R & OMICS

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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.

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
```

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

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

```
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
```

```
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
```

  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
```

  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
```

  # 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
```

14

```
    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
```

```r
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
```

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

6 Basic dplyr operations on data rows

6.1 dplyr::filter

```
# 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

```
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)

```
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
```

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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
```

	Trabecular Meshwork	Tracheal Epithelial	Urothelial	n
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