Data Management with the `tidyverse`

Adapted from parts of Mine Çetinkaya-Rundel's tidyverse course

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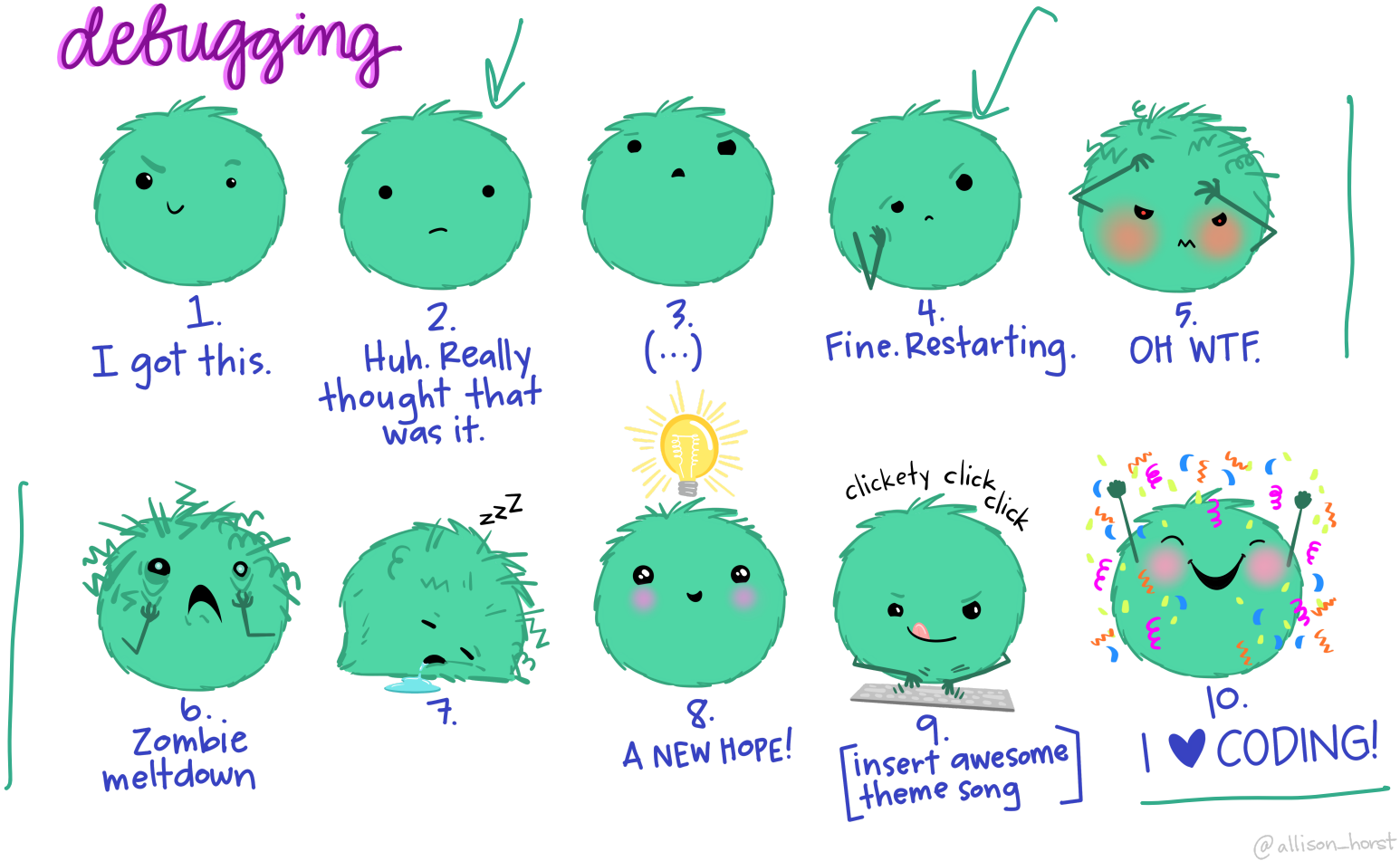
Slides Overview

- Introduction to the `tidyverse`
- `ggplot2` revisited
- Functions for data management
- Data manipulation
- Summarizing Data
- Resources



Artwork by @allison_horst

Introduction to the `tidyverse`


SPIDER-MAN
INTO THE SPIDER-VERSE

What is the tidyverse?

The **tidyverse** is a collection of R packages designed for data science. All packages share an underlying design philosophy, grammar, and data structures.

- **ggplot2** - data visualisation
- **dplyr** - data manipulation
- **tidyr** - tidy data
- **readr** - read rectangular data
- **purrr** - functional programming
- **tibble** - modern data frames
- **stringr** - string manipulation
- **forcats** - factors
- and many more …

Tidy data[1]

1. Each variable must have its own column.
2. Each observation must have its own row.
3. Each value must have its own cell.

Pipe operator (`magrittr`)

- The pipe operator (`%>%`) allows us to step through sequential functions in the same way we follow if-then statements or steps from instructions

> I want to find my keys, then start my car, then drive to work, then park my car.

Nested Base R

```
park(drive(start_car(find("keys")),
           to = "work"))
```

Piped

```
find("keys") %>%
  start_car() %>%
  drive(to = "work") %>%
  park()
```

Recoding a binary variable with pipe operator

Let's say I want a variable `transmission` to show the category names that are assigned to numeric values in the code. I want `0` to be coded as `automatic` and `1` to be coded as `manual`.

Base R:

```
mtcars$transmission <-
  ifelse(
    mtcars$am == 0,
    "automatic",
    "manual"
  )
```

Tidyverse:

```
mtcars <- mtcars %>%
  mutate(
    transmission = case_when(
      am == 0 ~ "automatic",
      am == 1 ~ "manual"
    )
  )
```

automatic / manual

`mutate()` creates new columns that are functions of existing variables

Recoding a multi-level variable

Let's say I want a variable `gear` to show the category names that are assigned to numeric values in the code. I want `3` to be coded as gear `three`, `4` to be coded as gear `four`, `5` to be coded as gear `five`.

Base R:

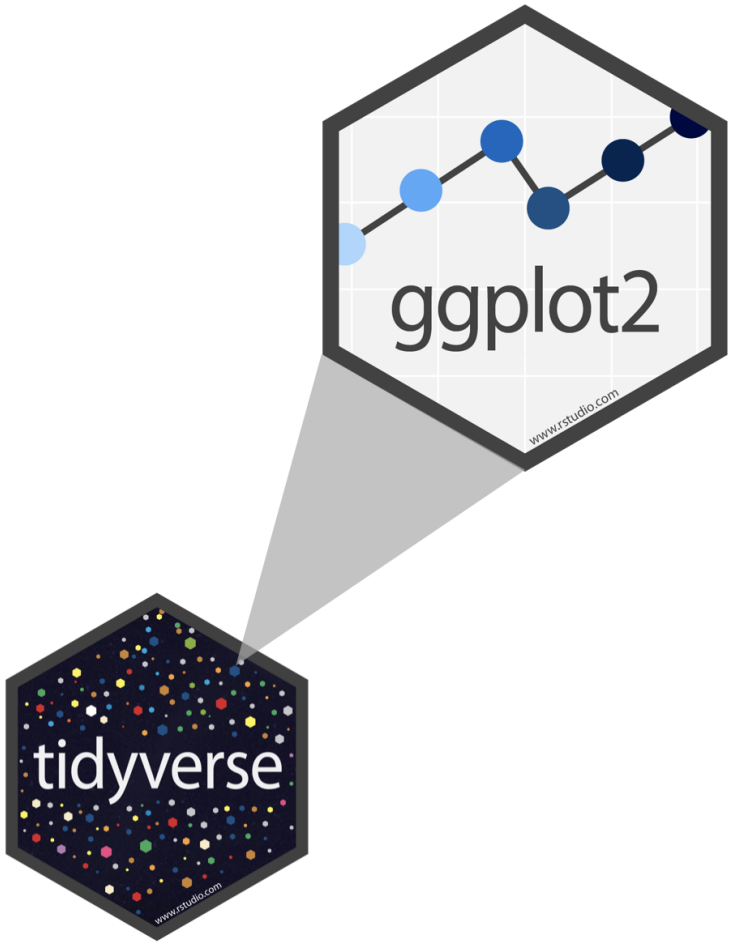
```
mtcars$gear_char <-
  ifelse(
    mtcars$gear == 3,
    "three",
    ifelse(
      mtcars$gear == 4,
      "four",
      "five"
    )
  )
```

Tidyverse:

```
mtcars <- mtcars %>%
  mutate(
    gear_char = case_when(
      gear == 3 ~ "three",
      gear == 4 ~ "four",
      gear == 5 ~ "five"
    )
  )
```

`ggplot2` revisited

ggplot2 in tidyverse



- We talked about this in our review notes
  - I want to revisit it: always helps to have more examples!
  - This example is closer to the multivariable work we'll do in this class!

- **ggplot2** is tidyverse's data visualization package

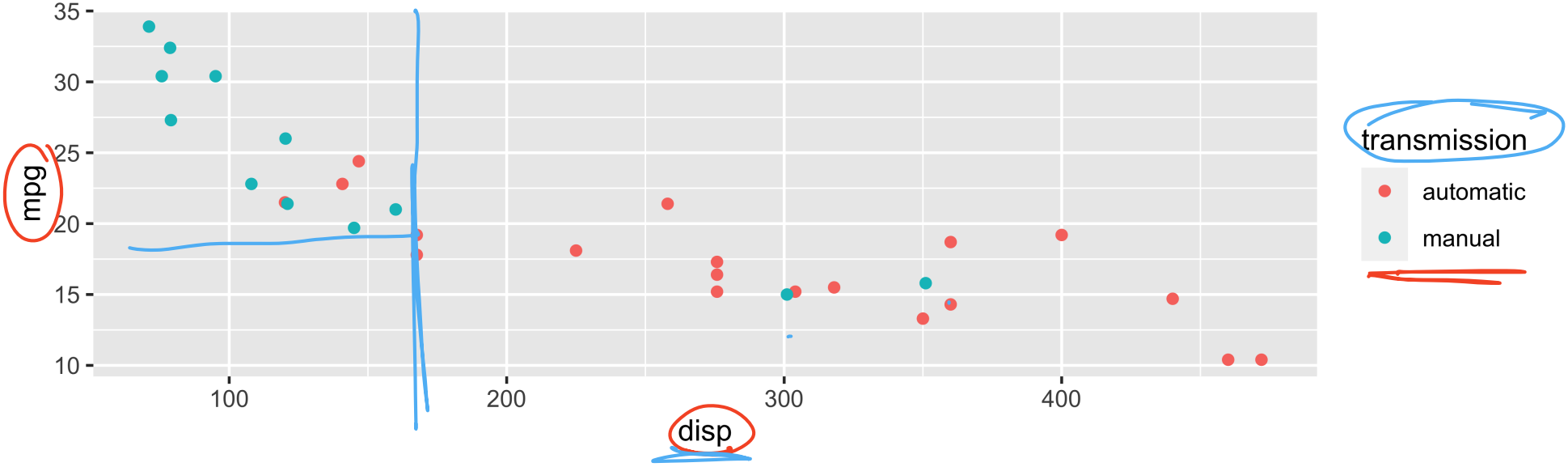
- The gg in "ggplot2" stands for Grammar of Graphics

- It is inspired by the book **Grammar of Graphics** by Leland Wilkinson

Tidyverse: Visualizing multiple variables

engine displacement = disp

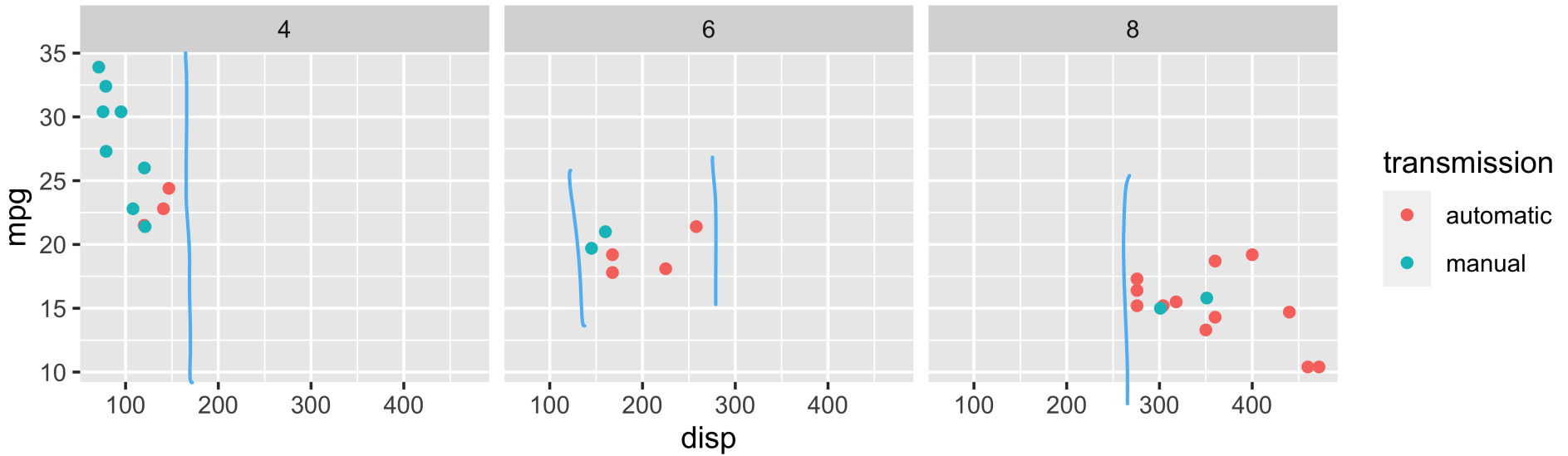
```
1 ggplot(
2   mtcars,
3   aes(x = disp, y = mpg, color = transmission)) +
4   geom_point()
```



Poll Everywhere Question 1

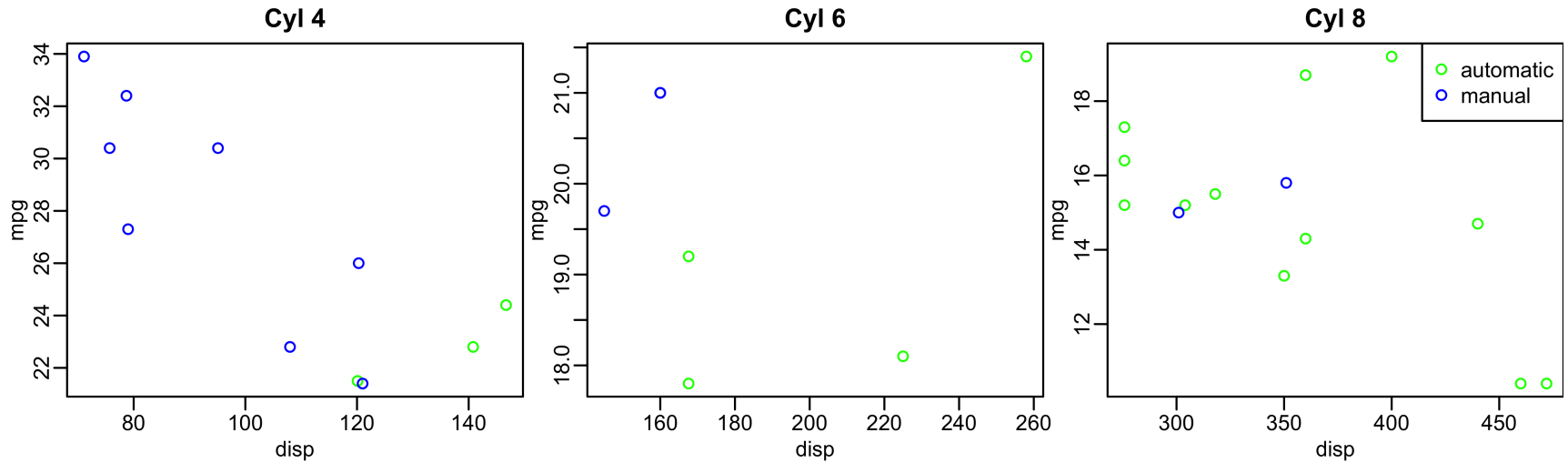
Tidyverse: Visualizing even more variables

```
1 ggplot(
2   mtcars,
3   aes(x = disp, y = mpg, color = transmission)) +
4   geom_point() +
5   facet_wrap(~ cyl)
```



Base R: Visualizing even more variables

```r
mtcars$trans_color <- ifelse(mtcars$transmission == "automatic", "green", "blue")
mtcars_cyl4 = mtcars[mtcars$cyl == 4, ]
mtcars_cyl6 = mtcars[mtcars$cyl == 6, ]
mtcars_cyl8 = mtcars[mtcars$cyl == 8, ]
par(mfrow = c(1, 3), mar = c(2.5, 2.5, 2, 0), mgp = c(1.5, 0.5, 0))
plot(mpg ~ disp, data = mtcars_cyl4, col = trans_color, main = "Cyl 4")
plot(mpg ~ disp, data = mtcars_cyl6, col = trans_color, main = "Cyl 6")
plot(mpg ~ disp, data = mtcars_cyl8, col = trans_color, main = "Cyl 8")
legend("topright", legend = c("automatic", "manual"), pch = 1, col = c("green", "bl
```



Functions for data management

Important functions for data management

Data manipulation

- `pivot_longer()` and `pivot_wider()`
- `rename()`
- `mutate()`
- `filter()`
- `select()`

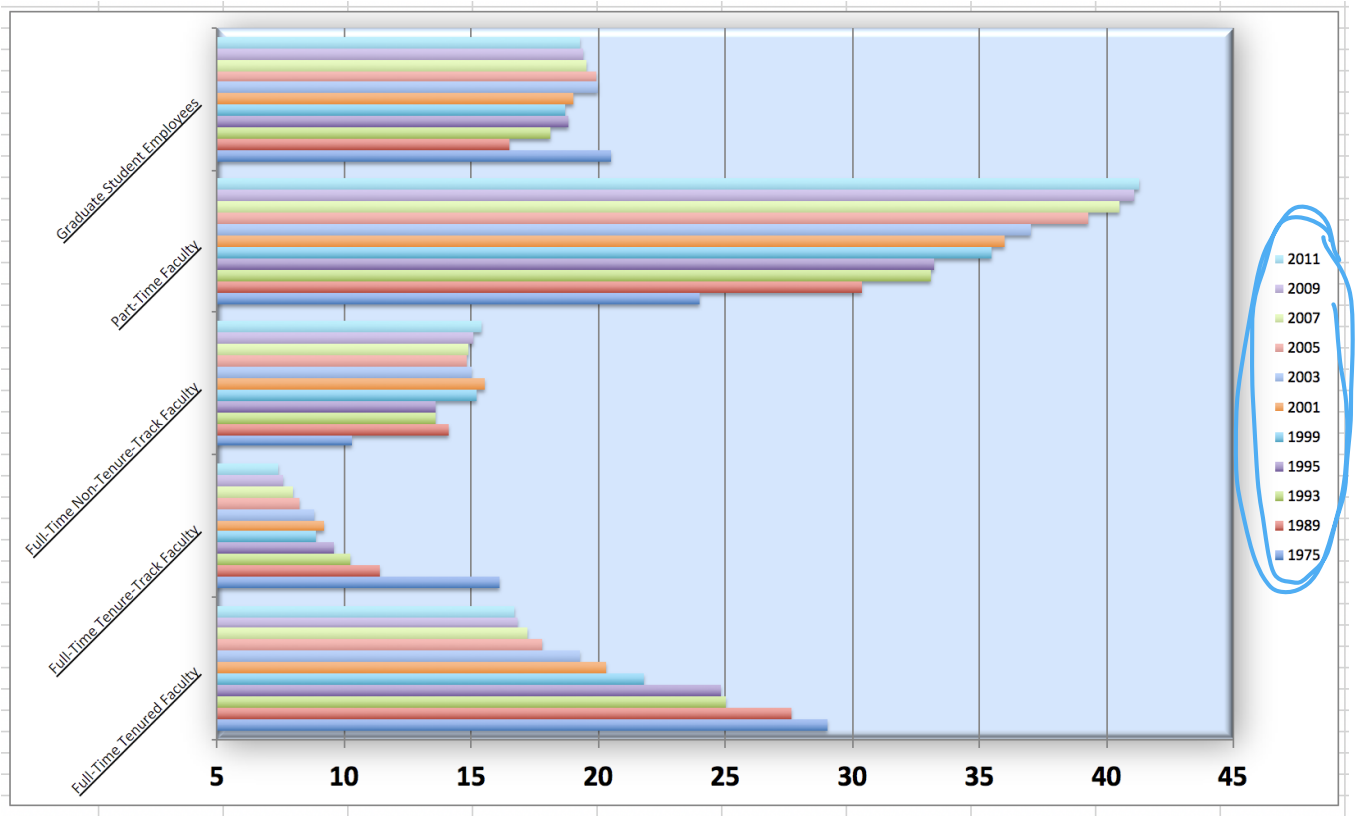
Summarizing data

- `tbl_summary()`
- `group_by()`
- `summarize()`
- `across()`

Data manipulation

Example for `pivot_longer()`: Instructional staff employment trends

The American Association of University Professors (AAUP) is a nonprofit membership association of faculty and other academic professionals. This report by the AAUP shows trends in instructional staff employees between 1975 and 2011, and contains an image very similar to the one given below.



Data

Each row in this dataset represents a faculty type, and the columns are the years for which we have data. The values are percentage of hires of that type of faculty for each year.

```
 1 (staff <- read_csv("data/instructional-staff.csv"))
```

```
# A tibble: 5 × 12
  faculty_type      `1975` `1989` `1993` `1995` `1999` `2001` `2003` `2005` `2007`
  <chr>              <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>
1 Full-Time Tenu…     29     27.6   25     24.8   21.8   20.3   19.3   17.8   17.2
2 Full-Time Tenu…     16.1   11.4   10.2    9.6    8.9    9.2    8.8    8.2    8
3 Full-Time Non-…     10.3   14.1   13.6   13.6   15.2   15.5   15     14.8   14.9
4 Part-Time Facu…     24     30.4   33.1   33.2   35.5   36     37     39.3   40.5
5 Graduate Stude…     20.5   16.5   18.1   18.8   18.7   19     20     19.9   19.5
# ℹ 2 more variables: `2009` <dbl>, `2011` <dbl>
```

Poll Everywhere Question 2

Activity is now locked.
Responses are not accepted at this time.

Is the instructional staff data in a tidy format?

Yes! Looks good! 29%

```
 1 (staff <- read_csv("data/instructional-staff.csv"))
```

```
# A tibble: 5 × 12
  faculty_type     `1975` `1989` `1993` `1995` `1999` `2001` `2003` `2005` `2007`
  <chr>             <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>  <dbl>
1 Full-Time Tenu…   29     27.6   25     24.8   21.8   20.3   19.3   17.8   17.2
2 Full-Time Tenu…   16.1   11.4   10.2    9.6    8.9    9.2    8.8    8.2    8
3 Full-Time Non-…   10.3   14.1   13.6   13.6   15.2   15.5   15     14.8   14.9
4 Part-Time Facu…   24     30.4   33.1   33.2   35.5   36     37     39.3   40.5
5 Graduate Stude…   20.5   16.5   18.1   18.8   18.7   19     20     19.9   19.5
# ℹ 2 more variables: `2009` <dbl>, `2011` <dbl>
```

No! Tidy it up! 71%

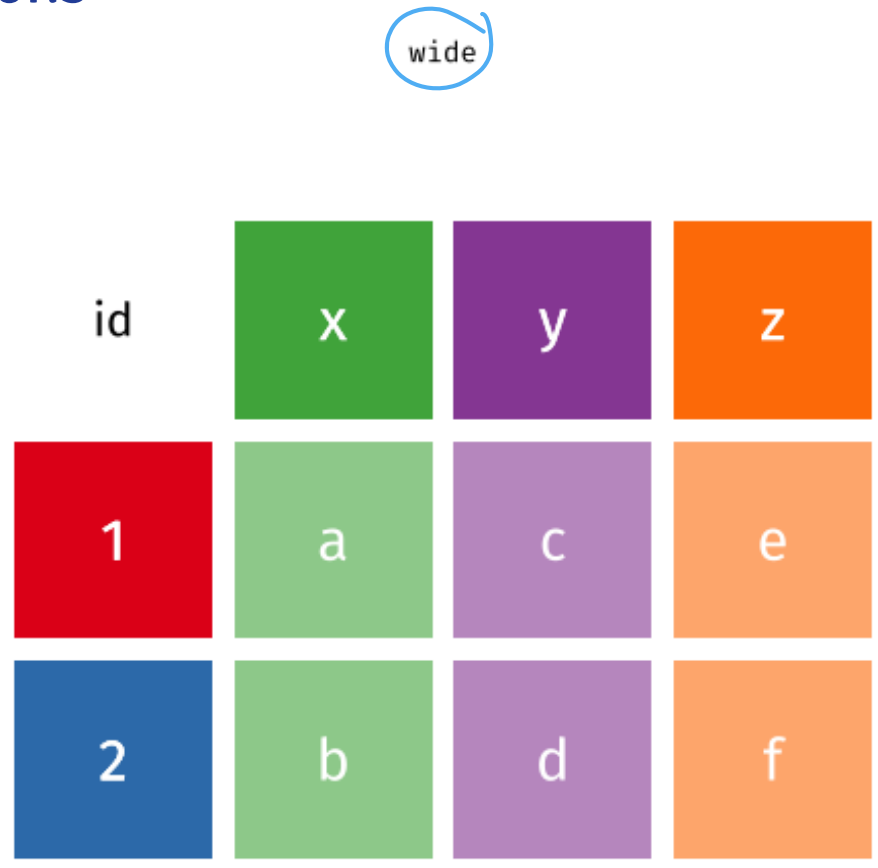
Recreate the visualization

- In order to recreate this visualization we need to first reshape the data:
  - one variable for faculty type
  - one variable for year

- Convert the data from the wide format to long format
  - `pivot_longer()`


PIVOT!!!

`pivot_*()` functions



Poll Everywhere Question 3

Pivot staff data and mutate percentage

★ muddiest points ★

```
1  (staff_long <- staff %>%
2    pivot_longer(
3      cols = -faculty_type,     # columns to pivot
4      names_to = "year",        # name of new column for variable names
5      values_to = "percentage" # name of new column for values
6    ) %>%
7    mutate(percentage = as.numeric(percentage))
8  )
```

```
# A tibble: 55 × 3
   faculty_type                year  percentage
   <chr>                       <chr>      <dbl>
 1 Full-Time Tenured Faculty   1975        29
 2 Full-Time Tenured Faculty   1989        27.6
 3 Full-Time Tenured Faculty   1993        25
 4 Full-Time Tenured Faculty   1995        24.8
 5 Full-Time Tenured Faculty   1999        21.8
 6 Full-Time Tenured Faculty   2001        20.3
 7 Full-Time Tenured Faculty   2003        19.3
```

1-12

cols = 2:12

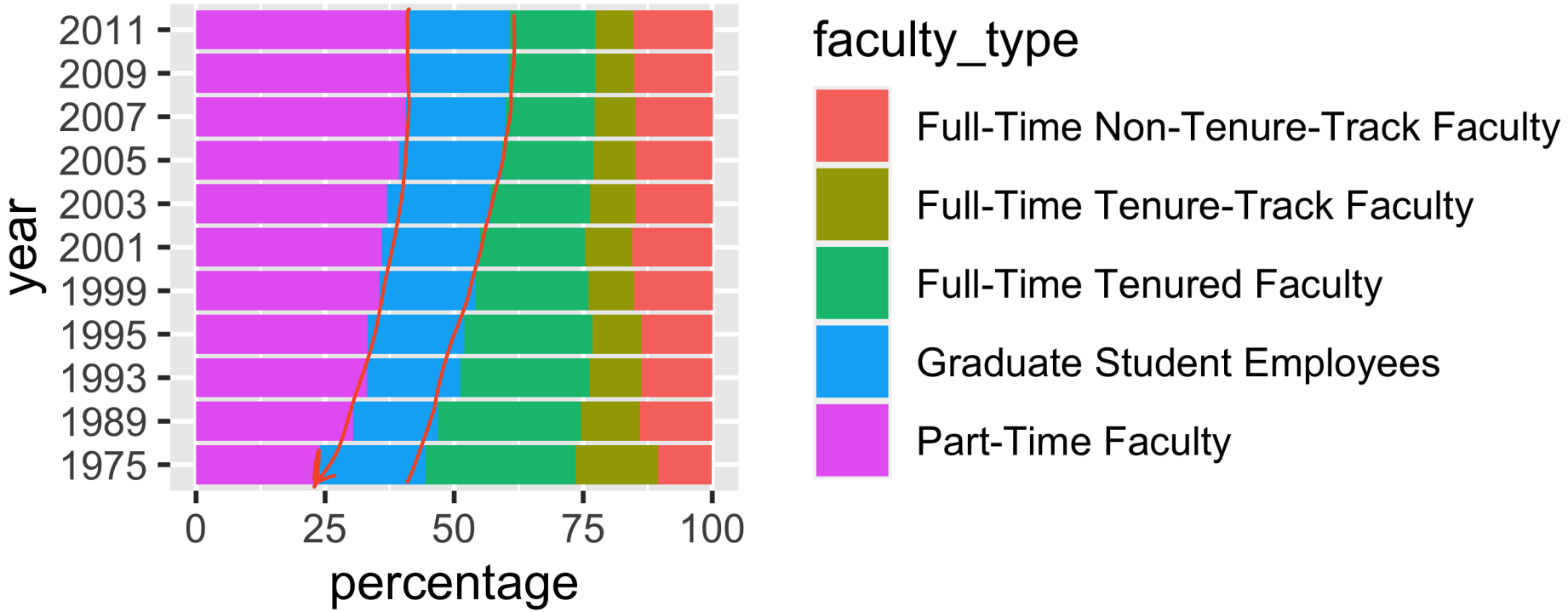
cols = -faculty_type

cols = c('1975', '1989', ...

listing variable names

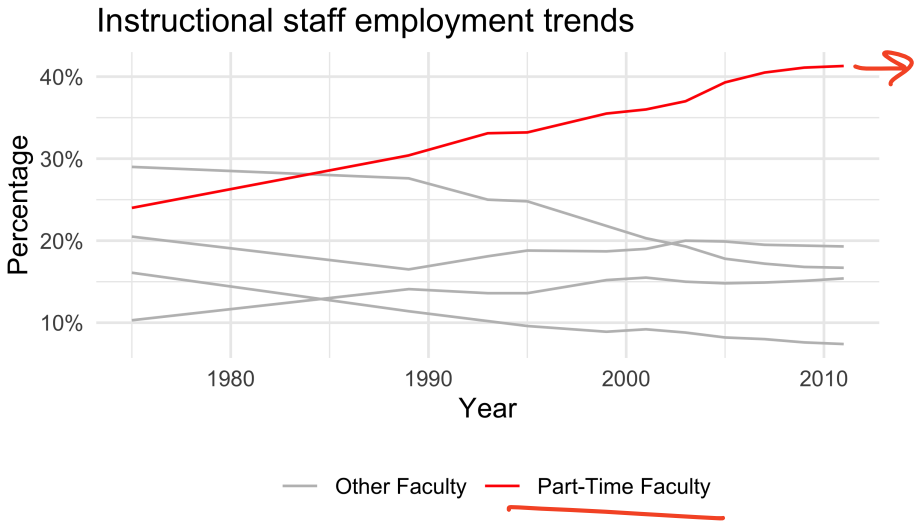
A “meh” plot over the years

```
1 ggplot(staff_long, aes(x = percentage, y = year, fill = faculty_type)) +
2   geom_col()
```



More improvement

```
staff_long %>%
  mutate(
    part_time = if_else(faculty_type == "Part-Time Facult
                        "Part-Time Faculty", "Other Facul
    year = as.numeric(year)) %>%
  ggplot(
    aes(x = year, y = percentage/100, group = faculty_typ
  geom_line() +
  scale_color_manual(values = c("gray", "red")) +
  scale_y_continuous(labels = label_percent(accuracy = 1)
  theme_minimal() +
  labs(
    title = "Instructional staff employment trends",
    x = "Year", y = "Percentage", color = NULL) +
  theme(legend.position = "bottom")
```



All that just to show one helpful function

Now we can move onto the other functions mentioned:

Data manipulation

- `pivot_longer()` and `pivot_wider()`
- `rename()`
- `mutate()`
- `filter()`
- `select()`

Summarizing data

- `tbl_summary()`
- `group_by()`
- `summarize()`
- `across()`

Let's look back at the `dds.discr` dataset that I briefly used last class

- We will load the data (This is a special case! `dds.discr` is a built-in R dataset)

```
1 data("dds.discr")
```

- Now, let's take a glimpse at the dataset:

```
1 glimpse(dds.discr)
```

```
Rows: 1,000
Columns: 6
$ id           <int> 10210, 10409, 10486, 10538, 10568, 10690, 10711, 10778, 1…
$ age.cohort   <fct> 13-17, 22-50, 0-5, 18-21, 13-17, 13-17, 13-17, 13-17, 13-…
$ age          <int> 17, 37, 3, 19, 13, 15, 13, 17, 14, 13, 13, 14, 15, 17, 20…
$ gender       <fct> Female, Male, Male, Female, Male, Female, Female, Male, F…
$ expenditures <int> 2113, 41924, 1454, 6400, 4412, 4566, 3915, 3873, 5021, 28…
$ ethnicity    <fct> White not Hispanic, White not Hispanic, Hispanic, Hispani…
```

rename( ): one of the first things I usually do

- I notice that two variables have values that don't necessarily match the variable name
  - Female and male are not genders
  - "White not Hispanic" combines race and ethnicity into one category

I want to rename gender to SAB (sex assigned at birth) and rename ethnicity to R_E (race and ethnicity)

↳ current sex

```
1 dds.discr1 = dds.discr %>%
2   rename(SAB = gender,
3          R_E = ethnicity)
4
5 glimpse(dds.discr1)
```

```
Rows: 1,000
Columns: 6
$ id          <int> 10210, 10409, 10486, 10538, 10568, 10690, 10711, 10778, 1…
$ age.cohort  <fct> 13-17, 22-50, 0-5, 18-21, 13-17, 13-17, 13-17, 13-17, 13-…
$ age         <int> 17, 37, 3, 19, 13, 15, 13, 17, 14, 13, 13, 14, 15, 17, 20…
$ SAB         <fct> Female, Male, Male, Female, Male, Female, Female, Male, F…
$ expenditures <int> 2113, 41924, 1454, 6400, 4412, 4566, 3915, 3873, 5021, 28…
$ R_E         <fct> White not Hispanic, White not Hispanic, Hispanic, Hispani…
```

age_fac

`mutate()`: constructing new variables from what you have

- We've seen a couple examples for `mutate()` so far (mostly because its used so often!)
- We haven't seen an example where we make a new variable from two variables

> I want to make a variable that is the ratio of expenditures over age

```
1 dds.discr2 = dds.discr1 %>%
2   mutate(exp_to_age = expenditures/age)
3
4 glimpse(dds.discr2)
```

```
Rows: 1,000
Columns: 7
$ id           <int> 10210, 10409, 10486, 10538, 10568, 10690, 10711, 10778, 1…
$ age.cohort   <fct> 13-17, 22-50, 0-5, 18-21, 13-17, 13-17, 13-17, 13-17, 13-…
$ age          <int> 17, 37, 3, 19, 13, 15, 13, 17, 14, 13, 13, 14, 15, 17, 20…
$ SAB          <fct> Female, Male, Male, Female, Male, Female, Female, Male, F…
$ expenditures <int> 2113, 41924, 1454, 6400, 4412, 4566, 3915, 3873, 5021, 28…
$ R_E          <fct> White not Hispanic, White not Hispanic, Hispanic, Hispani…
$ exp_to_age   <dbl> 124.2941, 1133.0811, 484.6667, 336.8421, 339.3846, 304.40…
```

Poll Everywhere Question 4

`filter()`: keep rows that match a condition

- What if I want to subset the data frame? (keep certain rows of observations)

> I want to look at the data for people who between 50 and 60 years old

$50 \leq age \leq 60$

```
1  dds.discr3 = dds.discr2 %>%
2    filter(age >= 50 & age <= 60)
3
4  glimpse(dds.discr3)
```

instead of & : you used |

OR

```
Rows: 23
Columns: 7
$ id           <int> 15970, 19412, 29506, 31658, 36123, 39287, 39672, 43455, 4…
$ age.cohort   <fct> 51+, 51+, 51+, 51+, 51+, 51+, 51+, 51+, 51+, 51+, 51+, 51…
$ age          <int> 51, 60, 56, 60, 59, 59, 54, 57, 52, 57, 55, 52, 59, 54, 5…
$ SAB          <fct> Female, Female, Female, Female, Male, Female, Female, Mal…
$ expenditures <int> 54267, 57702, 48215, 46873, 42739, 44734, 52833, 48363, 5…
$ R_E          <fct> White not Hispanic, White not Hispanic, White not Hispani…
$ exp_to_age   <dbl> 1064.0588, 961.7000, 860.9821, 781.2167, 724.3898, 758.20…
```

`select()`: keep or drop columns using their names and types

- What if I want to remove or keep certain variables?

I want to only have age and expenditure in my data frame

```
1 dds.discr4 = dds.discr2 %>%
2   select(age, expenditures)
3
4 glimpse(dds.discr4)
```

keep

select(- age , - expenditures)

remove age & expenditures

```
Rows: 1,000
Columns: 2
$ age          <int> 17, 37, 3, 19, 13, 15, 13, 17, 14, 13, 13, 14, 15, 17, 20…
$ expenditures <int> 2113, 41924, 1454, 6400, 4412, 4566, 3915, 3873, 5021, 28…
```

Summarizing Data

`tbl_summary()` : table summary (1/2)

- What if I want one of those fancy summary tables that are at the top of most research articles? (lovingly called "Table 1")

```
1  library(gtsummary)
2  tbl_summary(dds.discr2)
```

★ options to change from median to mean

Characteristic	N = 1,000[1]
id	55,385 (31,809, 76,135)
age.cohort	
0-5	82 (8.2%)
6-12	175 (18%)
13-17	212 (21%)
18-21	199 (20%)
22-50	226 (23%)
51+	106 (11%)
age → Age	18 (12, 26)
SAB	
Female	503 (50%)
Male	497 (50%)
expenditures	7,026 (2,899, 37,713)
R_E → Race/Ethnicity	
American Indian	4 (0.4%)
Asian	129 (13%)
Black	59 (5.9%)
Hispanic	376 (38%)
Multi Race	26 (2.6%)
Native Hawaiian	3 (0.3%)
Other	2 (0.2%)
White not Hispanic	401 (40%)
exp_to_age	462 (274, 938)
[1] Median (IQR); n (%)	

`tbl_summary()`: table summary (2/2)

- Let's make this more presentable

```
1 dds.discr2 %>%
2   select(-id, -age.cohort, -exp_to_age) %>%
3   tbl_summary(label = c(age ~ "Age",
4                         R_E ~ "Race/Ethnicity",
5                         SAB ~ "Sex Assigned at Birth",
6                         expenditures ~ "Expenditures"))
```

Characteristic	N = 1,000[1]
Age	18 (12, 26)
Sex Assigned at Birth	
Female	503 (50%)
Male	497 (50%)
Expenditures	7,026 (2,899, 37,713)
Race/Ethnicity	
American Indian	4 (0.4%)
Asian	129 (13%)
Black	59 (5.9%)
Hispanic	376 (38%)
Multi Race	26 (2.6%)
Native Hawaiian	3 (0.3%)
Other	2 (0.2%)
White not Hispanic	401 (40%)

[1] Median (IQR); n (%)

`group_by()`: group by one or more variables

- What if I want to quickly look at group differences?
- It will not change how the data look, but changes the actions of following functions

I want to group my data by sex assigned at birth.

```
1 dds.discr5 = dds.discr2 %>%
2   group_by(SAB)
3 glimpse(dds.discr5)
```

```
Rows: 1,000
Columns: 7
Groups: SAB [2]
$ id           <int> 10210, 10409, 10486, 10538, 10568, 10690, 10711, 10778, 1…
$ age.cohort   <fct> 13-17, 22-50, 0-5, 18-21, 13-17, 13-17, 13-17, 13-17, 13-…
$ age          <int> 17, 37, 3, 19, 13, 15, 13, 17, 14, 13, 13, 14, 15, 17, 20…
$ SAB          <fct> Female, Male, Male, Female, Male, Female, Female, Male, F…
$ expenditures <int> 2113, 41924, 1454, 6400, 4412, 4566, 3915, 3873, 5021, 28…
$ R_E          <fct> White not Hispanic, White not Hispanic, Hispanic, Hispani…
$ exp_to_age   <dbl> 124.2941, 1133.0811, 484.6667, 336.8421, 339.3846, 304.40…
```

- Let's see how the groups change something like the `summarize()` function in the next slide

`summarize()`: summarize your data or grouped data into one row

- What if I want to calculate specific descriptive statistics for my variables?
- This function is often best used with `group_by()`
- If only presenting the summaries, functions like `tbl_summary()` is better
- `summarize()` creates a new data frame, which means you can plot and manipulate the summarized data

Over whole sample:

```
dds.discr2 %>%
  summarize(
    ave = mean(expenditures),
    SD = sd(expenditures),
    med = median(expenditures))
```

```
# A tibble: 1 × 3
     ave     SD   med
   <dbl>  <dbl> <dbl>
1 18066. 19543.  7026
```

Grouped by sex assigned at birth:

```
dds.discr2 %>%
  group_by(SAB) %>%
  summarize(
    ave = mean(expenditures),
    SD = sd(expenditures),
    med = median(expenditures))
```

```
# A tibble: 2 × 4
  SAB       ave     SD   med
  <fct>   <dbl>  <dbl> <int>
1 Female 18130. 20020.  6400
2 Male   18001. 19068.  7219
```

`across()`: apply a function across multiple columns

- Like `group_by()`, this function is often paired with another transformation function

> I want all my integer values to have two significant figures.

```
1  dds.discr6 = dds.discr2 %>%
2    mutate(across(where(is.integer), signif, digits = 2))
3
4  glimpse(dds.discr6)
```

signif()

option

which variables have int values?

id, age, expend.

```
Rows: 1,000
Columns: 7
$ id           <dbl> 10000, 10000, 10000, 11000, 11000, 11000, 11000, 11000, 1…
$ age.cohort   <fct> 13-17, 22-50, 0-5, 18-21, 13-17, 13-17, 13-17, 13-17, 13-…
$ age          <dbl> 17, 37, 3, 19, 13, 15, 13, 17, 14, 13, 13, 14, 15, 17, 20…
$ SAB          <fct> Female, Male, Male, Female, Male, Female, Female, Male, F…
$ expenditures <dbl> 2100, 42000, 1500, 6400, 4400, 4600, 3900, 3900, 5000, 29…
$ R_E          <fct> White not Hispanic, White not Hispanic, Hispanic, Hispani…
$ exp_to_age   <dbl> 124.2941, 1133.0811, 484.6667, 336.8421, 339.3846, 304.40…
```

Resources

`dplyr` resources

- More `dpylr` functions to reference!

Additional details and examples are available in the vignettes:

- column-wise operations vignette
- row-wise operations vignette

and the dplyr 1.0.0 release blog posts:

- working across columns
- working within rows

R programming class at OHSU!

You can check out Dr. Jessica Minnier's R class page if you want more notes, videos, etc.

The larger tidy ecosystem

Just to name a few…

- janitor
- kableExtra
- patchwork
- gghighlight
- tidybayes

Credit to Mine Çetinkaya-Rundel

- These notes were built from Mine's notes
  - Most pages and code were left as she made them
  - I changed a few things to match our class
- Please see her Github repository for the original notes