Lecture 16: Oct 10, 2018

Grammar of Data

- *Interrogating Data*
- *dplyr*
- *Split-Apply-Combine*
- *Resources*

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STAT 385 @ UIUC

Announcements

- **hw06** is due **Friday, Oct 12th, 2018** at **6:00 PM**
- **Office Hour Changes**
  - **John Lee's** are now from **4 - 5 PM** on **WF**
  - **Hassan Kamil's** are now from **2:30 - 3:30 PM** on **TR**
- **Quiz 07** covers Week 6 contents @ CBTF.
  - Window: Oct 9th - 11th
  - Sign up: https://cbtf.engr.illinois.edu/sched
- Want to review your homework or quiz grades?
  Schedule an appointment.

Last Time

- **Designing a Graphic**
  - Emphasis the data's narrative.
  - Be ware of *Simpson's paradox*, *Apophenia*, and lying with graphics.
- **CRAP**
  - **C**ontrast, **R**epetition, **A**lignment, **P**roximity
  - Tenets of Gestalt Design
- **Chart Junk**
  - Useless embellishment on the plot that impacts clarity of plot
- **Modern Graphics**
  - Ability to modify display or view data over time.

Lecture Objectives

- Deriving appropriate domain questions for data.
- Describe the three stages of Split-Apply-Combine.
- Explain and apply the grammar of data to manipulate data.

Interrogating Data

Example Data

… tidied version of enrollment figures …

Year	Gender	Enrolled
Undergrad	Men	18,345
Undergrad	Women	15,267
Undergrad	Unknown	12
Professional	Men	352
Professional	Women	640
Professional	Unknown	0
Graduate	Men	7,173
Graduate	Women	6,028
Graduate	Unknown	9

9 x 3

enrolled_fa2017

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Questions

… digging into the data …

1. What **variable holds** admission figures / gender / class?

```
enrolled_fa2017$Enrollment
enrolled_fa2017[["Gender"]]
enrolled_fa2017[, "Year"]
```

2. Are undergraduates **found** in the data?

```
enrolled_fa2017$Year == "Undergraduate"
```

3. Who has **highest enrollment** amount?

```
enrolled_fa2017[enrolled_fa2017$Enrollment == max(enrolled_fa2017$Enrollment), ]
```

What happened here?

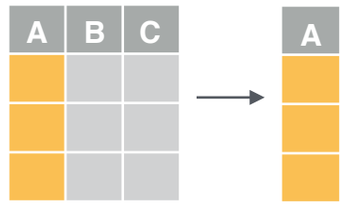
Data Wrangling

Manipulating raw data through
transformations to obtain a useful format

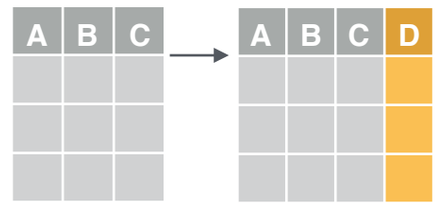
Underlying Grammar

… phrasing of questions using **verbs** …

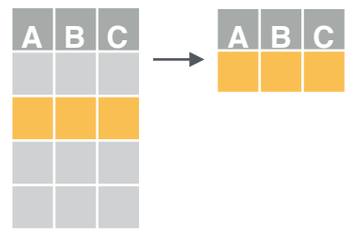
select: Retrieve a variable



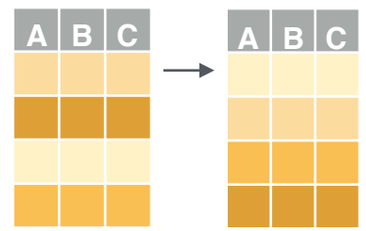
mutate: Add a variable to the data



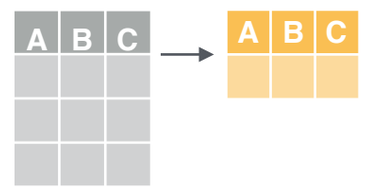
filter: Extracts cases based on values



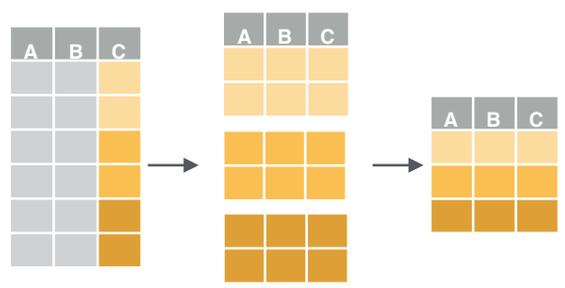
arrange: Change the order of the data



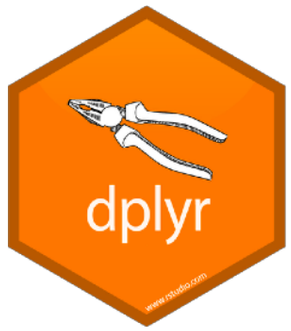
summarise: Reduce multiple values to statistics



group_by: Split the data by trait



dplyr



… grammar for manipulating data …

```
install.packages("dplyr")
library("dplyr")
```

Function	Description
filter(.data, …)	Extracts cases based on values
select(.data, …)	Include or exclude variables (var / -var)
arrange(.data, …)	Change the order of the data
mutate(.data, …)	Add new variables to the data
summarise(.data, …)	Reduce multiple values to statistics
group_by(data, …)	Split the data by trait

Filter Data

… subset by **men** …

Dataset

No quotes on variable!
Non-standard evaluation (NSE)

```
enrolled_fa2017_men = filter(enrolled_fa2017, Gender == "Men")
```

Year	Gender	Enrolled
Undergrad	Men	18,345
Undergrad	Women	15,267
Undergrad	Unknown	12
Professional	Men	352
Professional	Women	640
Professional	Unknown	0
Graduate	Men	7,173
Graduate	Women	6,028
Graduate	Unknown	9

enrolled_fa2017

9 x 3

Year	Gender	Enrolled
Undergrad	Men	18,345
Professional	Men	352
Graduate	Men	7,173

3 x 3

enrolled_fa2017_men

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Filter Data

… subset by ***women*** …

```
enrolled_fa2017_women = filter(enrolled_fa2017, Gender == "Women")                  # dplyr
enrolled_fa2017_women = enrolled_fa2017[enrolled_fa2017$Gender == "Women", ] # base R
```

Year	Gender	Enrolled
Undergrad	Men	18,345
Undergrad	Women	15,267
Undergrad	Unknown	12
Professional	Men	352
Professional	Women	640
Professional	Unknown	0
Graduate	Men	7,173
Graduate	Women	6,028
Graduate	Unknown	9

enrolled_fa2017

9 x 3

Year	Gender	Enrolled
Undergrad	Women	15,267
Professional	Women	640
Graduate	Women	6,028

3 x 3

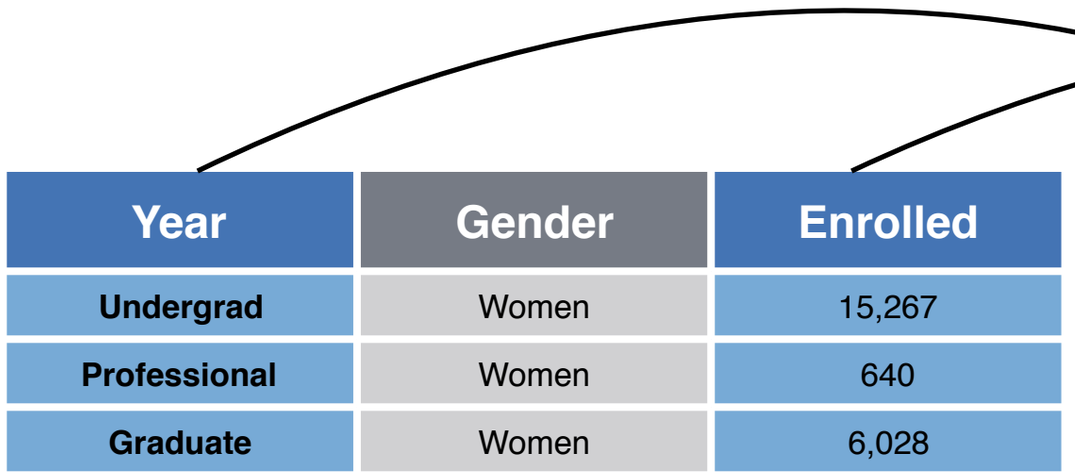
enrolled_fa2017_women

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Select Variables

… retrieve year and enrolled …

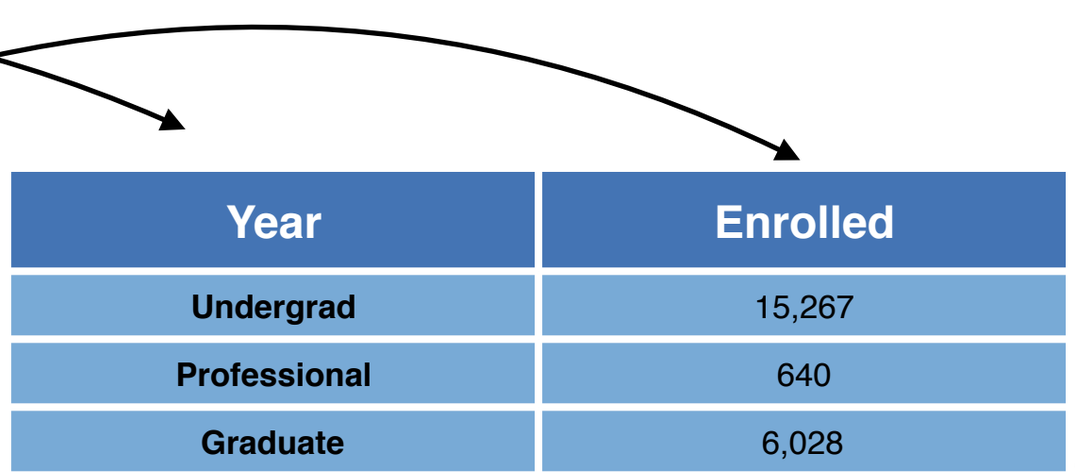
```
enrolled_fa2017_women_info = select(enrolled_fa2017_women,
                                    Year, Enrolled)
```



Year	Gender	Enrolled
Undergrad	Women	15,267
Professional	Women	640
Graduate	Women	6,028

3 x 3

enrolled_fa2017_women



Year	Enrolled
Undergrad	15,267
Professional	640
Graduate	6,028

3 x 2

enrolled_fa2017_women_info

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Arrange Data

… changing order of data …

```
enrolled_fa2017_women_ordered = arrange(enrolled_fa2017_women_info,
                                        Enrolled)
```

Year	Enrolled
Undergrad	15,267
Professional	640
Graduate	6,028

3 x 2

enrolled_fa2017_women_info

Year	Enrolled
Professional	640
Graduate	6,028
Undergrad	15,267

3 x 2

enrolled_fa2017_ordered_women

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Arranging Data

… descending order …

```
enrolled_fa2017_women_ordered =
                    arrange(enrolled_fa2017_women_info, desc(Enrolled))
```

Year	Enrolled
Undergrad	15,267
Professional	640
Graduate	6,028

3 x 2

enrolled_fa2017_women_info

Year	Enrolled
Undergrad	15,267
Graduate	6,028
Professional	640

3 x 2

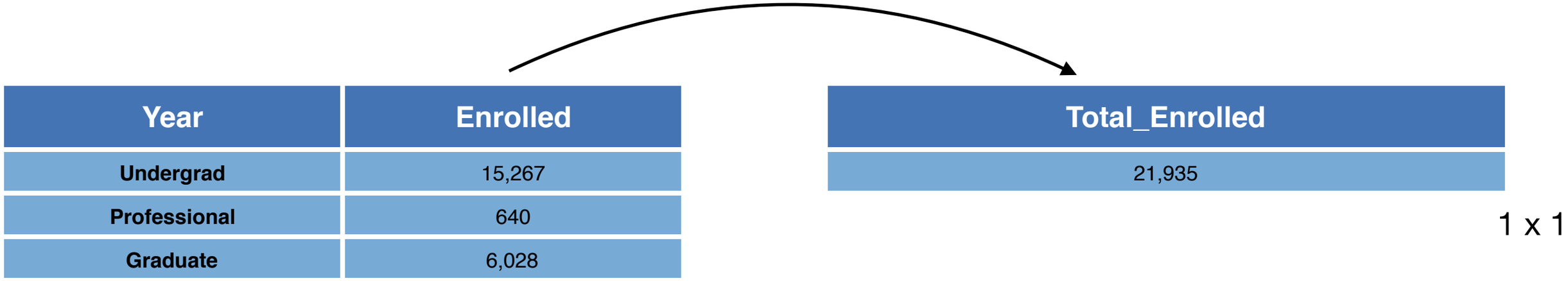
enrolled_fa2017_ordered_women

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Summarise

… figuring out total enrollment across years …

```
enrolled_fa2017_total_women = summarise(enrolled_fa2017_women_info,
                                        Total_Enrolled = sum(Enrolled))
```



Year	Enrolled
Undergrad	15,267
Professional	640
Graduate	6,028

3 x 2

enrolled_fa2017_women_info

Total_Enrolled
21,935

1 x 1

enrolled_fa2017_total_women

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Mutating Data

… padding the women enrollment …

```
enrolled_fa2017_women_add = mutate(enrolled_fa2017_women_info,
                                   Additional = Enrolled + 550)
```

Year	Enrolled
Undergrad	15,267
Professional	640
Graduate	6,028

3 x 2

enrolled_fa2017_women_info

Year	Enrolled	Additional
Undergrad	15,267	15,817
Professional	640	1190
Graduate	6,028	6,578

3 x 3

enrolled_fa2017_women_add

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Previously

Definition:

Piping is the act of taking one value and immediately placing it into another function to form a flow of results.

Left Function
Transmitting function result
`rnorm(10)`

Pipe Operator
Facilitate moving left result to the function on right

Right Function
Receiving function result in first parameter
`abs(rnorm(10))`

```
rnorm(10) %>% abs()
```

%>% is read as "and, then"

dplyr with Pipes

… piping together different chunks of code …

```
enrolled_fa2017_total_women =
    enrolled_fa2017 %>%           # Take the enrollment data and, then
    filter(Gender == "Women") %>% # Retrieve all Women data and, then
    select(Year, Enrolled) %>%    # Take Year and Enrolled variables and, then
    arrange(Enrolled) %>%         # Order Enrolled in Ascending order and, then
    summarise(Total_Enrolled = sum(Enrolled)) # Get total women enrollment
```

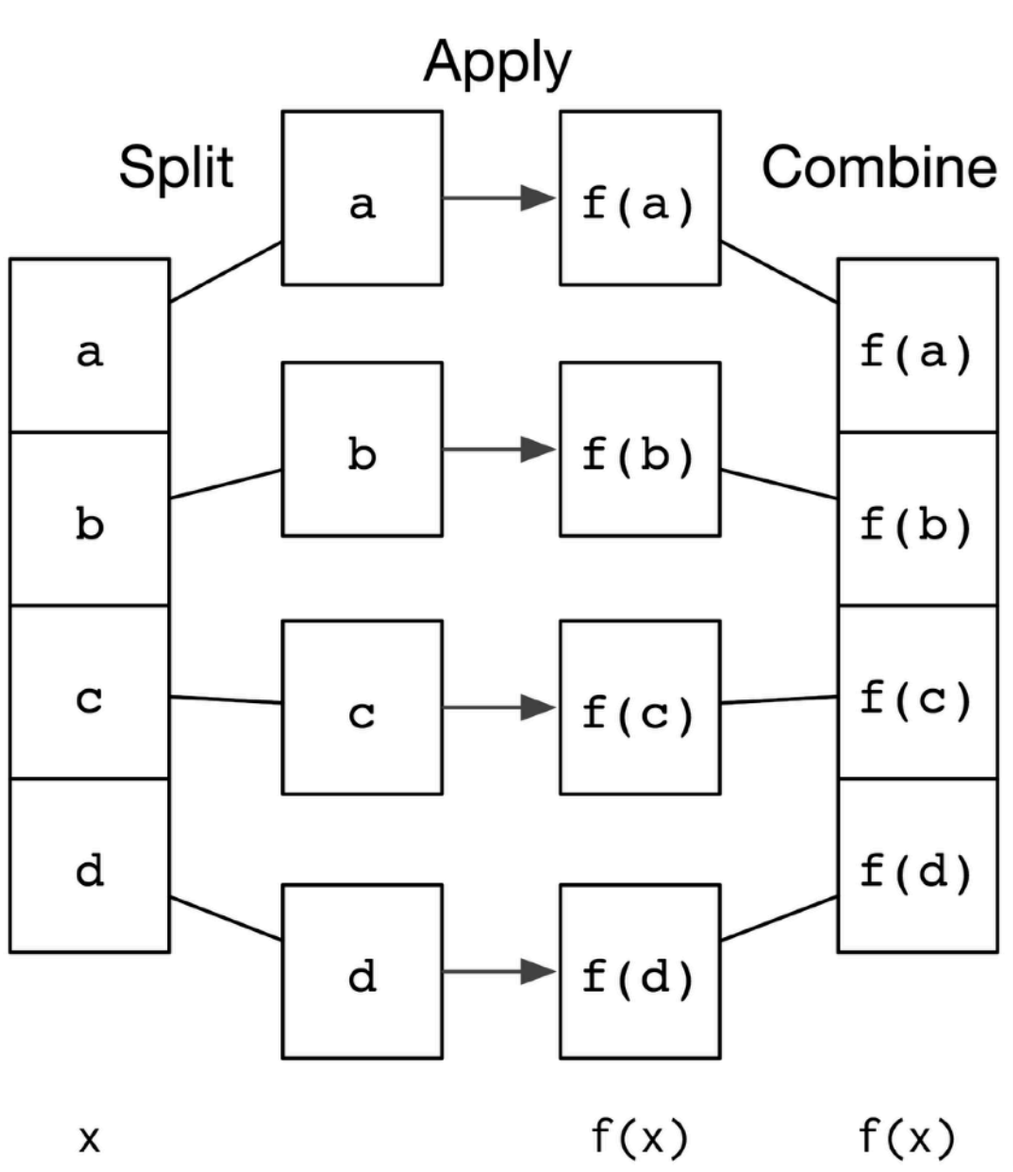
Your Turn

1. Select the Sepal.Length and Petal.Length variables in the **iris** data set
2. Retrieve all of the virginica **Species** observations from **iris**

Split-Apply-Combine

Split-Apply-Combine

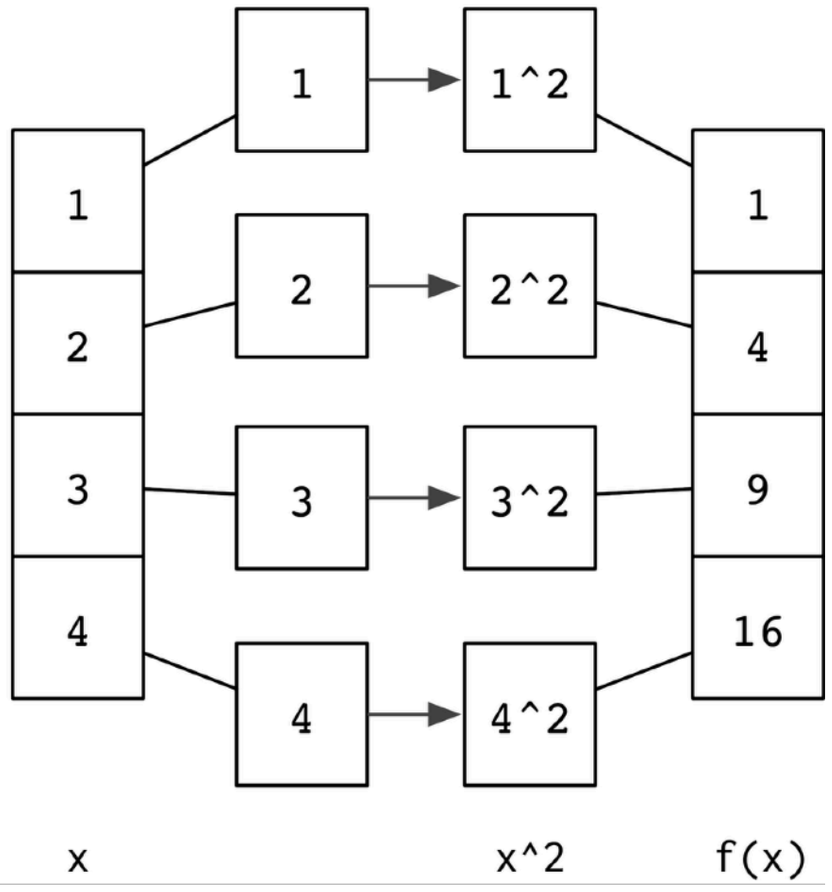
… overview …



1. **Split** Data into pieces, 2. **Apply** function to each piece, and 3. **Combine** result

Vectorization

… in the split-apply-combine framework …




```
x = 1L:4L
(y = x^2)
# [1] 1 4 9 16
```

Split-Apply-Combine

AKA

MapReduce

Summarise by Group

… summary statistics broken down by groups …

```
enrolled_fa2017_grouped =  group_by(enrolled_fa2017, Gender)
enrolled_fa2017_gender = summarise(enrolled_fa2017_grouped,
                                   Total_Enrollment = sum(Enrolled))
```

Year	Gender	Enrolled
Undergrad	Men	18,345
Undergrad	Women	15,267
Undergrad	Unknown	12
Professional	Men	352
Professional	Women	640
Professional	Unknown	0
Graduate	Men	7,173
Graduate	Women	6,028
Graduate	Unknown	9

9 x 3

enrolled_fa2017

Gender	Total_Enrollment
Men	25,870
Women	21,935
Unknown	21

3 x 2

enrolled_fa2017_gender

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Split Step

SPLIT by Gender

```
enrolled_fa2017_grouped =  group_by(enrolled_fa2017 , Gender)
```

Year	Gender	Enrolled
Undergrad	Men	18,345
Undergrad	Women	15,267
Undergrad	Unknown	12
Professional	Men	352
Professional	Women	640
Professional	Unknown	0
Graduate	Men	7,173
Graduate	Women	6,028
Graduate	Unknown	9

9 x 3

enrolled_fa2017

Men

Women

Unknown

Year	Gender	Enrolled
Undergrad	Men	18,345
Professional	Men	352
Graduate	Men	7,173

3 x 3

Year	Gender	Enrolled
Undergrad	Women	15,267
Professional	Women	640
Graduate	Women	6,028

3 x 3

Year	Gender	Enrolled
Undergrad	Unknown	12
Professional	Unknown	0
Graduate	Unknown	9

3 x 3

enrolled_fa2017_grouped

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Apply Step: Using a Function

APPLY sum on Enrolled

```
summarise(enrolled_fa2017_grouped, Total_Enrollment = sum(Enrolled))
```

Year	Gender	Enrolled
Undergrad	Men	18,345
Professional	Men	352
Graduate	Men	7,173

3 x 3

Year	Gender	Enrolled
Undergrad	Women	15,267
Professional	Women	640
Graduate	Women	6,028

3 x 3

Year	Gender	Enrolled
Undergrad	Unknown	12
Professional	Unknown	0
Graduate	Unknown	9

3 x 3

enrolled_fa2017_grouped

SPLIT by Gender

sum

18,345	+	352	+	7,173	=	Total Enrollment: 25,870

sum

15,267	+	640	+	6,028	=	Total Enrollment: 21,935

sum

12	+	0	+	9	=	Total Enrollment: 21

Unassigned data

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Apply Step: Match to Group

APPLY sum on Enrolled

summarise(enrolled_fa2017_grouped, **Total_Enrollment** = **sum**(**Enrolled**))

Year	Gender	Enrolled
Undergrad	Men	18,345
Professional	Men	352
Graduate	Men	7,173

3 x 3

sum →

Gender	Total_Enrollment
Men	25,870

1 x 2

Year	Gender	Enrolled
Undergrad	Women	15,267
Professional	Women	640
Graduate	Women	6,028

3 x 3

sum →

Gender	Total_Enrollment
Women	21,935

1 x 2

Year	Gender	Enrolled
Undergrad	Unknown	12
Professional	Unknown	0
Graduate	Unknown	9

3 x 3

sum →

Gender	Total_Enrollment
Unknown	12

1 x 2

enrolled_fa2017_grouped

SPLIT by Gender

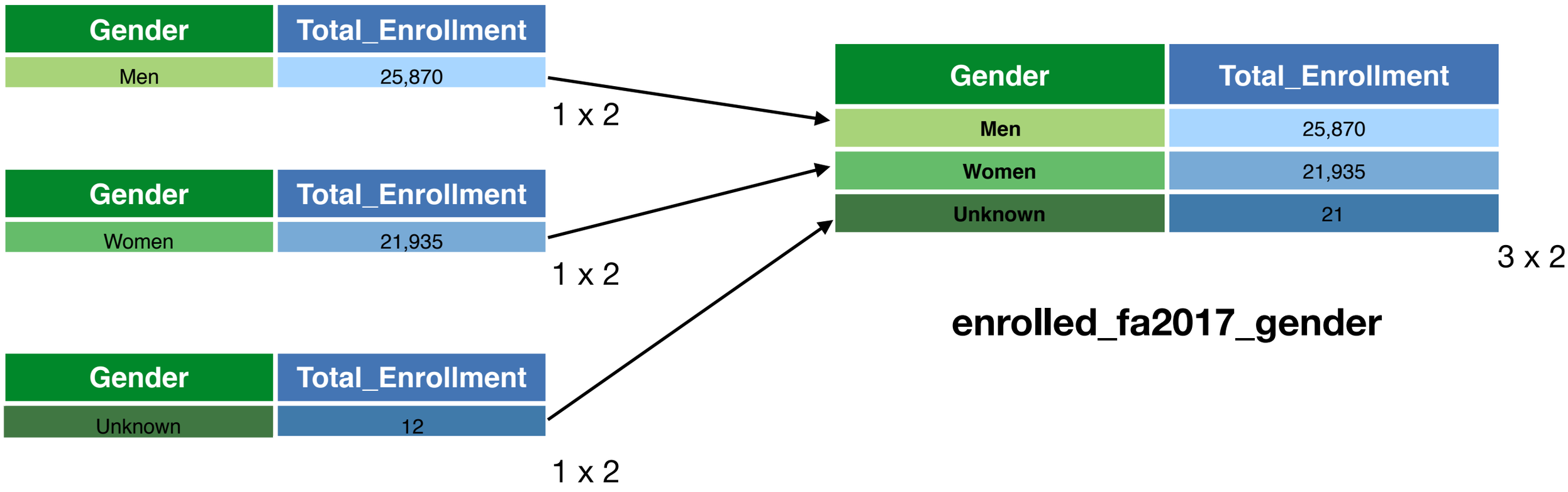
Unassigned data

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Combine Step

COMBINE Total_Enrollment by Gender

```
enrolled_fa2017_gender = summarise(enrolled_fa2017_grouped,
                                   Total_Enrollment = sum(Enrolled))
```



APPLY sum on Enrolled

Source: http://www.dmi.illinois.edu/stuenr/abstracts/FA17_ten.htm

Your Turn

Provide the *mean*, *maximum*, *minimum* of the Sepal.Length for each of species of **iris** alongside a **count**.

Recap

- **Grammar of Data**
  - Pose question about the data
  - Answer the questions through **five** verbs: select, filter, mutate, arrange, and summarise
- **Split-Apply-Combine**
  - **Split** Data into pieces
  - **Apply** function to each piece, and
  - **Combine** result

Resources

Cheatsheet

… dplyr cheat sheet …

Data Transformation with dplyr : : CHEAT SHEET

dplyr functions work with pipes and expect **tidy data**. In tidy data:

Each **variable** is in its own **column**

&

Each **observation**, or **case**, is in its own **row**

x %>% f(y) becomes **f(x, y)**

Summarise Cases

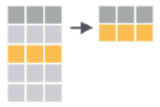
These apply **summary functions** to columns to create a new table of summary statistics. Summary functions take vectors as input and return one value (see back).

summarise(.data, …)
Compute table of summaries.
summarise(mtcars, avg = mean(mpg))

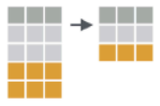
Manipulate Cases

EXTRACT CASES

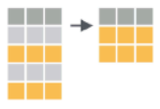
Row functions return a subset of rows as a new table.



filter(.data, …**)** Extract rows that meet logical criteria. *filter(iris, Sepal.Length > 7)*



distinct(.data, ..., .keep_all = FALSE**)** Remove rows with duplicate values.
distinct(iris, Species)



sample_frac(tbl, size = 1, replace = FALSE, weight = NULL, .env = parent.frame()**)** Randomly select fraction of rows.
sample_frac(iris, 0.5, replace = TRUE)

sample_n(tbl, size, replace = FALSE, weight = NULL, .env = parent.frame()**)** Randomly select size rows. *sample_n(iris, 10, replace = TRUE)*

Manipulate Variables

EXTRACT VARIABLES

Column functions return a set of columns as a new vector or table.

pull(.data, var = -1**)** Extract column values as a vector. Choose by name or index.
pull(iris, Sepal.Length)

select(.data, …**)**
Extract columns as a table. Also **select_if()**.
select(iris, Sepal.Length, Species)

Use these helpers with select (),
e.g. select(iris, starts_with("Sepal"))

contains(match**)**	**num_range(**prefix, range**)**	**:**, e.g. mpg:cyl
ends_with(match**)**	**one_of(**…**)**	**-**, e.g, -Species
matches(match**)**	**starts_with(**match**)**	

https://github.com/rstudio/cheatsheets/raw/master/data-transformation.pdf

Acknowledgements

Acknowledgements

- Style of the RStudio Cheatsheet for Data Transformations

- The Split-Apply-Combine Strategy for Data Analytics by Hadley Wickham