Introduction to the Tidyverse

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Tidy format (murders data)

We say that a data table is in **tidy** format if each row represents one observation and columns represent the different variables available for each of these observations. For example, the following data is in tidy format:

```
data(murders)
head(murders)
```

```
##        state abb region population total
## 1    Alabama  AL  South    4779736   135
## 2     Alaska  AK   West     710231    19
## 3    Arizona  AZ   West    6392017   232
## 4   Arkansas  AR  South    2915918    93
## 5 California  CA   West   37253956  1257
## 6   Colorado  CO   West    5029196    65
```

Not tidy format (fertility)

The following dataset is organized, but not tidy. Why?

```
path <- system.file("extdata", package = "dslabs")
filename <- file.path(path, "fertility-two-countries-example.csv")
wide_data <- read_csv(filename)
```

```
## Rows: 2 Columns: 57
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (1): country
## dbl (56): 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, ...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
select(wide_data, country, `1960`:`1962`) %>% as.data.frame()
```

```
##       country 1960 1961 1962
## 1     Germany 2.41 2.44 2.47
## 2 South Korea 6.16 5.99 5.79
```

Tidy format (fertility)

Here is how we would organize these data to be tidy:

```
data("gapminder")
tidy_data <- gapminder %>%
  filter(country %in% c("South Korea", "Germany") & !is.na(fertility)) %>%
  select(country, year, fertility)
head(tidy_data, 6)
```

```
##       country year fertility
## 1     Germany 1960      2.41
## 2 South Korea 1960      6.16
## 3     Germany 1961      2.44
## 4 South Korea 1961      5.99
## 5     Germany 1962      2.47
## 6 South Korea 1962      5.79
```

Tidy format

The same information is provided, but there are important differences in the format. For the **tidyverse** packages to be optimally used, data need to be reshaped into 'tidy' format. The advantage of working in tidy format allows the data analyst to focus on more important aspects of the analysis rather than the format of the data.

Tidy data wrangling

The **dplyr** package, which is part of the **tidyverse**, presents a basic grammar for wrangling tidy data:

- mutate(): add or modify existing columns
- select(): take a subset of the columns (variables)
- filter(): take a subset of the rows (observations)
- arrange(): sort the rows
- summarize(): aggregate data across rows

Note an important point: most dplyr functions (and most functions in the tidyverse) input a tibble and then output a modified tibble!

Mutate

The function **mutate** takes the data frame, the instructions for the new columns in next arguments, and returns a modified data frame. For example:

```r
head(murders)
```

```
##        state abb region population total
## 1    Alabama  AL  South    4779736   135
## 2     Alaska  AK   West     710231    19
## 3    Arizona  AZ   West    6392017   232
## 4   Arkansas  AR  South    2915918    93
## 5 California  CA   West   37253956  1257
## 6   Colorado  CO   West    5029196    65
```

Mutate

To add murder rates, we mutate as follows:

```
murdersRate <- mutate(murders,
  rate = total / population * 100000
)
head(murdersRate)
```

```
##        state abb region population total     rate
## 1    Alabama  AL  South    4779736   135 2.824424
## 2     Alaska  AK   West     710231    19 2.675186
## 3    Arizona  AZ   West    6392017   232 3.629527
## 4   Arkansas  AR  South    2915918    93 3.189390
## 5 California  CA   West   37253956  1257 3.374138
## 6   Colorado  CO   West    5029196    65 1.292453
```

Filter

Now suppose that we want to filter the data table to only show the entries for which the murder rate is lower than 0.71. We do this as follows:

```
filter(murdersRate, rate <= 0.71)
```

```
##              state abb        region population total      rate
## 1           Hawaii  HI          West    1360301     7 0.5145920
## 2             Iowa  IA North Central    3046355    21 0.6893484
## 3 New Hampshire  NH     Northeast    1316470     5 0.3798036
## 4   North Dakota  ND North Central     672591     4 0.5947151
## 5          Vermont  VT     Northeast     625741     2 0.3196211
```

Select

If we want to view just a few of our columns, we can use the following:

```
murdersRate <- mutate(murders,
  rate = total / population * 100000
)
murdersRateSelect <- select(murdersRate, state, rate)
filter(murdersRateSelect, rate <= 0.71)
```

```
##           state      rate
## 1        Hawaii 0.5145920
## 2          Iowa 0.6893484
## 3 New Hampshire 0.3798036
## 4  North Dakota 0.5947151
## 5       Vermont 0.3196211
```

Nesting functions

Instead of defining new objects along the way, we could do everything in one complex nested function:

```
filter(
  select(
    mutate(murders, rate = total / population * 100000),
    state, rate
  ),
  rate <= 0.71
)
```

```
##              state      rate
## 1           Hawaii 0.5145920
## 2             Iowa 0.6893484
## 3 New Hampshire 0.3798036
## 4  North Dakota 0.5947151
## 5          Vermont 0.3196211
```

This is fairly concise but a little confusing. Is there a better, clearer way?

Pipes

In the previous example, we performed the following wrangling operations:

$$\text{original data} \;\rightarrow\; \text{mutate} \;\rightarrow\; \text{select} \;\rightarrow\; \text{filter}$$

As with Unix, we can perform a series of operations in R by sending the results of one function to another using the **pipe operator**: %>%. As of R version 4.1.0, you can also use |>.

The pipe is a combination of characters that when used properly does two things: *It shortens and simplifies the code* and it makes the code intuitive to read

Pipes

All the pipe does is provide **forward application** of an object to the first argument of a function. The pipe sends left side of the input to the function to the right of the pipe. For example, if we wanted to calculate

$$\log_2(\sqrt{}(16))$$

We could use:

```
16 %>% sqrt() %>% log2()
```

```
## [1] 2
```

Since the pipe sends values to the first argument, we can define other arguments as follows:

```
16 %>% sqrt() %>% log(base = 2)
```

```
## [1] 2
```

Pipes (murders)

Completing the prior tibble operation using pipes:

```
murders %>%
  mutate(rate = total / population * 100000) %>%
  select(state, rate) %>%
  filter(rate <= 0.71)
```

```
##              state      rate
## 1           Hawaii 0.5145920
## 2             Iowa 0.6893484
## 3 New Hampshire 0.3798036
## 4   North Dakota 0.5947151
## 5          Vermont 0.3196211
```

Note that as you can see, the pipe operators (%>% or |>) are not specific to the tidyverse, in fact they come from the **magrittr** package (which is loaded by the tidyverse and dplyr libraries)

Arrange

We know about the **order** and **sort** functions, but for ordering entire tables, the **arrange** function is much more useful. For example, here we order the states murder rate:

```
murdersRate %>%
  arrange(rate) %>%
  head()
```

```
##              state abb        region population total      rate
## 1          Vermont  VT     Northeast     625741     2 0.3196211
## 2 New Hampshire  NH     Northeast    1316470     5 0.3798036
## 3           Hawaii  HI          West    1360301     7 0.5145920
## 4     North Dakota  ND North Central     672591     4 0.5947151
## 5             Iowa  IA North Central    3046355    21 0.6893484
## 6            Idaho  ID          West    1567582    12 0.7655102
```

Arrange (descending order)

Note that the default behavior is to order in ascending order. The function **desc** transforms a vector so that it is in descending order. To sort the table in descending order, we can type:

```
murdersRate %>%
  arrange(desc(rate)) %>%
  head()
```

```
##                  state abb        region population total
## 1 District of Columbia  DC         South     601723    99 16.
## 2            Louisiana  LA         South    4533372   351  7.
## 3             Missouri  MO North Central    5988927   321  5.
## 4             Maryland  MD         South    5773552   293  5.
## 5       South Carolina  SC         South    4625364   207  4.
## 6             Delaware  DE         South     897934    38  4.
```

Nested sorting

If we are ordering by a column with ties, we can use a second (or third) column to break the tie. for example:

```
murdersRate %>%
  arrange(region, rate) %>%
  head()
```

```
##              state abb    region population total      rate
## 1          Vermont  VT Northeast     625741     2 0.3196211
## 2 New Hampshire  NH Northeast    1316470     5 0.3798036
## 3            Maine  ME Northeast    1328361    11 0.8280881
## 4     Rhode Island  RI Northeast    1052567    16 1.5200933
## 5    Massachusetts  MA Northeast    6547629   118 1.8021791
## 6         New York  NY Northeast   19378102   517 2.6679599
```

The **summarize** function computes summary statistics in an intuitive way. The 'heights' dataset includes heights and sex reported by students in an in-class survey.

```
data(heights)
heights %>%
  filter(sex == "Female") %>%
  summarize(
    avg = mean(height),
    std_dev = sd(height)
  )
```

```
##          avg  std_dev
## 1 64.93942 3.760656
```

Group then summarize with 'group_by'

A common operation in data exploration is to first split data into groups and then compute summaries for each group. For example, we may want to compute the average and standard deviation for men's and women's heights separately. We can do the following

```
heights %>%
  group_by(sex) %>%
  summarize(
    average = mean(height),
    standard_deviation = sd(height)
  )
```

```
## # A tibble: 2 x 3
##   sex    average standard_deviation
##   <fct>    <dbl>              <dbl>
## 1 Female    64.9               3.76
## 2 Male      69.3               3.61
```

More on the tidyverse

In your homework you will explore a few more tidyverse operations, including the **inner_join**, **left_join**, **pull**, **dot**, and **do** functions, and the **tidyr** package.

Session info

```r
sessionInfo()
```

```
## R version 4.3.2 (2023-10-31)
## Platform: aarch64-apple-darwin20 (64-bit)
## Running under: macOS Ventura 13.5.1
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.3-arm64/Resources/lib/libRlapack.dylib;  LAPACK vers
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## time zone: America/Denver
## tzcode source: internal
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] dslabs_0.7.6    lubridate_1.9.3 forcats_1.0.0   stringr_1.5.0
##  [5] dplyr_1.1.3     purrr_1.0.2     readr_2.1.4     tidyr_1.3.0
##  [9] tibble_3.2.1    ggplot2_3.4.4   tidyverse_2.0.0
##
## loaded via a namespace (and not attached):
##  [1] bit_4.0.5         gtable_0.3.4      crayon_1.5.2      compiler_4.3.2
##  [5] tidyselect_1.2.0  parallel_4.3.2    scales_1.2.1      yaml_2.3.7
##  [9] fastmap_1.1.1     R6_2.5.1          generics_0.1.3    knitr_1.44
## [13] munsell_0.5.0     pillar_1.9.0      tzdb_0.4.0        rlang_1.1.1
## [17] utf8_1.2.4        stringi_1.7.12    xfun_0.40         bit64_4.0.5
## [21] timechange_0.2.0  cli_3.6.1         withr_2.5.2       magrittr_2.0.3
## [25] digest_0.6.33     grid_4.3.2        vroom_1.6.4       rstudioapi_0.15.0
## [29] hms_1.1.3         lifecycle_1.0.3   vctrs_0.6.4       evaluate_0.22
## [33] glue_1.6.2        fansi_1.0.5       colorspace_2.1-0  rmarkdown_2.25
## [37] tools_4.3.2       pkgconfig_2.0.3   htmltools_0.5.6.1
```