

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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Key points:

1. Each variable forms a column.
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, nycflights13)
```

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', 'microbenchmark', 'ggplot2'),
  lib = '~/RSPM/ubuntu20.04',
  library = TRUE)
```

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```
install.packages(c('tidyverse', 'nycflights13', 'data.table', 'dtplyr', 'tidyfast', 'microbenchmark', 'ggplot2'),
  lib = '~/RSPM',
  library = TRUE)
```

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.

¹ However, bear in mind that these packages will have to be loaded separately.
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 Zealand.

Key dplyr verbs

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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

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 Zealand.

1) dplyr::filter

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

```
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...
## # 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

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  masculi  
## 2 IG-88         200  140  none       metal      red          15  none  masculi  
## 3 Luke Sk...    172   77  blond      fair       blue         19  male  masculi  
## 4 Leia Or...    150   49  brown      light      brown         19  fema... femin...  
## 5 Wedge A...    170   77  brown      fair       hazel         21  male  masculi  
## 6 Plo Koon     188   80  none       orange     black         22  male  masculi  
## 7 Biggs D...    183   84  black      light      brown         24  male  masculi  
## 8 Han Solo     180   80  brown      fair       brown         29  male  masculi  
## 9 Lando C...    177   79  black      dark       brown         31  male  masculi  
## 10 Boba Fe...   183  78.2  black      fair       brown        31.5  male  masculi  
## # 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       293.3 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        293.3 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.

```
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), toupper)) %>%  
  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.

```
## 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.
```

5) dplyr::summarise cont.

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), mean, na.rm=T)) %>%  
  head(5)
```

```
## Warning: There was 1 warning in summarise().  
## i In argument: across(where(is.numeric), mean, na.rm = T).  
## i In group 1: species = "Aleena".  
## Caused by warning:  
## ! The ... argument of across() is deprecated as of dplyr 1.1.0.  
## Supply arguments directly to .fns through an anonymous function instead.  
##  
## # Previously  
##   across(a:b, mean, na.rm = TRUE)  
##  
## # Now  
##   across(a:b, \(x) mean(x, na.rm = TRUE))  
  
## # A tibble: 5 × 4  
##   species height mass birth_year  
##   <chr>    <dbl> <dbl>    <dbl>
```

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

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`slice`: Subset rows by position rather than filtering by values.

- E.g. `starwars %>% slice(c(1, 5))`

Other dplyr goodies

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

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

`slice`: Subset rows by position rather than filtering by values.

- E.g. `starwars %>% slice(c(1, 5))`

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

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

Other dplyr goodies

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

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

`slice`: Subset rows by position rather than filtering by values.

- E.g. `starwars %>% slice(c(1, 5))`

`pull`: Extract a column from 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 Management (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 Management (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, 1
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, 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-...
```

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.

```
## 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 occurrence 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

```
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
```

```
## 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.

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.
```

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)

```
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`
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1. `pivot_longer`
2. `pivot_wider`
3. `separate`
4. `unite`

Other useful items include: pipes (`%>%`), grouping (`group_by`), joining functions (`left_join`, `inner_join`, etc.).

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