Welcome to the tidyverse

Week 2

AEM 2850 / 5850 : R for Business Analytics

Cornell Dyson

Spring 2024

Acknowledgements: Grant McDermott, Allison Horst

Announcements

If you are new to the class, please review canvas and course site

Prelim dates: Feb 29 and May 7 in class

TA office hours: Mondays, exact time still TBD, starting next week

My office hours: Tuesdays 11:30 - 12:30 in Warren 464; aem2850.youcanbook.me

- Caveat: I cannot hold office hours today

Other reminders:

- Bookmark the schedule and visit often
- Submit assignments via canvas by Monday at 11:59pm going forward

Questions before we get started?

Plan for today

Prologue

Tidyverse basics

- tibbles and pipes

Data transformation with dplyr

- select
- filter
- arrange
- mutate
- summarize
- other goodies

Prologue

How we feel about the course, in a few words

- excited
- feeling great
- nervous but looking forward to it

Where we're from

How can we use your 76 survey responses to construct our origin story without having to read them one by one?

- **Caveat:** This is based on submissions as of 14:31 Monday

We can use R for this!

I won't go through details now

By the end of the course you should be able to do this kind of thing easily

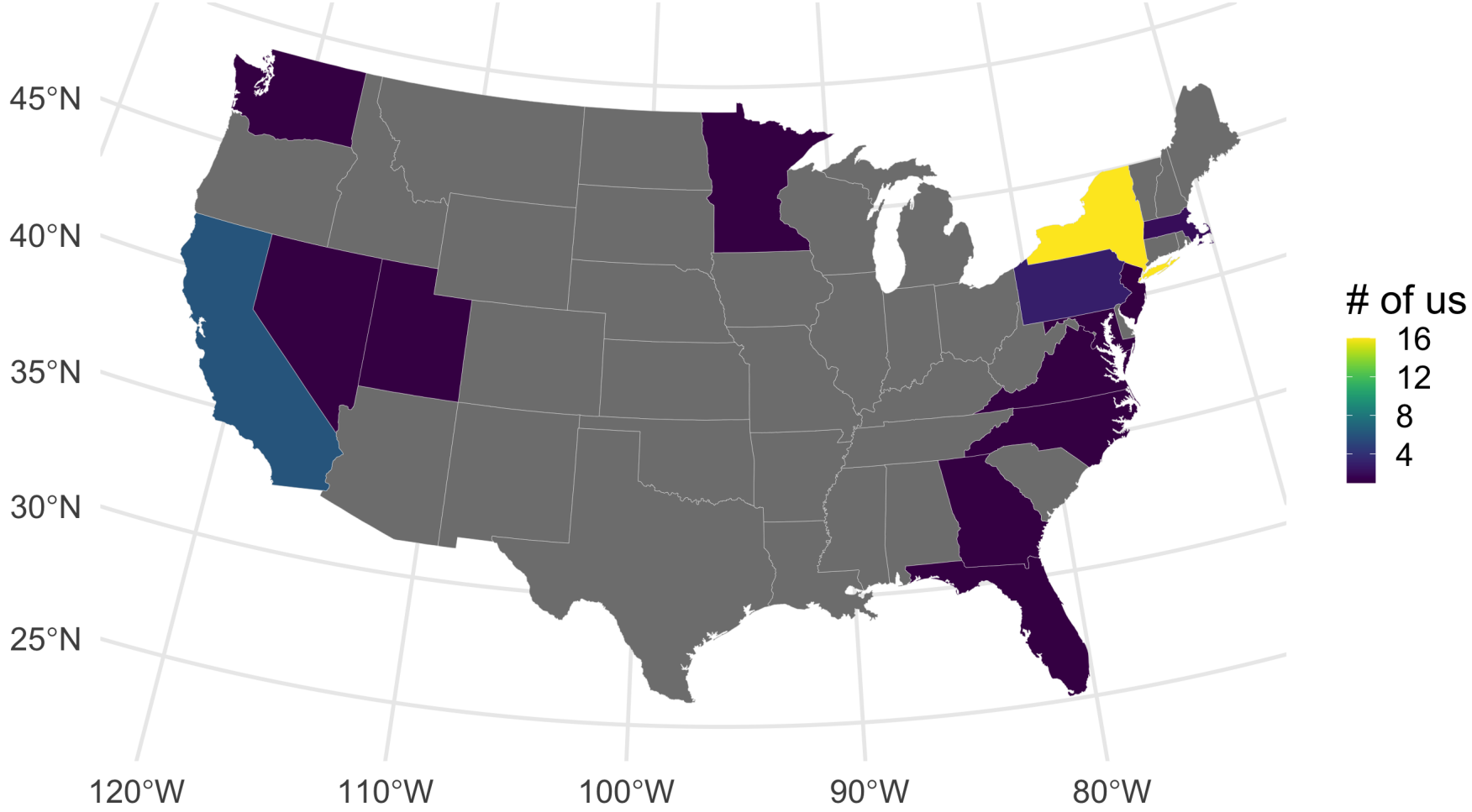
Are we all from New York?

What share of us are from the state of New York?

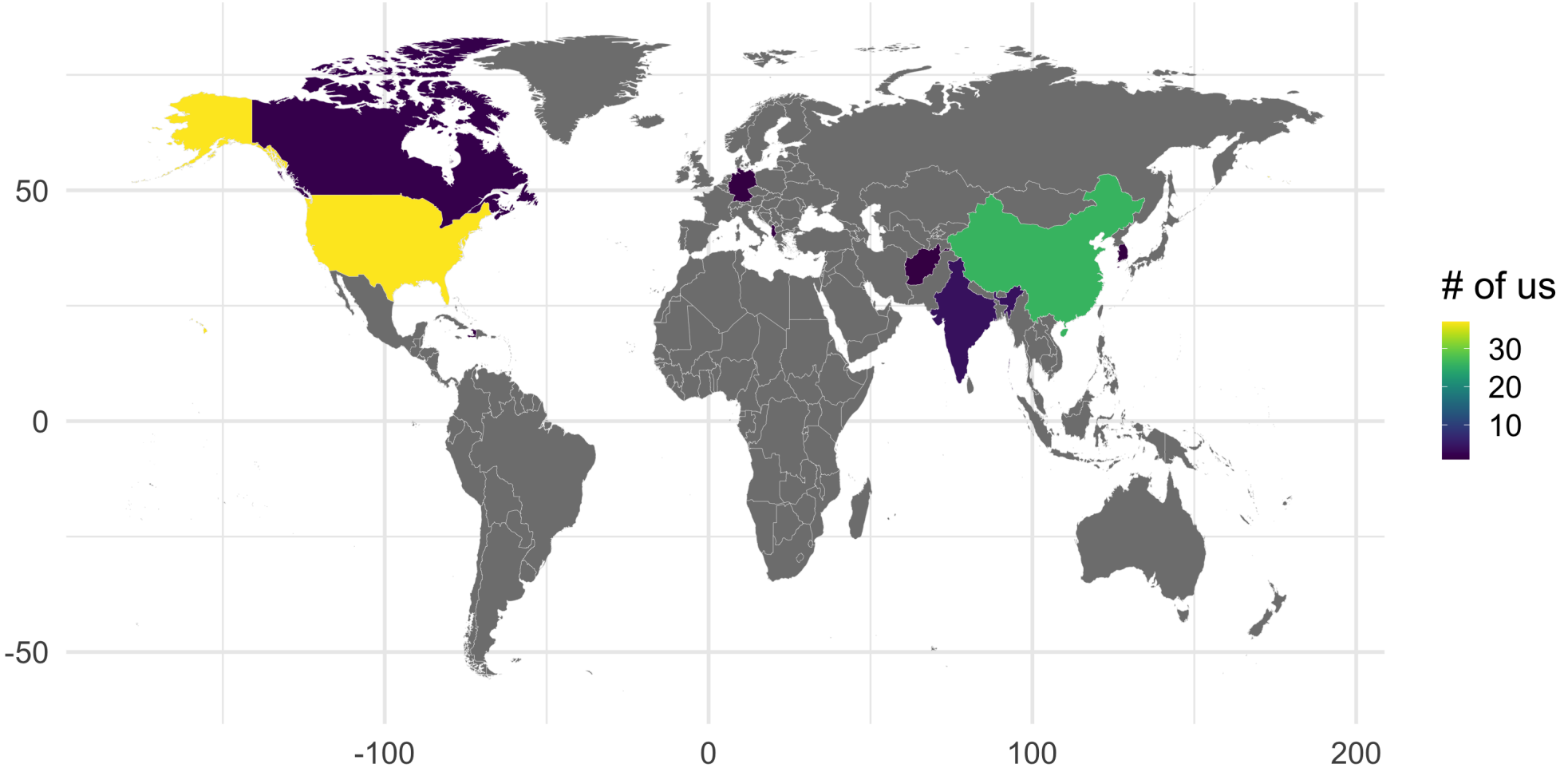
```
# step 1: do a bunch of stuff that's omitted for clarity
# step 2: show us the answer!
ny_share
```

```
## # A tibble: 1 × 2
##   origin   percent
##   <chr>      <dbl>
## 1 new york    20.8
```

Are we all from New York?



Are we all from the U.S.?



Tidyverse basics

R "dialects"

Last week we *briefly* introduced several R programming concepts:

- logical expressions
- assignment
- object types
- [object names, namespace conflicts]
- [indexing]

We did this using base R

- **pro:** comes in the box, close parallels to other programming languages
- **con:** can be confusing for new programmers (esp. indexing operations)

R "dialects"

This course will primarily use the tidyverse

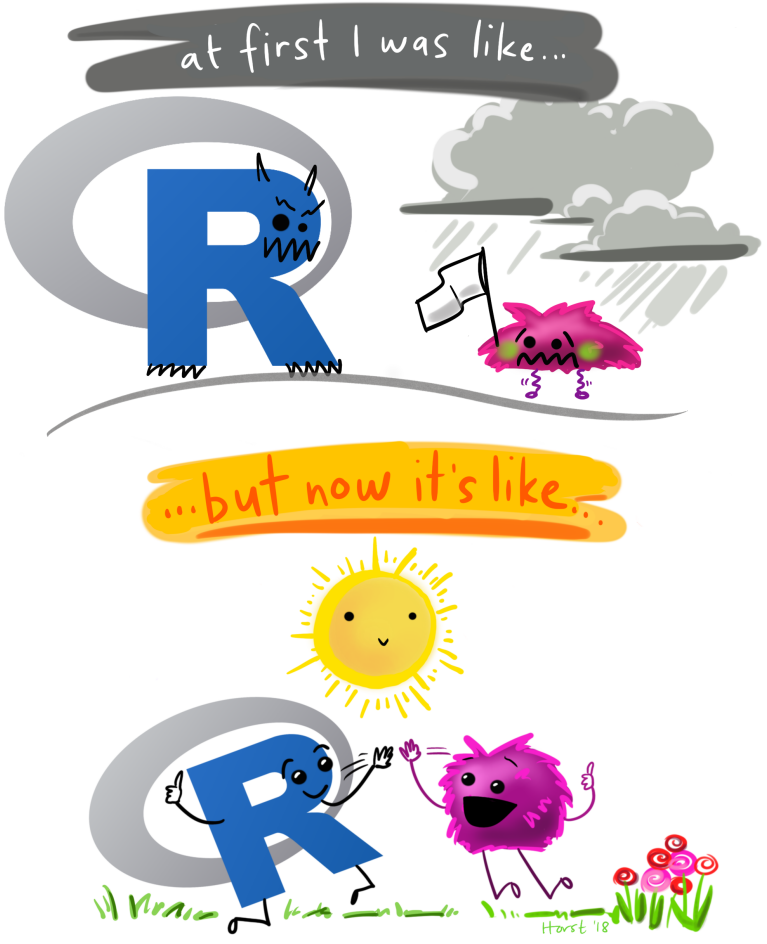
You can think of it as a particular "dialect" of R

This dialect is similar to human language

Intuitive if you're new to programming

Not representative of all R programming

Base R and `data.table` are alternative "dialects"



Tidyverse vs. base R

Lots of debate over tidyverse vs. base R

Why we're using the tidyverse:

- Consistent philosophy and syntax
- Great documentation and community support
- For data wrangling and plotting, tidyverse is 🔥

Base R is still great, can do some things tidyverse can't

data.table is another great alternative for data wrangling

Tidyverse vs. base R

Often a correspondence between tidyverse and base R commands:

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

Tidyverse alternatives typically offer extra features

Remember: There are always multiple ways to do something in R

Let's load the tidyverse meta-package

```
library(tidyverse)
```

```
## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
## ✔ dplyr     1.1.4     ✔ readr     2.1.5
## ✔ forcats   1.0.0     ✔ stringr   1.5.1
## ✔ ggplot2   3.4.4     ✔ tibble    3.2.1
## ✔ lubridate 1.9.3     ✔ tidyr     1.3.0
## ✔ purrr     1.0.2
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## ✖ dplyr::filter() masks stats::filter()
## ✖ dplyr::lag()    masks stats::lag()
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

We just loaded a bunch of packages: **ggplot2**, **dplyr**, **tidyr**, **tibble**, etc.

We also see some **namespace conflicts**

Tidyverse packages

When you install the tidyverse, you actually get a lot more packages:

```
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"
```

These other packages have to be loaded separately

Tidyverse packages

Today we'll focus on **dplyr**

But first let's talk about tibbles and pipes

Review: What are objects?

There are many different *types* (or *classes*) of objects

Here are some objects that we'll be working with regularly:

- vectors
- matrices
- data frames
- lists
- functions

Data frames

The most important object we'll work with is the **data frame**

You can think of it as an Excel spreadsheet

```
# Create a small data frame called "d"
d <- data.frame(x = 1:2, y = 3:4)
d
```

```
##   x y
## 1 1 3
## 2 2 4
```

This is essentially just a table with columns named x and y

Each row is an observation telling us the values of both x and y

Tibbles are data frames with opinions

For this class you can think of tibbles and data frames as synonymous

Tibbles have some advantages, such as pretty printing

We will primarily use tibbles in this course

Two functions may come in handy:

- `as_tibble()` converts data frames to tibbles
- `tibble()` creates new tibbles from scratch

See `vignette("tibble")` for more

Printing a data.frame

```
as.data.frame(starwars)
```

```
##                    name height   mass    hair_color          skin_color
## 1           Luke Skywalker    172   77.0         blond                fair
## 2                    C-3PO    167   75.0          <NA>                gold
## 3                    R2-D2     96   32.0          <NA>         white, blue
## 4              Darth Vader    202  136.0          none               white
## 5              Leia Organa    150   49.0         brown               light
## 6                Owen Lars    178  120.0   brown, grey               light
## 7       Beru Whitesun Lars    165   75.0         brown               light
## 8                    R5-D4     97   32.0          <NA>          white, red
## 9        Biggs Darklighter    183   84.0         black               light
## 10         Obi-Wan Kenobi    182   77.0 auburn, white                fair
## 11       Anakin Skywalker    188   84.0         blond                fair
## 12         Wilhuff Tarkin    180     NA  auburn, grey                fair
## 13              Chewbacca    228  112.0         brown             unknown
## 14               Han Solo    180   80.0         brown                fair
## 15                 Greedo    173   74.0          <NA>               green
## 16 Jabba Desilijic Tiure    175 1358.0          <NA>   green-tan, brown
## 17        Wedge Antilles    170   77.0         brown                fair
## 18      Jek Tono Porkins    180  110.0         brown                fair
## 19                  Yoda     66   17.0         white               green
```

How could we make this look nicer?

```
as.data.frame(starwars)
```

```
##                    name height   mass    hair_color          skin_color
## 1           Luke Skywalker    172   77.0         blond                fair
## 2                  C-3PO    167   75.0          <NA>                gold
## 3                  R2-D2     96   32.0          <NA>         white, blue
## 4              Darth Vader    202  136.0          none               white
## 5              Leia Organa    150   49.0         brown               light
## 6                Owen Lars    178  120.0   brown, grey               light
## 7       Beru Whitesun Lars    165   75.0         brown               light
## 8                  R5-D4     97   32.0          <NA>          white, red
## 9        Biggs Darklighter    183   84.0         black               light
## 10         Obi-Wan Kenobi    182   77.0 auburn, white                fair
## 11       Anakin Skywalker    188   84.0         blond                fair
## 12         Wilhuff Tarkin    180     NA  auburn, grey                fair
## 13              Chewbacca    228  112.0         brown             unknown
## 14              Han Solo    180   80.0         brown                fair
## 15                 Greedo    173   74.0          <NA>               green
## 16 Jabba Desilijic Tiure    175 1358.0          <NA>   green-tan, brown
## 17        Wedge Antilles    170   77.0         brown                fair
## 18      Jek Tono Porkins    180  110.0         brown                fair
## 19                  Yoda     66   17.0         white               green
```

Printing a data.frame with head()

```
head(as.data.frame(starwars))
```

```
##             name height mass  hair_color  skin_color eye_color birth_year
## 1 Luke Skywalker    172   77       blond        fair      blue       19.0
## 2          C-3PO    167   75        <NA>        gold    yellow      112.0
## 3          R2-D2     96   32        <NA> white, blue       red       33.0
## 4    Darth Vader    202  136        none       white    yellow       41.9
## 5    Leia Organa    150   49       brown       light     brown       19.0
## 6      Owen Lars    178  120 brown, grey       light      blue       52.0
##      sex    gender homeworld species
## 1   male masculine  Tatooine   Human
## 2   none masculine  Tatooine   Droid
## 3   none masculine     Naboo   Droid
## 4   male masculine  Tatooine   Human
## 5 female  feminine  Alderaan   Human
## 6   male masculine  Tatooine   Human
##
## 1                                          A New Hope, The Empire Strikes Back, Return of the Jedi, Re
## 2                    A New Hope, The Empire Strikes Back, Return of the Jedi, The Phantom Menace, Attac
## 3 A New Hope, The Empire Strikes Back, Return of the Jedi, The Phantom Menace, Attack of the Clones, Re
## 4                                                                A New Hope, The Empire Strikes Back, Ret
## 5                                          A New Hope, The Empire Strikes Back, Return of the Jedi, Re
```

This still doesn't look very nice...

```
head(as.data.frame(starwars))
```

```
##             name height mass  hair_color  skin_color eye_color birth_year
## 1 Luke Skywalker    172   77       blond        fair      blue       19.0
## 2          C-3PO    167   75        <NA>        gold    yellow      112.0
## 3          R2-D2     96   32        <NA> white, blue       red       33.0
## 4    Darth Vader    202  136        none       white    yellow       41.9
## 5    Leia Organa    150   49       brown       light     brown       19.0
## 6      Owen Lars    178  120 brown, grey       light      blue       52.0
##      sex    gender homeworld species
## 1   male masculine  Tatooine   Human
## 2   none masculine  Tatooine   Droid
## 3   none masculine     Naboo   Droid
## 4   male masculine  Tatooine   Human
## 5 female  feminine  Alderaan   Human
## 6   male masculine  Tatooine   Human
##
## 1                                          A New Hope, The Empire Strikes Back, Return of the Jedi, Re
## 2                    A New Hope, The Empire Strikes Back, Return of the Jedi, The Phantom Menace, Attac
## 3 A New Hope, The Empire Strikes Back, Return of the Jedi, The Phantom Menace, Attack of the Clones, Re
## 4                                                                A New Hope, The Empire Strikes Back, Ret
## 5                                          A New Hope, The Empire Strikes Back, Return of the Jedi, Re
```

Printing a tibble

```
starwars
```

```
## # 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 Luke Sk…    172    77 blond      fair       blue             19   male  mascu…
##  2 C-3PO       167    75 <NA>       gold       yellow          112   none  mascu…
##  3 R2-D2        96    32 <NA>       white, bl… red              33   none  mascu…
##  4 Darth V…    202   136 none       white      yellow           41.9 male  mascu…
##  5 Leia Or…    150    49 brown      light      brown            19   fema… femin…
##  6 Owen La…    178   120 brown, gr… light      blue             52   male  mascu…
##  7 Beru Wh…    165    75 brown      light      blue             47   fema… femin…
##  8 R5-D4        97    32 <NA>       white, red red              NA   none  mascu…
##  9 Biggs D…    183    84 black      light      brown            24   male  mascu…
## 10 Obi-Wan…    182    77 auburn, w… fair       blue-gray        57   male  mascu…
## # ℹ 77 more rows
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

Pipes

Generic programming question: Does anyone know what pipes do?

Pipes allow us to pass information through a sequence of operations

The tidyverse loads the `magrittr` pipe, denoted `%>%`

R now has a native pipe, denoted `|>` (since R version 4.1.0)

They are identical for simple cases, but have some differences

We will use `|>` in class

Keyboard shortcut: use `Ctrl/Cmd+Shift+m` to insert the pipe (with spaces)

- You can set the RStudio keyboard shortcut to use either `%>%` or `|>`

Pipe usage

To see why using pipes is so powerful, consider this contrived example based on what we did this morning:

1. Wake up
2. Get out of bed
3. Get dressed
4. Drink coffee
5. Go to class

A day without pipes

You could code this through a series of assignment operations:

```
me <- wake_up(me)
me <- get_out_of_bed(me)
me <- get_dressed(me)
me <- drink(me, "coffee")
me <- go(me, "class")
```

Or by putting all these operations in a single line of code:

```
me <- go(drink(get_dressed(get_out_of_bed(wake_up(me))), "coffee"), "class")
```

Neither is ideal

Pipes are the best of both worlds

We can do everything at once, in order:

```
me |>
  wake_up() |>
  get_out_of_bed() |>
  get_dressed() |>
  drink("coffee") |>
  go("class")
```

Emphasis is on verbs (e.g., `wake_up`, `get_out_of_bed`, etc.), not nouns (i.e., `me`)

Pipes: Best practices

Write linear code

Spread code out for readability: use one line per verb

Don't use pipes...

- when you need more than 10 (use intermediate objects instead)
- for multiple inputs or outputs
- for non-linear relationships

Reminder: `|>` and `%>%` can both be used, though they have some important differences for more advanced work. We will us `|>` in this class.

dplyr

What is dplyr?

What is dplyr?

The dplyr package provides a **grammar of data manipulation**

dplyr's functions are **verbs** that correspond to things we want to **do**

dplyr functions all have these things in common:

1. their first argument is a data frame
2. their other arguments describe what you want to do
3. their output is a new data frame

1 + **3** + **pipes** allow us to combine simple steps to achieve complex results

dplyr has five key verbs we will use

1. `filter`: subset rows based on their values
2. `arrange`: reorder rows based on their values
3. `select`: select columns (i.e., variables)
4. `mutate`: create new columns
5. `summarize`: collapse multiple rows into a single summary value

dplyr verbs operate on different things

- Rows:
  - `filter`: subset rows based on their values
  - `arrange`: reorder rows based on their values
- Columns:
  - `select`: select columns (i.e., variables)
  - `mutate`: create new columns
- Groups of rows:
  - `summarize`: collapse multiple rows into a single summary value

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

Starwars

This is what the `starwars` dataset looks like:

```
starwars
```

```
## # 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 Luke Sk…    172    77 blond      fair       blue             19   male  mascu…
##  2 C-3PO       167    75 <NA>       gold       yellow          112   none  mascu…
##  3 R2-D2        96    32 <NA>       white, bl… red              33   none  mascu…
##  4 Darth V…    202   136 none       white      yellow           41.9 male  mascu…
##  5 Leia Or…    150    49 brown      light      brown            19   fema… femin…
##  6 Owen La…    178   120 brown, gr… light      blue             52   male  mascu…
##  7 Beru Wh…    165    75 brown      light      blue             47   fema… femin…
##  8 R5-D4        97    32 <NA>       white, red red              NA   none  mascu…
##  9 Biggs D…    183    84 black      light      brown            24   male  mascu…
## 10 Obi-Wan…    182    77 auburn, w… fair       blue-gray        57   male  mascu…
## # ℹ 77 more rows
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

1) dplyr::select

`select` allows us to select columns / variables:

```
starwars |> select(name)
```

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

`select` returns a tibble even though you only asked for one variable

To get a vector, you can use:

- `starwars |> pull(name)`

1) dplyr::select

You can get fancy: use commas to select multiple columns, deselect a column using "-", and select consecutive columns using "first:last"

```
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
```

1) dplyr::select

You can also rename your selected variables at the same time:

```
starwars |>
  select(alias = name, crib = homeworld)
```

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

1) dplyr::select

If you just want to rename columns without subsetting them, use `rename`:

```
starwars |>
  rename(alias = name, crib = homeworld)
```

```
## # A tibble: 87 × 14
##    alias    height  mass hair_color skin_color eye_color birth_year sex   gender
##    <chr>     <int> <dbl> <chr>      <chr>      <chr>           <dbl> <chr> <chr>
##  1 Luke Sk…    172    77 blond      fair       blue             19   male  mascu…
##  2 C-3PO       167    75 <NA>       gold       yellow          112   none  mascu…
##  3 R2-D2        96    32 <NA>       white, bl… red              33   none  mascu…
##  4 Darth V…    202   136 none       white      yellow           41.9 male  mascu…
##  5 Leia Or…    150    49 brown      light      brown            19   fema… femin…
##  6 Owen La…    178   120 brown, gr… light      blue             52   male  mascu…
##  7 Beru Wh…    165    75 brown      light      blue             47   fema… femin…
##  8 R5-D4        97    32 <NA>       white, red red              NA   none  mascu…
##  9 Biggs D…    183    84 black      light      brown            24   male  mascu…
## 10 Obi-Wan…    182    77 auburn, w… fair       blue-gray        57   male  mascu…
## # ℹ 77 more rows
## # ℹ 5 more variables: crib <chr>, species <chr>, films <list>, vehicles <list>,
## #   starships <list>
```

1) dplyr::select

`select(contains(PATTERN))` provides a handy shortcut:

```
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
```

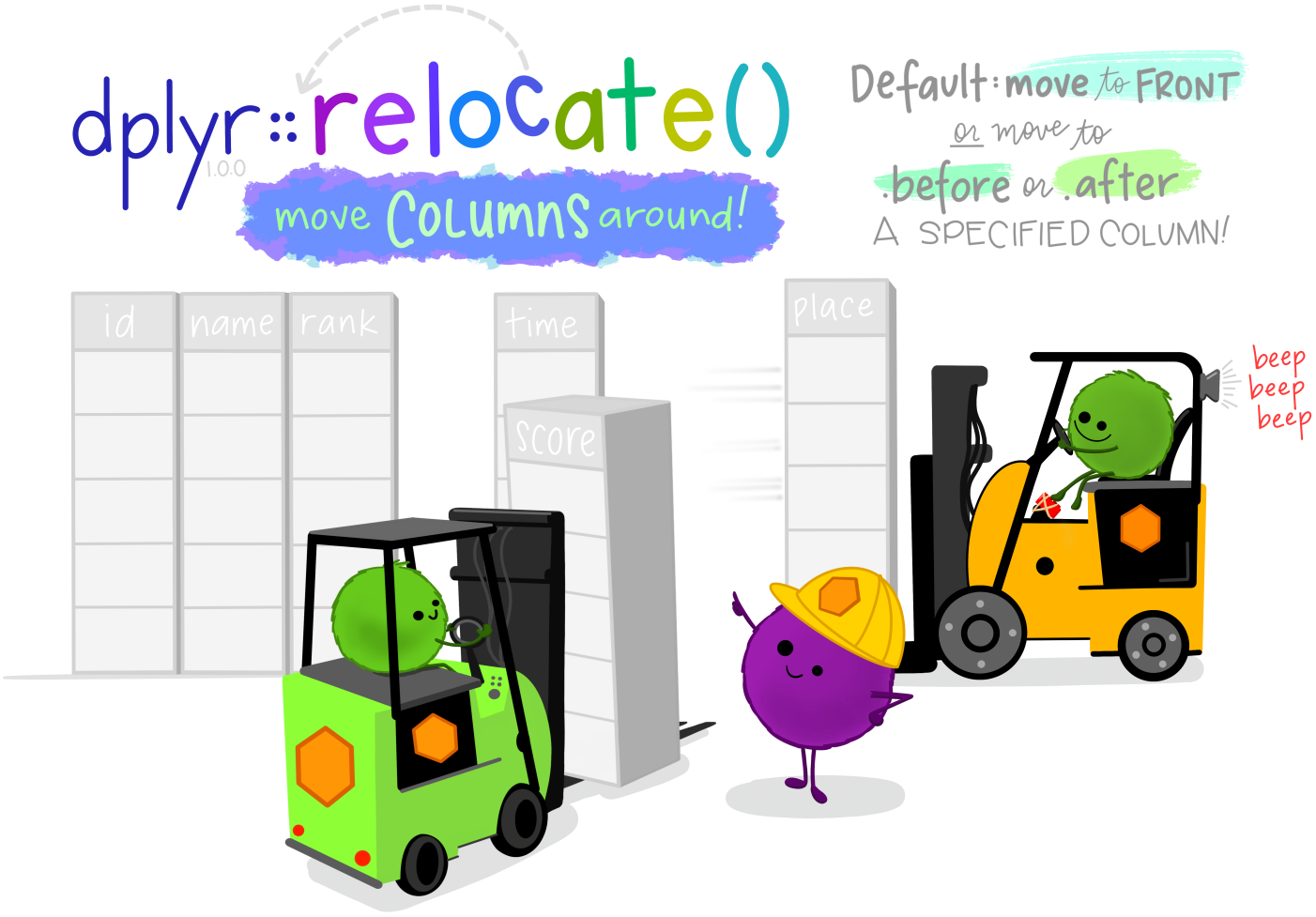
1) dplyr::~~select~~ relocate

You can also use `relocate` to move important variables to the "front" of a data frame without subsetting:

```
starwars |>
  relocate(species, homeworld) |>
  head(5)
```

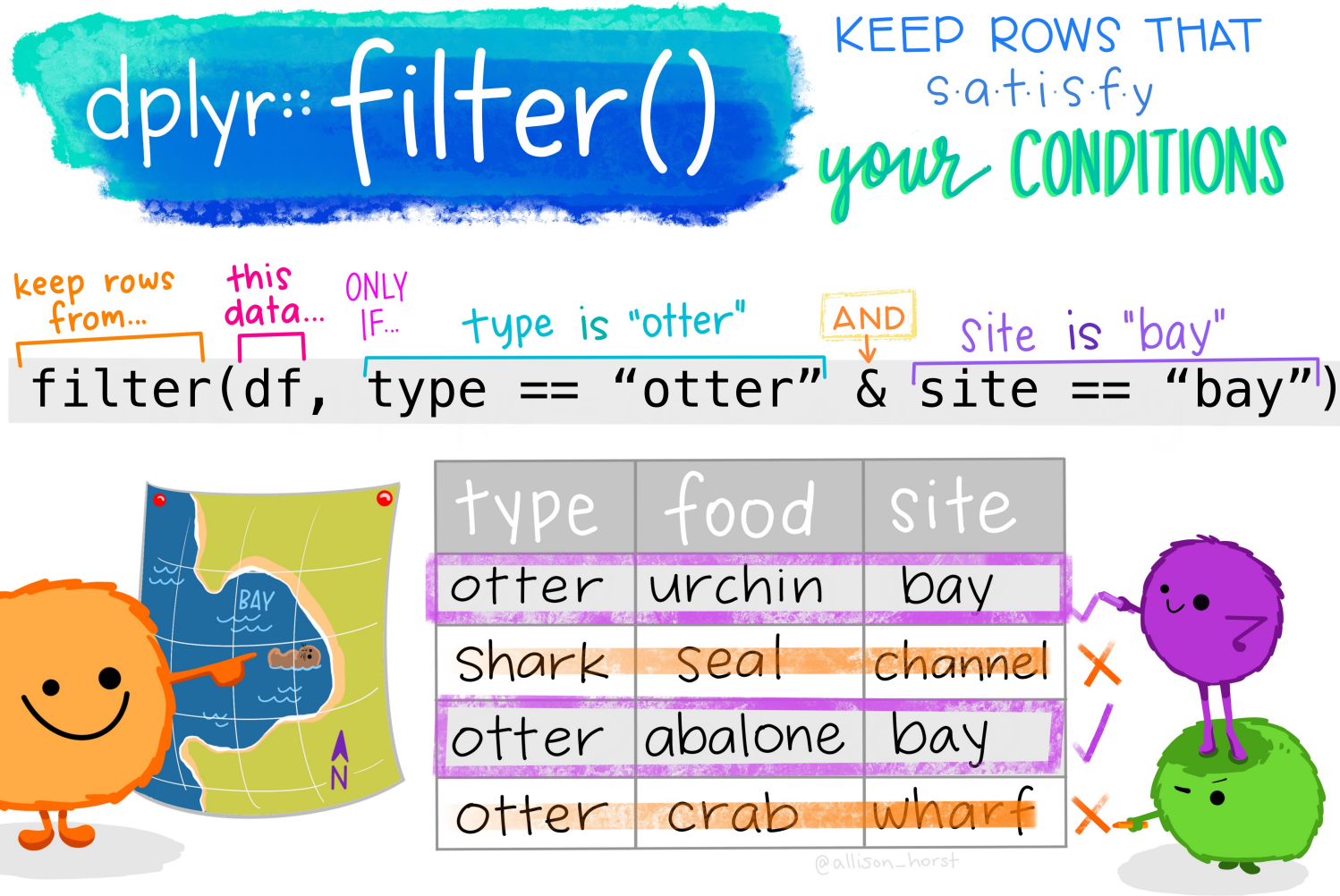
```
## # A tibble: 5 × 14
##   species homeworld name           height  mass hair_color skin_color  eye_color
##   <chr>   <chr>     <chr>           <int> <dbl> <chr>      <chr>       <chr>
## 1 Human   Tatooine  Luke Skywalker    172    77 blond      fair        blue
## 2 Droid   Tatooine  C-3PO             167    75 <NA>       gold        yellow
## 3 Droid   Naboo     R2-D2              96    32 <NA>       white, blue red
## 4 Human   Tatooine  Darth Vader       202   136 none       white       yellow
## 5 Human   Alderaan  Leia Organa       150    49 brown      light       brown
## # ℹ 6 more variables: birth_year <dbl>, sex <chr>, gender <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

1) dplyr::~~select~~ relocate



Let's work through an example on Posit Cloud

2) dplyr::filter



2) dplyr::filter

`filter` allows us to focus on certain rows / observations

For example, you may only be interested in droids:

```
starwars |>
  filter(species == "Droid")
```

```
## # 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 C-3PO     167    75 <NA>       gold        yellow            112 none  masculi…
## 2 R2-D2      96    32 <NA>       white, blue red                33 none  masculi…
## 3 R5-D4      97    32 <NA>       white, red  red                NA none  masculi…
## 4 IG-88     200   140 none       metal       red                15 none  masculi…
## 5 R4-P17     96    NA none       silver, red red, blue          NA none  feminine
## 6 BB8        NA    NA none       none        black              NA none  masculi…
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

2) dplyr::filter

Or perhaps you want to subset the humans that are taller than I am:

```
starwars |>
  filter(
    species == "Human",
    height >= 194
    )
```

Can you name one? *Hint: there's only one*

```
## # A tibble: 1 × 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…
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

2) dplyr::filter

Regular expressions work here too, with the help of the `stringr` package:

```
starwars |>
  filter(str_detect(name, "Skywalker"))
```

```
## # 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>
```

2) dplyr::filter

A common `filter` use case is identifying/removing missing data using `is.na`:

```
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 none       none       unknown            NA fema… femin…
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

2) dplyr::filter

How could you build on this to remove rows with missing data?

```
starwars |>
  filter(!is.na(height)) # use ! for negation
```

```
## # A tibble: 81 × 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 Sk…    172    77 blond      fair       blue             19   male  mascu…
##  2 C-3PO       167    75 <NA>       gold       yellow          112   none  mascu…
##  3 R2-D2        96    32 <NA>       white, bl… red              33   none  mascu…
##  4 Darth V…    202   136 none       white      yellow           41.9 male  mascu…
##  5 Leia Or…    150    49 brown      light      brown            19   fema… femin…
##  6 Owen La…    178   120 brown, gr… light      blue             52   male  mascu…
##  7 Beru Wh…    165    75 brown      light      blue             47   fema… femin…
##  8 R5-D4        97    32 <NA>       white, red red              NA   none  mascu…
##  9 Biggs D…    183    84 black      light      brown            24   male  mascu…
## 10 Obi-Wan…    182    77 auburn, w… fair       blue-gray        57   male  mascu…
## # ℹ 71 more rows
## # ℹ 5 more variables: homeworld <chr>, species <chr>, films <list>,
## #   vehicles <list>, starships <list>
```

3) dplyr::arrange

`arrange` sorts the data frame based on the variable(s) you supply:

```
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>
```

3) dplyr::arrange

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>
```

4) dplyr::mutate

4) dplyr::mutate

You can create new columns from scratch or by transforming existing columns:

```
starwars |>
  select(name, birth_year) |>
  mutate(dog_years = birth_year * 7)
```

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

4) dplyr::mutate

You can create new columns from scratch or by transforming existing columns:

```
starwars |>
  select(name, birth_year) |>
  mutate(dog_years = birth_year * 7) |>
  mutate(comment = str_glue("{name} is {dog_years} in dog years.")) # or could use paste()
```

```
## # A tibble: 87 × 4
##    name               birth_year dog_years comment
##    <chr>                   <dbl>     <dbl> <glue>
##  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

`mutate` creates variables in order, so we can chain them together in a single call:

```
starwars |>
  select(name, birth_year) |>
  mutate(dog_years = birth_year * 7, # separate with a comma
         comment = str_glue("{name} is {dog_years} in dog years."))
```

```
## # A tibble: 87 × 4
##    name               birth_year dog_years comment
##    <chr>                   <dbl>     <dbl> <glue>
##  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

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

```
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 labels
```

How many rows do you think this will return? How many columns?

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

5) dplyr::summarize

Often we want to get summary statistics or *collapse* our data

`summarize` provides an easy way to do this

Example: "What are the mininum, maximum, and average prices of `diamonds`?"

```
diamonds |>
  summarize(min = min(price),       # calculate the min price
            max = max(price),       # calculate the max price
            average = mean(price)) # calculate the mean price
```

```
## # A tibble: 1 × 3
##     min   max average
##   <int> <int>   <dbl>
## 1   326 18823   3933.
```

5) dplyr::summarize

Including `na.rm = TRUE` keeps NAs from propagating to the end result:

```
# probably not what we want
starwars |>
  summarize(mh = mean(height))
```

```
## # A tibble: 1 × 1
##      mh
##   <dbl>
## 1    NA
```

```
# better
starwars |>
  summarize(mh = mean(height, na.rm = TRUE))
```

```
## # A tibble: 1 × 1
##      mh
##   <dbl>
## 1  175.
```

Is this a feature or a bug?

It depends on the context!

Bonus: dplyr::group_by

`summarize` is particularly useful in combination with `group_by`:

```
starwars |>
  group_by(species, gender) |> # for each species-gender combo
  summarize(mean_height = mean(height, na.rm = TRUE)) |> # calculate the mean height
  head() # then just print the first 6 rows for clarity
```

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

```
## # A tibble: 6 × 3
## # Groups:   species [6]
##   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
```

Bonus: dplyr::ungroup

Groups are persistent (sort of), `ungroup` removes them

Other dplyr goodies for your reference

Other dplyr goodies: count

`count` to get the number of observations:

```
starwars |>
  count(species)
```

```
## # A tibble: 38 × 2
##    species       n
##    <chr>     <int>
##  1 Aleena        1
##  2 Besalisk      1
##  3 Cerean        1
##  4 Chagrian      1
##  5 Clawdite      1
##  6 Droid         6
##  7 Dug           1
##  8 Ewok          1
##  9 Geonosian     1
## 10 Gungan        3
## # ℹ 28 more rows
```

```
starwars |>
  group_by(species) |> summarize(num = n())
```

```
## # A tibble: 38 × 2
##    species     num
##    <chr>     <int>
##  1 Aleena        1
##  2 Besalisk      1
##  3 Cerean        1
##  4 Chagrian      1
##  5 Clawdite      1
##  6 Droid         6
##  7 Dug           1
##  8 Ewok          1
##  9 Geonosian     1
## 10 Gungan        3
## # ℹ 28 more rows
```

Other dplyr goodies: distinct

`distinct` to isolate unique observations:

```
starwars |> distinct(species)
```

```
## # A tibble: 38 × 1
##    species
##    <chr>
##  1 Human
##  2 Droid
##  3 Wookiee
##  4 Rodian
##  5 Hutt
##  6 <NA>
##  7 Yoda's species
##  8 Trandoshan
##  9 Mon Calamari
## 10 Ewok
## # ℹ 28 more rows
```

Other dplyr goodies: window functions

Window functions make it easy to get leads and lags, percentiles, cumulative sums, etc.

- These are often used in conjunction with grouped mutates
- See `vignette("window-functions")`

The final set of dplyr "goodies" worth mentioning are the family of join operations, but we'll come back to those later