Data Science for Economists

Lecture 5: Data cleaning & wrangling: (1) Tidyverse

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Bates College | EC/DCS 368

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Prologue

Housekeeping

- Full version of these slides available on Grant McDermott's website

- Problem Set 2 has been posted and is due 10/9 by Midnight

- Sync your fork, pull the latest changes to your computer

What is "tidy" data?

Resources:

- Vignette (from the **tidyr** package)
- Original paper (Hadley Wickham, 2014 JSS)

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2. Each observation forms a row.
3. Each type of observational unit forms a table.

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Key points:

1. Each variable forms a column.
2. Each observation forms a row.
3. Each type of observational unit forms a table.

Basically, tidy data is more likely to be long (i.e. narrow) format than wide format.

Checklist

R packages you'll need for this lecture

☑ **tidyverse**

☑ **nycflights13**

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The following code chunk will install (if necessary) and load everything for you.

```
if (!require(pacman)) install.packages('pacman', repos = 'https://cran.rstudio.com')
pacman::p_load(tidyverse, data.table, dtplyr, tidyfast, microbenchmark, ggplot2, nycfl
```

Tip: If you're on Linux, then I *strongly* recommend installing the pre-compiled binary versions of these packages from RSPM instead of CRAN. The exact repo mirror varies by distro (see the link). But on Ubuntu 20.04, for example, you'd use:

```
install.packages(c('tidyverse', 'nycflights13','data.table','dtplyr','tidyfast','micro
library(tidyverse)
library(data.table)
#etc.
```

Tidyverse basics

Tidyverse vs. base R

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I won't delve into this debate here, because I think the answer is clear: We should teach the tidyverse first (or, at least, early).

- The documentation and community support are outstanding.
- Having a consistent philosophy and syntax makes it easier to learn.
- Provides a convenient "front-end" to big data tools that we'll use later in the course.
- For data cleaning, wrangling, and plotting, the tidyverse really is a no-brainer.[1]

[1] I'm also a huge fan of **data.table**. This package will be the subject of our next lecture.

Tidyverse vs. base R

Much digital ink has been spilled over the "tidyverse vs. base R" debate.

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- Having a consistent philosophy and syntax makes it easier to learn.
- Provides a convenient "front-end" to big data tools that we'll use later in the course.
- For data cleaning, wrangling, and plotting, the tidyverse really is a no-brainer.[1]

But... this certainly shouldn't put you off learning base R alternatives.

- Base R is extremely flexible and powerful (and stable).
- There are some things that you'll have to venture outside of the tidyverse for.
- A combination of tidyverse and base R is often the best solution to a problem.
- Excellent base R data manipulation tutorials: here and here.

[1] I'm also a huge fan of **data.table**. This package will be the subject of our next lecture.

Tidyverse vs. base R (cont.)

One point of convenience is that there is often a direct correspondence between a tidyverse command and its base R equivalent.

These generally follow a `tidyverse :: snake_case` vs `base :: period.case` rule. E.g. Compare:

tidyverse	base
`?readr :: read_csv`	`?utils :: read.csv`
`?dplyr :: if_else`	`?base :: ifelse`
`?tibble :: tibble`	`?base :: data.frame`

Etcetera.

If you call up the above examples, you'll see that the tidyverse alternative typically offers some enhancements or other useful options (and sometimes restrictions) over its base counterpart.

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tidyverse	base
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Etcetera.

If you call up the above examples, you'll see that the tidyverse alternative typically offers some enhancements or other useful options (and sometimes restrictions) over its base counterpart.

Remember: There are (almost) always multiple ways to achieve a single goal in R.

Tidyverse packages

Let's load the tidyverse meta-package and check the output.

```
library(tidyverse)
```

Tidyverse packages

Let's load the tidyverse meta-package and check the output.

```
library(tidyverse)
```

We see that we have actually loaded a number of packages (which could also be loaded individually): **ggplot2**, **tibble**, **dplyr**, etc.

- We can also see information about the package versions and some namespace conflicts.

Tidyverse packages (cont.)

The tidyverse actually comes with a lot more packages than those that are just loaded automatically.[1]

```
tidyverse_packages()
```

```
##  [1] "broom"        "conflicted"    "cli"        "dbplyr"
##  [5] "dplyr"        "dtplyr"        "forcats"    "ggplot2"
##  [9] "googledrive"  "googlesheets4" "haven"      "hms"
## [13] "httr"         "jsonlite"      "lubridate"  "magrittr"
## [17] "modelr"       "pillar"        "purrr"      "ragg"
## [21] "readr"        "readxl"        "reprex"     "rlang"
## [25] "rstudioapi"   "rvest"         "stringr"    "tibble"
## [29] "tidyr"        "xml2"          "tidyverse"
```

We'll use several of these additional packages during the remainder of this course.

- E.g. The **lubridate** package for working with dates and the **rvest** package for webscraping.
- However, bear in mind that these packages will have to be loaded separately.

[1] It also includes a *lot* of dependencies upon installation. This is a matter of some controversy.

Tidyverse packages (cont.)

I hope to cover most of the tidyverse packages over the length of this course.

Today, however, I'm only really going to focus on two packages:

1. **dplyr**
2. **tidyr**

These are the workhorse packages for cleaning and wrangling data. They are thus the ones that you will likely make the most use of (alongside **ggplot2**, which we already met back in Lecture 1).

- Data cleaning and wrangling occupies an inordinate amount of time, no matter where you are in your research career.

dplyr

dplyr

Note: **dplyr** 1.0.0 also notifies you about grouping variables every time you do operations on or with them. YMMV, but, personally, I find these messages annoying and so prefer to switch them off.

```
options(dplyr.summarise.inform = FALSE) ## Add to .Rprofile to make permanent
```

Key dplyr verbs

There are five key dplyr verbs that you need to learn.

1. `filter`: Filter (i.e. subset) rows based on their values.

2. `arrange`: Arrange (i.e. reorder) rows based on their values.

3. `select`: Select (i.e. subset) columns by their names:

4. `mutate`: Create new columns.

5. `summarise`: Collapse multiple rows into a single summary value.[1]

---

[1] `summarize` with a "z" works too, but Hadley Wickham is from New Sealand.

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Let's practice these commands together using the `starwars` data frame that comes pre-packaged with dplyr.

---

[1] `summarize` with a "z" works too, but Hadley Wickham is from New Sealand.

1) dplyr::filter

We can chain multiple filter commands with the pipe `%>%`[1], or just separate them within a single filter command using commas.

```r
starwars %>%
  filter(
    species == "Human",
    height >= 190
    )
```

```
## # A tibble: 4 × 14
##   name       height  mass hair_color skin_color eye_color birth_year sex   gender
##   <chr>       <int> <dbl> <chr>      <chr>      <chr>          <dbl> <chr> <chr>
## 1 Darth Va…     202   136 none       white      yellow          41.9 male  mascu…
## 2 Qui-Gon …     193    89 brown      fair       blue            92   male  mascu…
## 3 Dooku         193    80 white      fair       brown          102   male  mascu…
## 4 Bail Pre…     191    NA black      tan        brown           67   male  mascu…
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

[1] Pipes were invented by Doug McIlroy in 1964, are widely used in Unix shells (e.g. bash) and other programming languages (e.g. `F#`). They pass the preceding object as the first argument to the following function. In R, they allow you to chain together code in a way that reads from left to right.

1) dplyr::filter *cont.*

Regular expressions work well too.

```
starwars %>%
  filter(grepl("Skywalker", name))
```

```
## # A tibble: 3 × 14
##   name       height  mass hair_color skin_color eye_color birth_year sex    gender
##   <chr>       <int> <dbl> <chr>      <chr>      <chr>          <dbl> <chr>  <chr>
## 1 Luke Sky…     172    77 blond      fair       blue              19 male   mascu…
## 2 Anakin S…     188    84 blond      fair       blue            41.9 male   mascu…
## 3 Shmi Sky…     163    NA black      fair       brown             72 fema…  femin…
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

1) dplyr::filter *cont.*

A very common `filter` use case is identifying (or removing) missing data cases.

```
starwars %>%
  filter(is.na(height))
```

```
## # A tibble: 6 × 14
##    name        height  mass hair_color skin_color eye_color birth_year sex    gender
##    <chr>        <int> <dbl> <chr>      <chr>      <chr>          <dbl> <chr> <chr>
## 1 Arvel Cr…       NA    NA brown      fair       brown             NA male  mascu…
## 2 Finn            NA    NA black      dark       dark              NA male  mascu…
## 3 Rey             NA    NA brown      light      hazel             NA fema… femin…
## 4 Poe Dame…       NA    NA brown      light      brown             NA male  mascu…
## 5 BB8             NA    NA none       none       black             NA none  mascu…
## 6 Captain …       NA    NA unknown    unknown    unknown           NA <NA>  <NA>
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

1) dplyr::filter *cont.*

A very common `filter` use case is identifying (or removing) missing data cases.

```
starwars %>%
  filter(is.na(height))


## # A tibble: 6 × 14
##   name        height  mass hair_color skin_color eye_color birth_year sex    gender
##   <chr>        <int> <dbl> <chr>      <chr>      <chr>           <dbl> <chr>  <chr>
## 1 Arvel Cr…       NA    NA brown      fair       brown              NA male   mascu…
## 2 Finn            NA    NA black      dark       dark               NA male   mascu…
## 3 Rey             NA    NA brown      light      hazel              NA fema…  femin…
## 4 Poe Dame…       NA    NA brown      light      brown              NA male   mascu…
## 5 BB8             NA    NA none       none       black              NA none   mascu…
## 6 Captain …       NA    NA unknown    unknown    unknown            NA <NA>   <NA>
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

To remove missing observations, simply use negation: `filter(!is.na(height))`. Try this yourself.

2) dplyr::arrange

```
starwars %>%
  arrange(birth_year)
```

```
## # A tibble: 87 × 14
##    name       height  mass hair_color skin_color eye_color birth_year sex   gender
##    <chr>       <int> <dbl> <chr>      <chr>      <chr>          <dbl> <chr> <chr>
##  1 Wicket …       88    20 brown      brown      brown              8 male  mascu…
##  2 IG-88         200   140 none       metal      red               15 none  mascu…
##  3 Luke Sk…      172    77 blond      fair       blue              19 male  mascu…
##  4 Leia Or…      150    49 brown      light      brown             19 fema… femin…
##  5 Wedge A…      170    77 brown      fair       hazel             21 male  mascu…
##  6 Plo Koon      188    80 none       orange     black             22 male  mascu…
##  7 Biggs D…      183    84 black      light      brown             24 male  mascu…
##  8 Han Solo      180    80 brown      fair       brown             29 male  mascu…
##  9 Lando C…      177    79 black      dark       brown             31 male  mascu…
## 10 Boba Fe…      183  78.2 black      fair       brown           31.5 male  mascu…
## # i 77 more rows
## # i 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

2) dplyr::arrange

```
starwars %>%
  arrange(birth_year)
```

```
## # A tibble: 87 × 14
##    name        height  mass hair_color skin_color eye_color birth_year sex   gender
##    <chr>        <int> <dbl> <chr>      <chr>      <chr>          <dbl> <chr> <chr>
##  1 Wicket …        88    20 brown      brown      brown              8 male  mascu…
##  2 IG-88          200   140 none       metal      red               15 none  mascu…
##  3 Luke Sk…       172    77 blond      fair       blue              19 male  mascu…
##  4 Leia Or…       150    49 brown      light      brown             19 fema… femin…
##  5 Wedge A…       170    77 brown      fair       hazel             21 male  mascu…
##  6 Plo Koon       188    80 none       orange     black             22 male  mascu…
##  7 Biggs D…       183    84 black      light      brown             24 male  mascu…
##  8 Han Solo       180    80 brown      fair       brown             29 male  mascu…
##  9 Lando C…       177    79 black      dark       brown             31 male  mascu…
## 10 Boba Fe…       183  78.2 black      fair       brown           31.5 male  mascu…
## # ℹ 77 more rows
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

Note: Arranging on a character-based column (i.e. strings) will sort alphabetically. Try this yourself by arranging according to the "name" column.

2) dplyr::arrange *cont.*

We can also arrange items in descending order using `arrange(desc())`.

```
starwars %>%
  arrange(desc(birth_year))
```

```
## # A tibble: 87 × 14
##     name       height  mass hair_color skin_color eye_color birth_year sex    gender
##     <chr>       <int> <dbl> <chr>      <chr>      <chr>          <dbl> <chr>  <chr>
##  1 Yoda           66    17 white      green      brown            896 male   mascu…
##  2 Jabba D…      175  1358 <NA>       green-tan… orange           600 herm… mascu…
##  3 Chewbac…      228   112 brown      unknown    blue             200 male   mascu…
##  4 C-3PO         167    75 <NA>       gold       yellow           112 none   mascu…
##  5 Dooku         193    80 white      fair       brown            102 male   mascu…
##  6 Qui-Gon…      193    89 brown      fair       blue              92 male   mascu…
##  7 Ki-Adi-…      198    82 white      pale       yellow            92 male   mascu…
##  8 Finis V…      170    NA blond      fair       blue              91 male   mascu…
##  9 Palpati…      170    75 grey       pale       yellow            82 male   mascu…
## 10 Cliegg …      183    NA brown      fair       blue              82 male   mascu…
## # ℹ 77 more rows
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

3) dplyr::select

Use commas to select multiple columns out of a data frame. (You can also use "first:last" for consecutive columns). Deselect a column with "-".

```
starwars %>%
  select(name:skin_color, species, -height)
```

```
## # A tibble: 87 × 5
##    name                 mass hair_color    skin_color  species
##    <chr>               <dbl> <chr>         <chr>       <chr>
##  1 Luke Skywalker         77 blond         fair        Human
##  2 C-3PO                  75 <NA>          gold        Droid
##  3 R2-D2                  32 <NA>          white, blue Droid
##  4 Darth Vader           136 none          white       Human
##  5 Leia Organa            49 brown         light       Human
##  6 Owen Lars             120 brown, grey   light       Human
##  7 Beru Whitesun lars     75 brown         light       Human
##  8 R5-D4                  32 <NA>          white, red  Droid
##  9 Biggs Darklighter      84 black         light       Human
## 10 Obi-Wan Kenobi         77 auburn, white fair        Human
## # i 77 more rows
```

3) dplyr::select *cont.*

You can also rename some (or all) of your selected variables in place.

```
starwars %>%
  select(alias=name, crib=homeworld, sex=gender)
```

```
## # A tibble: 87 × 3
##    alias             crib     sex
##    <chr>             <chr>    <chr>
##  1 Luke Skywalker    Tatooine masculine
##  2 C-3PO             Tatooine masculine
##  3 R2-D2             Naboo    masculine
##  4 Darth Vader       Tatooine masculine
##  5 Leia Organa       Alderaan feminine
##  6 Owen Lars         Tatooine masculine
##  7 Beru Whitesun lars Tatooine feminine
##  8 R5-D4             Tatooine masculine
##  9 Biggs Darklighter Tatooine masculine
## 10 Obi-Wan Kenobi    Stewjon  masculine
## # ℹ 77 more rows
```

3) dplyr::select *cont.*

You can also rename some (or all) of your selected variables in place.

```
starwars %>%
  select(alias=name, crib=homeworld, sex=gender)
```

```
## # A tibble: 87 × 3
##    alias              crib     sex
##    <chr>              <chr>    <chr>
##  1 Luke Skywalker     Tatooine masculine
##  2 C-3PO              Tatooine masculine
##  3 R2-D2              Naboo    masculine
##  4 Darth Vader        Tatooine masculine
##  5 Leia Organa        Alderaan feminine
##  6 Owen Lars          Tatooine masculine
##  7 Beru Whitesun lars Tatooine feminine
##  8 R5-D4              Tatooine masculine
##  9 Biggs Darklighter  Tatooine masculine
## 10 Obi-Wan Kenobi     Stewjon  masculine
## # ℹ 77 more rows
```

If you just want to rename columns without subsetting them, you can use `rename`. Try this now by replacing `select( … )` in the above code chunk with `rename( … )`.

3) dplyr::select *cont.*

The `select(contains(PATTERN))` option provides a nice shortcut in relevant cases.

```
starwars %>%
  select(name, contains("color"))
```

```
## # A tibble: 87 × 4
##    name              hair_color    skin_color  eye_color
##    <chr>             <chr>         <chr>       <chr>
##  1 Luke Skywalker    blond         fair        blue
##  2 C-3PO             <NA>          gold        yellow
##  3 R2-D2             <NA>          white, blue red
##  4 Darth Vader       none          white       yellow
##  5 Leia Organa       brown         light       brown
##  6 Owen Lars         brown, grey   light       blue
##  7 Beru Whitesun lars brown        light       blue
##  8 R5-D4             <NA>          white, red  red
##  9 Biggs Darklighter black         light       brown
## 10 Obi-Wan Kenobi    auburn, white fair        blue-gray
## # i 77 more rows
```

4) dplyr::mutate

You can create new columns from scratch, or (more commonly) as transformations of existing columns.

```
starwars %>%
  select(name, birth_year) %>%
  mutate(dog_years = birth_year * 7) %>%
  mutate(comment = paste0(name, " is ", dog_years, " in dog years."))
```

```
## # A tibble: 87 × 4
##    name             birth_year dog_years comment
##    <chr>                 <dbl>     <dbl> <chr>
##  1 Luke Skywalker           19       133 Luke Skywalker is 133 in dog years.
##  2 C-3PO                   112       784 C-3PO is 784 in dog years.
##  3 R2-D2                    33       231 R2-D2 is 231 in dog years.
##  4 Darth Vader            41.9      293. Darth Vader is 293.3 in dog years.
##  5 Leia Organa              19       133 Leia Organa is 133 in dog years.
##  6 Owen Lars                52       364 Owen Lars is 364 in dog years.
##  7 Beru Whitesun lars       47       329 Beru Whitesun lars is 329 in dog yea…
##  8 R5-D4                    NA        NA R5-D4 is NA in dog years.
##  9 Biggs Darklighter        24       168 Biggs Darklighter is 168 in dog year…
## 10 Obi-Wan Kenobi           57       399 Obi-Wan Kenobi is 399 in dog years.
## # i 77 more rows
```

4) dplyr::mutate *cont.*

Note: `mutate` is order aware. So you can chain multiple mutates in a single call.

```
starwars %>%
  select(name, birth_year) %>%
  mutate(
    dog_years = birth_year * 7, ## Separate with a comma
    comment = paste0(name, " is ", dog_years, " in dog years.")
    )
```

```
## # A tibble: 87 × 4
##    name               birth_year dog_years comment
##    <chr>                   <dbl>     <dbl> <chr>
##  1 Luke Skywalker             19       133  Luke Skywalker is 133 in dog years.
##  2 C-3PO                     112       784  C-3PO is 784 in dog years.
##  3 R2-D2                      33       231  R2-D2 is 231 in dog years.
##  4 Darth Vader              41.9      293.  Darth Vader is 293.3 in dog years.
##  5 Leia Organa                19       133  Leia Organa is 133 in dog years.
##  6 Owen Lars                  52       364  Owen Lars is 364 in dog years.
##  7 Beru Whitesun lars         47       329  Beru Whitesun lars is 329 in dog yea…
##  8 R5-D4                      NA        NA  R5-D4 is NA in dog years.
##  9 Biggs Darklighter          24       168  Biggs Darklighter is 168 in dog year…
## 10 Obi-Wan Kenobi             57       399  Obi-Wan Kenobi is 399 in dog years.
## # ℹ 77 more rows
```

4) dplyr::mutate *cont.*

Boolean, logical and conditional operators all work well with `mutate` too.

```r
starwars %>%
  select(name, height) %>%
  filter(name %in% c("Luke Skywalker", "Anakin Skywalker")) %>%
  mutate(tall1 = height > 180) %>%
  mutate(tall2 = ifelse(height > 180, "Tall", "Short")) ## Same effect, but can choose
```

```
## # A tibble: 2 × 4
##   name              height tall1 tall2
##   <chr>              <int> <lgl> <chr>
## 1 Luke Skywalker       172 FALSE Short
## 2 Anakin Skywalker     188 TRUE  Tall
```

4) dplyr::mutate *cont.*

Lastly, combining `mutate` with the `across` feature allows you to easily work on a subset of variables. For example:

```
starwars %>%
  select(name:eye_color) %>%
  mutate(across(where(is.character), \(x) toupper(x))) %>%
  head(5)

## # A tibble: 5 × 6
##   name           height  mass hair_color skin_color  eye_color
##   <chr>           <int> <dbl> <chr>      <chr>       <chr>
## 1 LUKE SKYWALKER    172    77 BLOND      FAIR        BLUE
## 2 C-3PO             167    75 <NA>       GOLD        YELLOW
## 3 R2-D2              96    32 <NA>       WHITE, BLUE RED
## 4 DARTH VADER       202   136 NONE       WHITE       YELLOW
## 5 LEIA ORGANA       150    49 BROWN      LIGHT       BROWN
```

5) dplyr::summarise

Particularly useful in combination with the `group_by` command.

```
starwars %>%
  group_by(species, gender) %>%
  summarise(mean_height = mean(height, na.rm = TRUE))
```

```
## summarise() has grouped output by 'species'. You can override using the
## .groups argument.

## # A tibble: 42 × 3
## # Groups:   species [38]
##    species    gender     mean_height
##    <chr>      <chr>            <dbl>
##  1 Aleena     masculine           79
##  2 Besalisk   masculine          198
##  3 Cerean     masculine          198
##  4 Chagrian   masculine          196
##  5 Clawdite   feminine           168
##  6 Droid      feminine            96
##  7 Droid      masculine          140
##  8 Dug        masculine          112
##  9 Ewok       masculine           88
## 10 Geonosian  masculine          183
## # i 32 more rows
```

5) dplyr::summarise *cont.*

Note that including "na.rm = TRUE" (or, its alias "na.rm = T") is usually a good idea with summarise functions. Otherwise, your output will be missing too.

```r
## Probably not what we want
starwars %>%
  summarise(mean_height = mean(height))


## # A tibble: 1 × 1
##    mean_height
##          <dbl>
## 1           NA


## Much better
starwars %>%
  summarise(mean_height = mean(height, na.rm = TRUE))


## # A tibble: 1 × 1
##    mean_height
##          <dbl>
## 1         174.
```

The same `across` -based workflow that we saw with `mutate` a few slides back also works with `summarise` . For example:

```
starwars %>%
  group_by(species) %>%
  summarise(across(where(is.numeric), \(x) (mean(x, na.rm=T)))) %>%
  head(5)

## # A tibble: 5 × 4
##    species   height  mass birth_year
##    <chr>      <dbl> <dbl>      <dbl>
## 1 Aleena        79    15        NaN
## 2 Besalisk     198   102        NaN
## 3 Cerean       198    82         92
## 4 Chagrian     196   NaN        NaN
## 5 Clawdite     168    55        NaN
```

Other dplyr goodies

`group_by` and `ungroup` : For (un)grouping.

- Particularly useful with the `summarise` and `mutate` commands, as we've already seen.

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- E.g. `starwars %>% filter(gender=="female") %>% pull(height)`

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`pull`: Extract a column from as a data frame as a vector or scalar.

- E.g. `starwars %>% filter(gender=="female") %>% pull(height)`

`count` and `distinct`: Number and isolate unique observations.

- E.g. `starwars %>% count(species)`, or `starwars %>% distinct(species)`
- You could also use a combination of `mutate`, `group_by`, and `n()`, e.g. `starwars %>% group_by(species) %>% mutate(num = n())`.

Other dplyr goodies (cont.)

There are also a whole class of window functions for getting leads and lags, ranking, creating cumulative aggregates, etc.

- See `vignette("window-functions")`.

Other dplyr goodies (cont.)

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- See `vignette("window-functions")`.

The final set of dplyr "goodies" are the family of join operations. However, these are important enough that I want to go over some concepts in a bit more depth...

- We will encounter and practice these many more times as the course progresses.

Joins

One of the mainstays of the dplyr package is merging data with the family join operations.

- `inner_join(df1, df2)`
- `left_join(df1, df2)`
- `right_join(df1, df2)`
- `full_join(df1, df2)`
- `semi_join(df1, df2)`
- `anti_join(df1, df2)`

Joins are how you get Relational Database Managment (RDBM) to work in R.

(See visual depictions of the different join operations here.)

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Joins are how you get Relational Database Managment (RDBM) to work in R.

(See visual depictions of the different join operations here.)

For the simple examples that I'm going to show here, we'll need some data sets that come bundled with the **nycflights13** package.

- Load it now and then inspect these data frames in your own console.

```
library(nycflights13)
flights
planes
```

Joins (cont.)

Let's perform a left join on the flights and planes datasets.

- *Note*: I'm going subset columns after the join, but only to keep text on the slide.

Joins (cont.)

Let's perform a left join on the flights and planes datasets.

- *Note*: I'm going subset columns after the join, but only to keep text on the slide.

```
left_join(flights, planes) %>%
  select(year, month, day, dep_time, arr_time, carrier, flight, tailnum, type, model)
```

```
## Joining with by = join_by(year, tailnum)

## # A tibble: 336,776 × 10
##      year month   day dep_time arr_time carrier flight tailnum type  model
##     <int> <int> <int>    <int>    <int> <chr>    <int> <chr>   <chr> <chr>
##  1  2013     1     1      517      830 UA        1545 N14228  <NA>  <NA>
##  2  2013     1     1      533      850 UA        1714 N24211  <NA>  <NA>
##  3  2013     1     1      542      923 AA        1141 N619AA  <NA>  <NA>
##  4  2013     1     1      544     1004 B6         725 N804JB  <NA>  <NA>
##  5  2013     1     1      554      812 DL         461 N668DN  <NA>  <NA>
##  6  2013     1     1      554      740 UA        1696 N39463  <NA>  <NA>
##  7  2013     1     1      555      913 B6         507 N516JB  <NA>  <NA>
##  8  2013     1     1      557      709 EV        5708 N829AS  <NA>  <NA>
##  9  2013     1     1      557      838 B6          79 N593JB  <NA>  <NA>
## 10  2013     1     1      558      753 AA         301 N3ALAA  <NA>  <NA>
## # ℹ 336,766 more rows
```

Joins (cont.)

(*continued from previous slide*)

Note that dplyr made a reasonable guess about which columns to join on (i.e. columns that share the same name). It also told us its choices:

```
## Joining, by = c("year", "tailnum")
```

However, there's a problem here: the variable "year" does not have a consistent meaning across our joining datasets!

- In one it refers to the *year of flight*, in the other it refers to *year of construction*.

Joins (cont.)

(continued from previous slide)

Note that dplyr made a reasonable guess about which columns to join on (i.e. columns that share the same name). It also told us its choices:

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```

However, there's a problem here: the variable "year" does not have a consistent meaning across our joining datasets!

- In one it refers to the *year of flight*, in the other it refers to *year of construction*.

Luckily, there's an easy way to avoid this problem.

- See if you can figure it out before turning to the next slide.
- Try `?dplyr::join`.

Joins (cont.)

(*continued from previous slide*)

You just need to be more explicit in your join call by using the `by =` argument.

- You can also rename any ambiguous columns to avoid confusion.

```
left_join(
  flights,
  planes %>% rename(year_built = year), ## Not necessary w/ below line, but helpful
  by = "tailnum" ## Be specific about the joining column
  ) %>%
  select(year, month, day, dep_time, arr_time, carrier, flight, tailnum, year_built, t
  head(3) ## Just to save vertical space on the slide
```

```
## # A tibble: 3 × 11
##    year month   day dep_time arr_time carrier flight tailnum year_built type
##   <int> <int> <int>    <int>    <int> <chr>    <int> <chr>        <int> <chr>
## 1  2013     1     1      517      830 UA        1545 N14228        1999 Fixed w…
## 2  2013     1     1      533      850 UA        1714 N24211        1998 Fixed w…
## 3  2013     1     1      542      923 AA        1141 N619AA        1990 Fixed w…
## # ℹ 1 more variable: model <chr>
```

Joins (cont.)

(*continued from previous slide*)

Last thing I'll mention for now; note what happens if we again specify the join column... but don't rename the ambiguous "year" column in at least one of the given data frames.

```
left_join(
  flights,
  planes, ## Not renaming "year" to "year_built" this time
  by = "tailnum"
) %>%
  select(contains("year"), month, day, dep_time, arr_time, carrier, flight, tailnum, 
  head(3)
```

```
## # A tibble: 3 × 11
##   year.x year.y month   day dep_time arr_time carrier flight tailnum type  model
##    <int>  <int> <int> <int>    <int>    <int> <chr>    <int> <chr>   <chr> <chr>
## 1   2013   1999     1     1      517      830 UA        1545 N14228  Fixe… 737-…
## 2   2013   1998     1     1      533      850 UA        1714 N24211  Fixe… 737-…
## 3   2013   1990     1     1      542      923 AA        1141 N619AA  Fixe… 757-…
```

Joins (cont.)

(*continued from previous slide*)

Last thing I'll mention for now; note what happens if we again specify the join column... but don't rename the ambiguous "year" column in at least one of the given data frames.

```
left_join(
  flights,
  planes, ## Not renaming "year" to "year_built" this time
  by = "tailnum"
  ) %>%
  select(contains("year"), month, day, dep_time, arr_time, carrier, flight, tailnum, 1
  head(3)
```

```
## # A tibble: 3 × 11
##   year.x year.y month   day dep_time arr_time carrier flight tailnum type  model
##    <int>  <int> <int> <int>    <int>    <int> <chr>    <int> <chr>   <chr> <chr>
## 1   2013   1999     1     1      517      830 UA        1545 N14228  Fixe… 737-…
## 2   2013   1998     1     1      533      850 UA        1714 N24211  Fixe… 737-…
## 3   2013   1990     1     1      542      923 AA        1141 N619AA  Fixe… 757-…
```

Make sure you know what "year.x" and "year.y" are. Again, it pays to be specific.

tidyr

Key tidyr verbs

1. `pivot_longer`: Pivot wide data into long format (i.e. "melt").[1]

2. `pivot_wider`: Pivot long data into wide format (i.e. "cast").[2]

3. `separate`: Separate (i.e. split) one column into multiple columns.

4. `unite`: Unite (i.e. combine) multiple columns into one.

---

[1] Updated version of `tidyr :: gather`.

[2] Updated version of `tidyr :: spread`.

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Let's practice these verbs together in class.

- Side question: Which of `pivot_longer` vs `pivot_wider` produces "tidy" data?

[1] Updated version of `tidyr::gather`.

[2] Updated version of `tidyr::spread`.

1) tidyr::pivot_longer

```
stocks = data.frame( ## Could use "tibble" instead of "data.frame" if you prefer
  time = as.Date('2009-01-01') + 0:1,
  X = rnorm(2, 0, 1),
  Y = rnorm(2, 0, 2),
  Z = rnorm(2, 0, 4)
  )
stocks
```

```
##          time          X         Y         Z
## 1 2009-01-01 0.02307661 -2.082060 -2.217609
## 2 2009-01-02 1.24565052 -3.450151  6.013777
```

```
stocks %>% pivot_longer(-time, names_to="stock", values_to="price")
```

```
## # A tibble: 6 × 3
##   time       stock   price
##   <date>     <chr>   <dbl>
## 1 2009-01-01 X       0.0231
## 2 2009-01-01 Y      -2.08
## 3 2009-01-01 Z      -2.22
## 4 2009-01-02 X       1.25
## 5 2009-01-02 Y      -3.45
## 6 2009-01-02 Z       6.01
```

1) tidyr::pivot_longer *cont.*

Let's quickly save the "tidy" (i.e. long) stocks data frame for use on the next slide.

```r
## Write out the argument names this time: i.e. "names_to=" and "values_to="
tidy_stocks =
  stocks %>%
  pivot_longer(-time, names_to="stock", values_to="price")
```

2) tidyr::pivot_wider

```
tidy_stocks %>% pivot_wider(names_from=stock, values_from=price)
```

```
## # A tibble: 2 × 4
##   time              X      Y      Z
##   <date>        <dbl>  <dbl>  <dbl>
## 1 2009-01-01 0.0231  -2.08  -2.22
## 2 2009-01-02 1.25    -3.45   6.01
```

```
tidy_stocks %>% pivot_wider(names_from=time, values_from=price)
```

```
## # A tibble: 3 × 3
##   stock 2009-01-01  2009-01-02
##   <chr>       <dbl>       <dbl>
## 1 X          0.0231        1.25
## 2 Y         -2.08         -3.45
## 3 Z         -2.22          6.01
```

2) tidyr::pivot_wider

```
tidy_stocks %>% pivot_wider(names_from=stock, values_from=price)


## # A tibble: 2 × 4
##   time          X     Y     Z
##   <date>      <dbl> <dbl> <dbl>
## 1 2009-01-01 0.0231 -2.08 -2.22
## 2 2009-01-02 1.25   -3.45  6.01


tidy_stocks %>% pivot_wider(names_from=time, values_from=price)


## # A tibble: 3 × 3
##   stock 2009-01-01  2009-01-02
##   <chr>      <dbl>       <dbl>
## 1 X         0.0231        1.25
## 2 Y         -2.08        -3.45
## 3 Z         -2.22         6.01
```

Note that the second example — which has combined different pivoting arguments — has effectively transposed the data.

Aside: Remembering the pivot_* syntax

There's a long-running joke about no-one being able to remember Stata's "reshape" command. (Exhibit A.)

It's easy to see this happening with the `pivot_*` functions too. However, I find that I never forget the commands as long as I remember the argument order is *"names"* then *"values"*.

3) tidyr::separate

```
economists = data.frame(name = c("Adam.Smith", "Paul.Samuelson", "Milton.Friedman"))
economists
```

```
##                name
## 1      Adam.Smith
## 2  Paul.Samuelson
## 3 Milton.Friedman
```

```
economists %>% separate(name, c("first_name", "last_name"))
```

```
##   first_name last_name
## 1       Adam     Smith
## 2       Paul Samuelson
## 3     Milton  Friedman
```

3) tidyr::separate

```
economists = data.frame(name = c("Adam.Smith", "Paul.Samuelson", "Milton.Friedman"))
economists
```

```
##               name
## 1      Adam.Smith
## 2  Paul.Samuelson
## 3 Milton.Friedman
```

```
economists %>% separate(name, c("first_name", "last_name"))
```

```
##   first_name last_name
## 1       Adam     Smith
## 2       Paul Samuelson
## 3     Milton  Friedman
```

This command is pretty smart. But to avoid ambiguity, you can also specify the separation character with `separate( ... , sep=".")`.

3) tidyr::separate *cont.*

A related function is `separate_rows`, for splitting up cells that contain multiple fields or observations (a frustratingly common occurence with survey data).

```
jobs = data.frame(
  name = c("Jack", "Jill"),
  occupation = c("Homemaker", "Philosopher, Philanthropist, Troublemaker")
  )
jobs
```

```
##   name                                    occupation
## 1 Jack                                     Homemaker
## 2 Jill Philosopher, Philanthropist, Troublemaker
```

```
## Now split out Jill's various occupations into different rows
jobs %>% separate_rows(occupation)
```

```
## # A tibble: 4 × 2
##   name  occupation
##   <chr> <chr>
## 1 Jack  Homemaker
## 2 Jill  Philosopher
## 3 Jill  Philanthropist
## 4 Jill  Troublemaker
```

4) tidyr::unite

```r
gdp = data.frame(
  yr = rep(2016, times = 4),
  mnth = rep(1, times = 4),
  dy = 1:4,
  gdp = rnorm(4, mean = 100, sd = 2)
  )
gdp
```

```
##      yr mnth dy      gdp
## 1 2016    1  1  98.78633
## 2 2016    1  2  98.44948
## 3 2016    1  3  95.33033
## 4 2016    1  4 101.95293
```

```r
## Combine "yr", "mnth", and "dy" into one "date" column
gdp %>% unite(date, c("yr", "mnth", "dy"), sep = "-")
```

```
##        date       gdp
## 1 2016-1-1  98.78633
## 2 2016-1-2  98.44948
## 3 2016-1-3  95.33033
## 4 2016-1-4 101.95293
```

4) tidyr::unite *cont.*

Note that `unite` will automatically create a character variable. You can see this better if we convert it to a tibble.

```
gdp_u = gdp %>% unite(date, c("yr", "mnth", "dy"), sep = "-") %>% as_tibble()
gdp_u
```

```
## # A tibble: 4 × 2
##   date        gdp
##   <chr>     <dbl>
## 1 2016-1-1   98.8
## 2 2016-1-2   98.4
## 3 2016-1-3   95.3
## 4 2016-1-4  102.
```

4) tidyr::unite *cont.*

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gdp_u
```

```
## # A tibble: 4 × 2
##   date        gdp
##   <chr>     <dbl>
## 1 2016-1-1   98.8
## 2 2016-1-2   98.4
## 3 2016-1-3   95.3
## 4 2016-1-4  102.
```

If you want to convert it to something else (e.g. date or numeric) then you will need to modify it using `mutate`. See the next slide for an example, using the lubridate package's super helpful date conversion functions.

4) tidyr::unite *cont.*

(continued from previous slide)

```r
library(lubridate)
gdp_u %>% mutate(date = ymd(date))
```

```
## # A tibble: 4 × 2
##   date            gdp
##   <date>        <dbl>
## 1 2016-01-01   98.8
## 2 2016-01-02   98.4
## 3 2016-01-03   95.3
## 4 2016-01-04  102.
```

Summary

Key verbs

dplyr

1. `filter`
2. `arrange`
3. `select`
4. `mutate`
5. `summarise`

tidyr

1. `pivot_longer`
2. `pivot_wider`
3. `separate`
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Other useful items include: pipes (`%>%`), grouping (`group_by`), joining functions (`left_join`, `inner_join`, etc.).

Next lecture: Data cleaning and wrangling: (2) data.table