    3:                3.791                             4.242
    4:                0.000                             0.000
    5:               10.586                            23.057
   ---
17259:                0.412                             0.063
17260:               10.694                            15.663
17261:              404.482                           398.606
17262:                6.075                             7.430
17263:               26.862                            22.748
        Mesenchymal precursor Cardiac Mesenchymal stem cell Adipose
    1:               16.772                           123.496
    2:                0.000                             0.000
    3:                2.287                            42.790
    4:                0.000                             0.000
    5:               22.477                            80.009
   ---
17259:                0.687                             0.109
17260:               12.000                            14.489
17261:              281.751                          1794.597
17262:                6.228                             8.004
17263:               23.183                            16.787
        Mesenchymal stem cell Amniotic Membrane
    1:                       21.221
    2:                        0.000
    3:                       64.543
    4:                        0.000
```

```
   5:                                              6.722
   ---
17259:                                            0.653
17260:                                           21.727
17261:                                          805.240
17262:                                            6.710
17263:                                           25.101
      Mesenchymal stem cell Bone Marrow Mesenchymal stem cell Hepatic
   1:                            10.101                            25.629
   2:                             0.000                             0.000
   3:                             1.121                             5.059
   4:                             0.000                             0.000
   5:                             4.531                             4.491
   ---
17259:                           1.463                             1.818
17260:                          12.460                            28.307
17261:                         739.854                           348.455
17262:                           8.035                             8.266
17263:                          10.272                            27.484
      Mesenchymal stem cell Umbilical Mesenchymal stem cell Wharton's Jelly
   1:                            50.172                               28.828
   2:                             0.000                                0.000
   3:                             0.000                                0.129
   4:                             0.000                                0.000
   5:                            13.804                                4.395
   ---
17259:                           0.264                                0.259
17260:                          10.866                               18.486
17261:                         485.315                              305.986
17262:                           7.237                                7.756
17263:                          10.922                               19.520
      Mesothelial Migratory Langerhans
   1:      34.815           22.289
   2:       0.000            0.000
   3:      91.831          100.280
   4:       0.000            0.065
   5:       9.413            2.969
   ---
17259:      0.067            0.000
17260:     17.012            8.426
17261:    471.516          641.794
17262:      8.412           16.995
17263:     13.762           26.937
```

	Multipot. Cord Blood Unrestrict.	Somatic stem cell	Myoblast	Myotube
1:		15.398	24.219	24.929
2:		0.000	0.000	0.000
3:		0.000	1.243	29.737
4:		0.000	0.000	0.000
5:		4.718	12.731	8.903

17259:		0.694	0.176	0.267
17260:		22.414	22.962	24.039
17261:		541.254	368.368	462.343
17262:		7.854	9.323	8.992
17263:		26.099	24.100	22.347

	NK cells	Nasal Epithelial	Neural stem cell	Neurons	Neutrophils
1:	10.954	10.309	6.114	6.177	0.802
2:	0.000	0.000	0.000	0.000	0.000
3:	0.066	0.311	96.416	22.745	0.000
4:	0.000	21.389	0.254	0.000	0.000
5:	0.171	9.087	0.127	0.223	0.000

17259:	0.229	0.140	0.905	0.000	0.000
17260:	16.003	14.102	45.513	32.986	65.872
17261:	150.932	224.852	348.359	176.113	1826.202
17262:	43.102	12.315	13.429	12.432	78.486
17263:	39.510	23.803	32.353	28.234	11.961

	Nucleus Pulposus	Olfactory Epithelial	Osteoblast	Osteocyte
1:	28.643	28.786	2.784	27.879
2:	0.000	0.000	0.000	0.000
3:	1.212	2.805	0.849	16.605
4:	0.000	0.000	0.000	0.000
5:	34.574	3.817	1.863	27.933

17259:	0.000	0.717	0.184	0.000
17260:	21.465	29.622	22.979	15.396
17261:	807.148	589.053	598.789	447.318
17262:	7.636	11.644	10.015	12.868
17263:	28.063	26.305	22.024	18.103

	Pancreatic Stromal	Pericytes	Placental Epithelial	Preadipocyte Breast
1:	25.804	81.360	2.573	26.514
2:	0.000	0.000	0.000	0.000
3:	6.343	1.740	0.101	17.948
4:	0.000	0.000	18.928	0.000
5:	9.818	13.108	8.783	23.957

```
17259:           0.695      0.098           0.202           0.140
17260:          27.281      4.923          13.618          23.652
17261:         504.272    790.225         427.509         494.841
17262:           9.210      8.964           8.024           6.965
17263:          29.106      9.846          11.451          24.937
       Preadipocyte Omental Preadipocyte Perirenal Preadipocyte Subcutaneous
   1:            31.362              57.883                   31.618
   2:             0.000               0.000                    0.000
   3:            20.348               7.421                    3.173
   4:             0.000               0.000                    0.000
   5:             8.280              17.810                    6.012
   ---
17259:           0.428               0.000                    0.397
17260:          28.414              14.842                   20.294
17261:         485.452             552.115                  647.132
17262:           7.652               4.453                    6.832
17263:          21.306              11.873                   16.432
       Preadipocyte Visceral Prostate Epithelial Prostate Stromal
   1:            17.867              3.093              16.122
   2:             0.000              7.816               0.000
   3:             0.622              0.138              13.502
   4:             0.000             15.235               0.000
   5:            17.783             13.987              10.854
   ---
17259:           0.570              0.242               1.390
17260:          20.144             16.644              19.337
17261:         504.228            313.816             457.992
17262:           8.435              7.171               8.223
17263:          25.769             19.604              20.297
       Renal Cortical Epithelial Renal Epithelial Renal Glomerular Endothelial
   1:                     3.642            8.393                        4.962
   2:                     0.000            0.000                        0.000
   3:                     0.000            0.000                       47.414
   4:                     0.039            0.000                        0.000
   5:                    12.396           31.502                       36.860
   ---
17259:                    1.133            2.336                        1.272
17260:                   11.790           12.459                        9.821
17261:                  339.622          581.510                      826.222
17262:                    8.704            4.548                       13.692
17263:                   16.972           16.062                       14.051
       Renal Mesangial Renal Proximal Tubular Epithelial Reticulocyte
   1:          19.607                         4.602           1.113
```

```
      2:            0.000                          0.000        0.000
      3:            0.251                          0.000        0.131
      4:            0.000                          0.000        0.000
      5:           36.755                         26.727       41.660
     ---
  17259:            0.522                          2.278        0.000
  17260:            7.441                         10.504        9.483
  17261:          925.429                        314.538       20.467
  17262:            7.887                          6.491       14.248
  17263:            8.118                         11.819       15.576
```

```
        Retinal Pigment Epithelial Salivary Acinar Sebocyte Sertoli
      1:                      4.445           8.125    9.870   3.214
      2:                      0.000           0.000    0.000   0.000
      3:                      0.194           2.552    0.000  35.350
      4:                      0.000          35.931   24.871   0.000
      5:                      4.433          21.075    5.033  27.316
     ---
  17259:                      1.083           0.069    1.912   0.000
  17260:                     16.906          12.555    9.280  25.709
  17261:                    369.460         268.938 1059.838 393.676
  17262:                      8.508          18.132   11.290  19.282
  17263:                     22.610          33.129    8.857  17.675
```

```
        Skeletal Muscle Skeletal Muscle Satellite Small Airway Epithelial
      1:         12.024                  14.713                       3.268
      2:          0.000                   0.000                       0.000
      3:          5.353                   4.979                       0.132
      4:          0.000                   0.000                       4.941
      5:          9.673                  13.759                      14.181
     ---
  17259:          0.487                   0.227                       0.055
  17260:         15.615                  24.160                      12.988
  17261:        444.258                 468.990                     406.527
  17262:          8.857                   9.533                       6.950
  17263:         28.755                  34.142                      27.946
```

```
        Smooth Muscle Aortic Smooth Muscle Brachiocephalic
      1:               40.748                       45.693
      2:                0.000                        0.000
      3:                0.174                        0.093
      4:                0.000                        0.000
      5:               16.562                       17.797
     ---
  17259:                1.135                        0.000
  17260:               11.313                       14.311
```

```
17261:              744.286                      547.700
17262:               10.759                        8.519
17263:                9.526                       17.754
       Smooth Muscle Brain Vascular Smooth Muscle Bronchial
   1:                25.877                       33.998
   2:                 0.000                        0.000
   3:                 3.687                       22.458
   4:                 0.000                        0.000
   5:                 4.468                       13.933
  ---
17259:                 0.890                        0.726
17260:                24.562                       11.288
17261:               414.742                     1125.933
17262:                10.198                        8.764
17263:                27.923                       18.051
       Smooth Muscle Carotid Smooth Muscle Colonic
   1:                39.639                       15.752
   2:                 0.000                        0.000
   3:                 0.159                       10.153
   4:                 0.000                        0.000
   5:                19.114                        7.930
  ---
17259:                 0.000                        0.331
17260:                12.293                       21.923
17261:               970.678                      358.749
17262:                 9.186                        9.284
17263:                13.333                       28.665
       Smooth Muscle Coronary Artery Smooth Muscle Esophageal
   1:               100.375                       21.456
   2:                 0.000                        0.000
   3:                 0.669                        0.975
   4:                 0.000                        0.000
   5:                19.340                       15.604
  ---
17259:                 0.202                        2.926
17260:                 8.915                        4.389
17261:               732.392                     1411.700
17262:                14.216                        6.339
17263:                 8.280                        8.777
       Smooth Muscle Internal Thoracic Artery Smooth Muscle Prostate
   1:                        43.965                        21.860
   2:                         0.000                         0.000
   3:                         0.122                         6.740
```

```
      4:                              0.000              0.000
      5:                             31.124              9.725
      ---
17259:                               0.244              1.311
17260:                               8.531             17.391
17261:                             534.323            374.423
17262:                              10.441              9.558
17263:                              13.609             24.070
          Smooth Muscle Pulmonary Artery Smooth Muscle Subclavian Artery
      1:                             48.593                         18.313
      2:                              0.000                          0.000
      3:                              2.260                          0.146
      4:                              0.000                          0.000
      5:                             30.512                         25.372
      ---
17259:                               0.000                          0.146
17260:                              16.951                         11.053
17261:                             679.179                        688.957
17262:                               6.780                         10.125
17263:                               6.780                         11.370
          Smooth Muscle Tracheal Smooth Muscle Umbilical Artery
      1:                             26.873                         34.897
      2:                              0.000                          0.000
      3:                             37.598                          2.324
      4:                              0.000                          0.000
      5:                             24.153                          8.914
      ---
17259:                               0.328                          0.237
17260:                              20.024                         10.054
17261:                             740.403                        977.311
17262:                               6.578                          9.201
17263:                              15.163                          9.848
          Smooth Muscle Umbilical Vein Smooth Muscle Uterine Synoviocyte Tenocyte
      1:                             13.021                18.802       9.504   18.775
      2:                              0.000                 0.000       0.000    0.000
      3:                              0.143                 3.193       2.208    5.266
      4:                              0.000                 0.000       0.000    0.000
      5:                              1.855                 2.129      65.447   61.794
      ---
17259:                               0.430                 1.064       0.481    0.000
17260:                              17.677                18.448      21.608   24.898
17261:                             510.591               433.518     467.281  489.985
17262:                               5.382                 9.933       7.342    6.676
```

17263:		23.406		24.833	25.040	22.721

	Trabecular Meshwork	Tracheal Epithelial	Urothelial	n
1:	30.337	10.808	2.750	1
2:	0.000	0.000	0.000	1
3:	0.000	0.223	0.000	1
4:	0.000	4.885	10.780	1
5:	6.097	11.199	26.715	1

17259:	2.393	0.096	0.000	1
17260:	10.372	7.905	11.614	1
17261:	1313.519	616.760	540.465	1
17262:	8.898	6.903	6.794	1
17263:	19.108	11.410	10.543	1

References