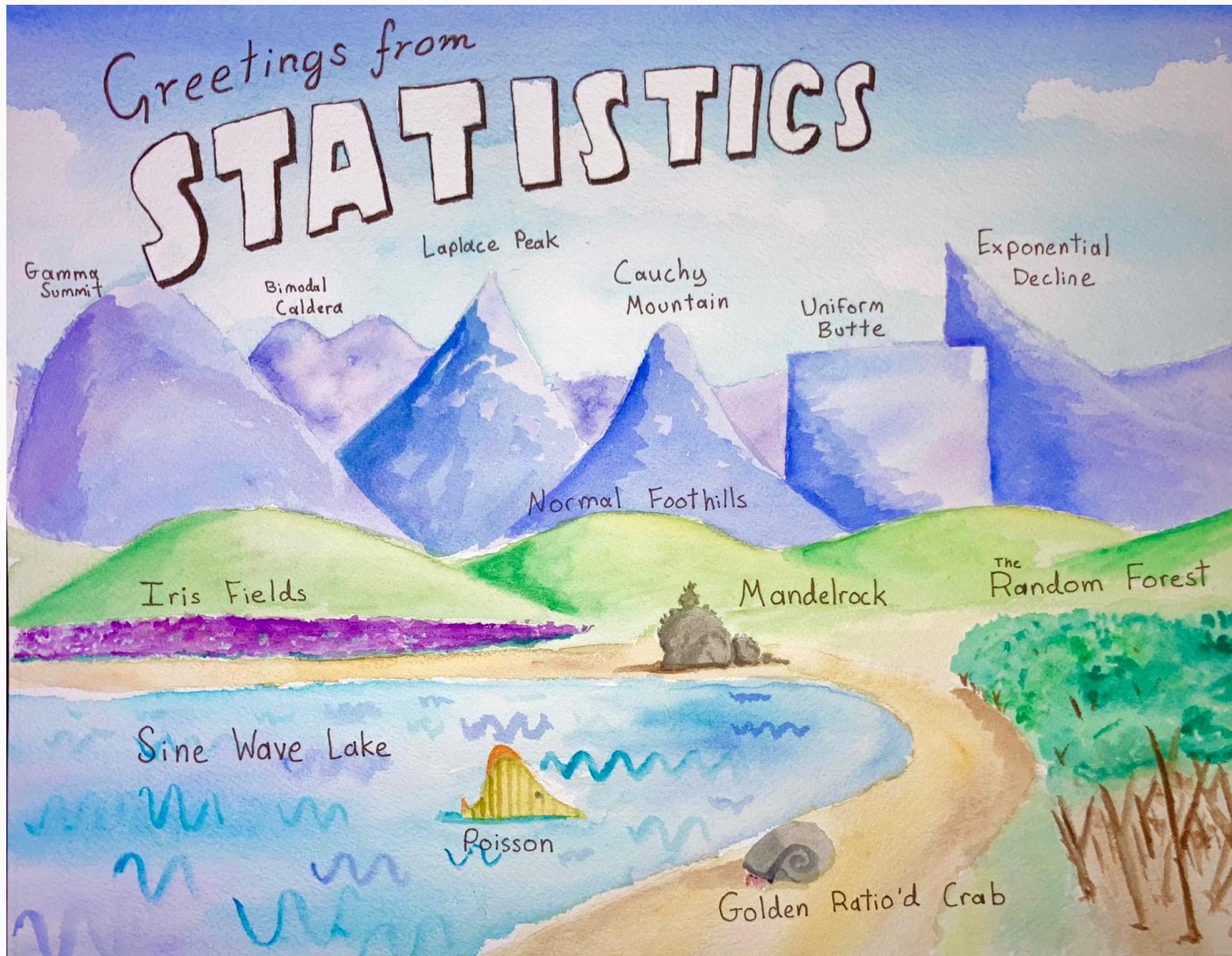


Introduction to DAV 5300

Computational Mathematics and Statistics

Jason Bryer, Ph.D.
Spring 2024

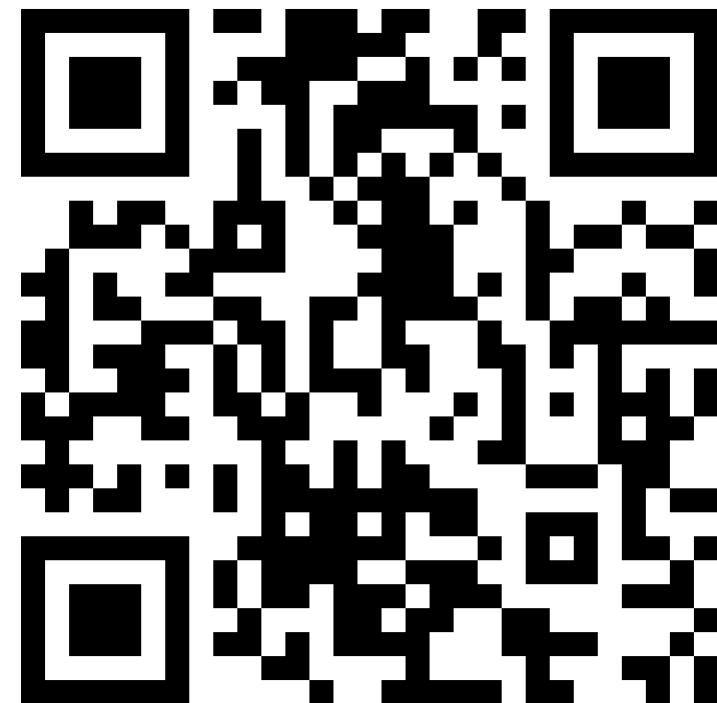


@skyetetra

Agenda

- About your instructor
- Syllabus
- Class meetups
- Course Schedule
- Assignments (how you will be graded)
- Software setup
- Brief introduction to R

While waiting, please complete this formative assessment:



A little about me...

- Earned my Ph.D. in Educational Psychology and Methodology from the University at Albany.
Dissertation: [A National Study Comparing Charter and Traditional Public Schools Using Propensity Score Analysis](#)
- Assistant Professor at CUNY in Data Science and Information Systems
- Principal Investigator for a Department of Education Grant (part of their FIPSE First in the World program) to develop a Diagnostic Assessment and Achievement of College Skills (www.DAACS.net)
- Authored over a dozen R packages including:
 - [likert](#)
 - [sqlutils](#)
 - [timeline](#)
- Specialize in propensity score methods. Three new methods/R packages developed include:
 - [multilevelPSA](#)
 - [TriMatch](#)
 - [PSAboot](#)

Also a Father...



Runner...



And photographer.



Syllabus

Syllabus and course materials are here: <https://github.com/jbryer/DAV5300-2024-Spring>

We will use Canvas primary for submitting assignments only. Please submit PDFs.

PDFs are preferred for the homework as there is some LaTeX formatting in the R markdown files. The `tinytex` R package helps with install LaTeX, but you can also install LaTeX using `MiKTeX` (for Windows) and `BasicTeX` (for Mac).

Class Meetings

Class will meet every Tuesday at 5:30pm to 7:30pm.

In order to get the most out of this class attendance is required.

One Minute Papers - Complete the one minute paper after each Meetup (whether you watch live or watch the recordings). It should take approximately one to two minutes to complete.

Schedule

Week	Start	End	Topic
1	Tuesday, January 16, 2024	Sunday, January 21, 2024	Introduction to R, Rstudio, and the course
2	Monday, January 22, 2024	Sunday, January 28, 2024	Introduction to Data
3	Monday, January 29, 2024	Sunday, February 04, 2024	Data Visualization
4	Monday, February 05, 2024	Sunday, February 18, 2024	Probability
5	Sunday, February 11, 2024	Sunday, February 18, 2024	Multiple Regression
6	Monday, February 19, 2024	Sunday, February 25, 2024	Maximum Likelihood Estimation and Logistic Regression
7	Monday, February 26, 2024	Sunday, March 03, 2024	Bivariate Regression
8	Monday, March 04, 2024	Sunday, March 10, 2024	Foundation for Inference / Central Limit Theorem
9	Monday, March 11, 2024	Sunday, March 17, 2024	Inference for Categorical Data
10	Monday, March 18, 2024	Sunday, March 24, 2024	Inference for Numerical Data
11	Monday, March 25, 2024	Sunday, March 31, 2024	ANOVA
12	Monday, April 01, 2024	Sunday, April 07, 2024	Introduction to Predictive Modeling
13	Monday, April 08, 2024	Sunday, April 14, 2024	Bayesian Analysis
14	Monday, April 15, 2024	Sunday, April 21, 2024	Poster Session
	Monday, April 22, 2024	Tuesday, April 30, 2024	Passover Recess
15	Wednesday, May 01, 2024	Tuesday, May 07, 2024	Final Exam

Textbooks

Introduction to Modern Statistics by Mine Çetinkaya-Rundel and Johanna Hardin - This will be the primary textbook.

R for Data Science by Hadley Wickham and Garrett Grolemund - Recommended reference for those new to R.

OpenIntro Statistics by David Diaz, Mine Çetinkaya-Rundel, and Christopher D Barr.

Assignments

Labs (30%) - Labs are designed to provide you an opportunity to apply statistical concepts using statistical software.

Textbook questions (15%) - The assigned questions from the textbook provide an opportunity to assess conceptional understandings.

Participation (10%) - You are expected to attend every class and to complete a [one minute paper](#) at the conclusion of class.

Poster (25%) - We will hold a poster session on the second to last class. In a group of 2 to 3 students will create poster presenting the results of analysis using a data set of your choice. More details will be provided a few weeks into the class.

Final exam (20%) - A multiple choice exam will be given on the last day of class.

All assignments are due on Sunday. Assignments submitted late will be penalized. Assignments will not be accepted more than one week after their due date.

Communication

- Email: jason.bryer@yu.edu.
- Canvas
- Office hours before and after class and by appointment.

Software Setup

Software



This is an applied statistics course so we will make extensive use of the **R statistical programming language**.

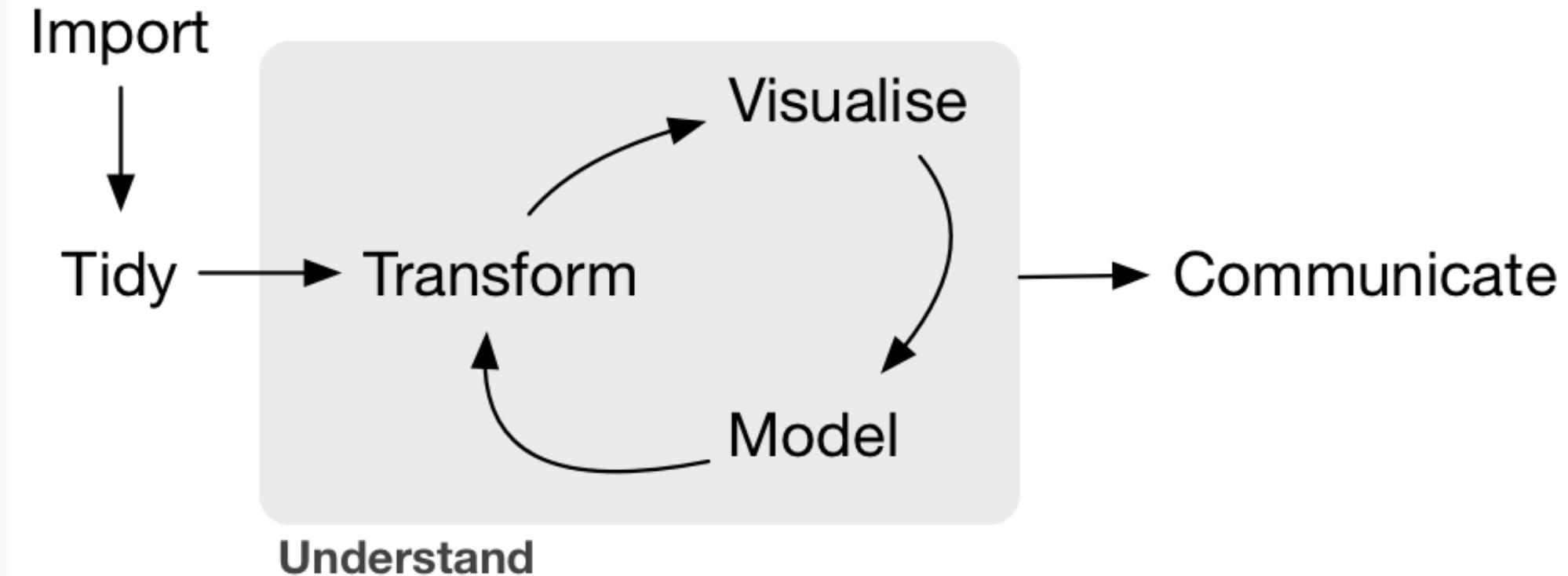
- Install **R** and **RStudio** on your own computer. I encourage everyone to do this at some point by the end of the semester.

You will also need to have **LaTeX** installed as well in order to create PDFs. The **tinytex** R package helps with this process:

```
install.packages('tinytex')
tinytex::install_tinytex()
```

Introduction to R

Workflow



Source: Wickham & Golemud, 2017

Tidy Data

“TIDY DATA is a standard way of mapping the meaning of a dataset to its structure.”

—HADLEY WICKHAM

In tidy data:

- each variable forms a column
- each observation forms a row
- each cell is a single measurement

each column a variable

each row an observation

id	name	color
1	floof	gray
2	max	black
3	cat	orange
4	donut	gray
5	merlin	black
6	panda	calico

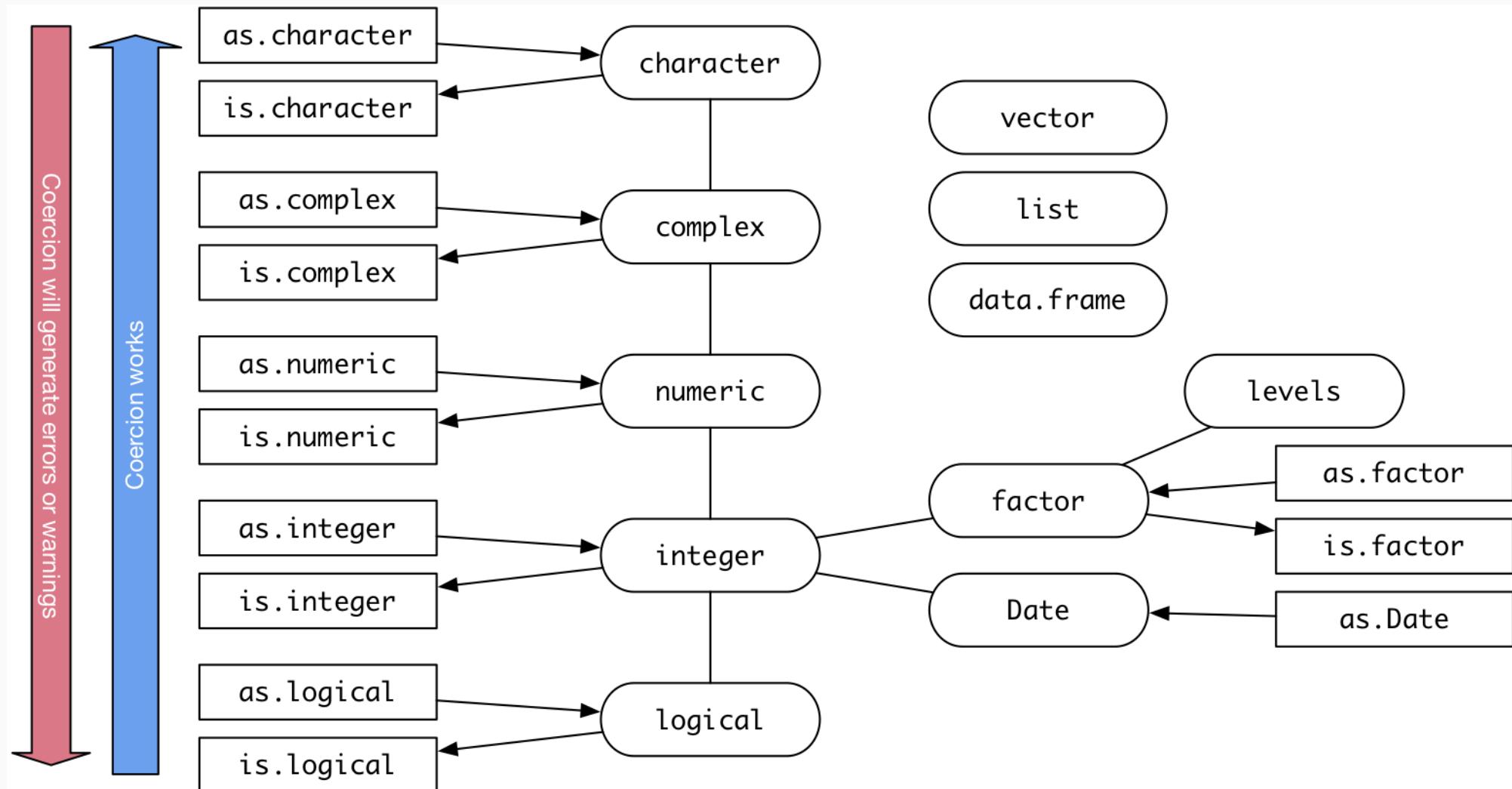
Wickham, H. (2014). Tidy Data. Journal of Statistical Software 59 (10). DOI: 10.18637/jss.v059.i10

Types of Data

- Numerical (quantitative)
 - Continuous
 - Discrete
- Categorical (qualitative)
 - Regular categorical
 - Ordinal



Data Types in R



Data Types / Descriptives / Visualizations

Data Type	Descriptive Stats	Visualization
Continuous	mean, median, mode, standard deviation, IQR	histogram, density, box plot
Discrete	contingency table, proportional table, median	bar plot
Categorical	contingency table, proportional table	bar plot
Ordinal	contingency table, proportional table, median	bar plot
Two quantitative	correlation	scatter plot
Two qualitative	contingency table, chi-squared	mosaic plot, bar plot
Quantitative & Qualitative	grouped summaries, ANOVA, t-test	box plot

Variance

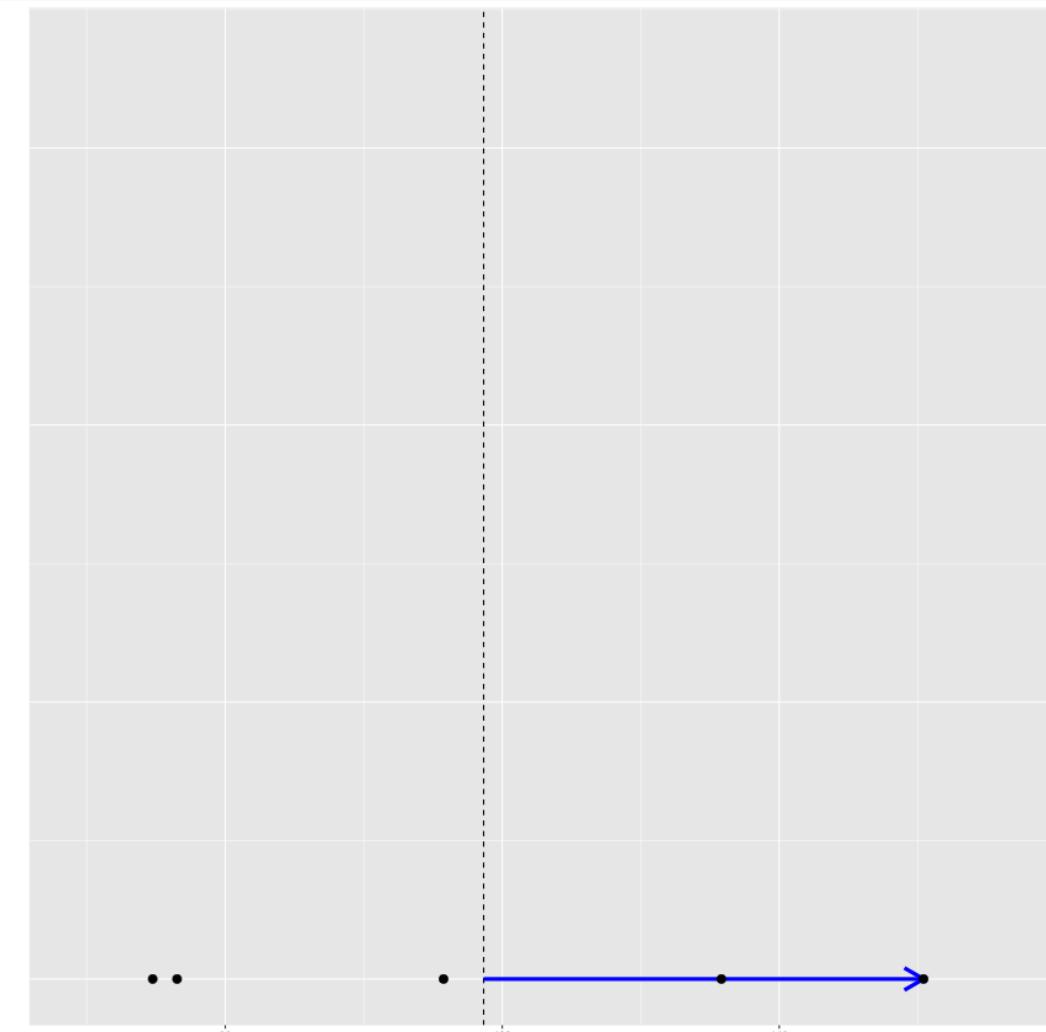
Population Variance:

$$S^2 = \frac{\Sigma(x_i - \bar{x})^2}{N}$$

Consider a dataset with five values (black points in the figure). For the largest value, the deviance is represented by the blue line ($x_i - \bar{x}$).

See also:

<https://shiny.rit.albany.edu/stat/visualizess/>
<https://github.com/jbryer/VisualStats/>

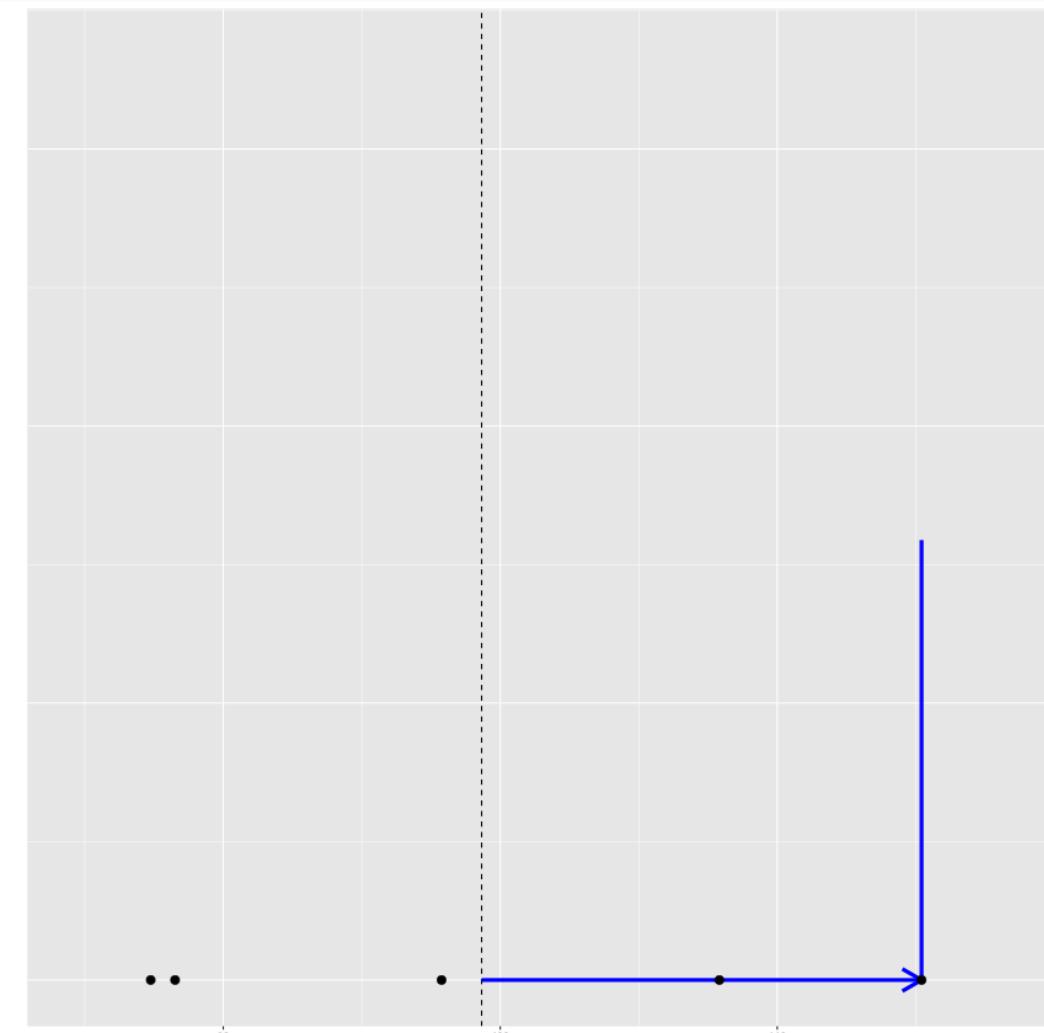


Variance (cont.)

Population Variance:

$$S^2 = \frac{\Sigma(x_i - \bar{x})^2}{N}$$

In the numerator, we square each of these deviances. We can conceptualize this as a square. Here, we add the deviance in the y direction.

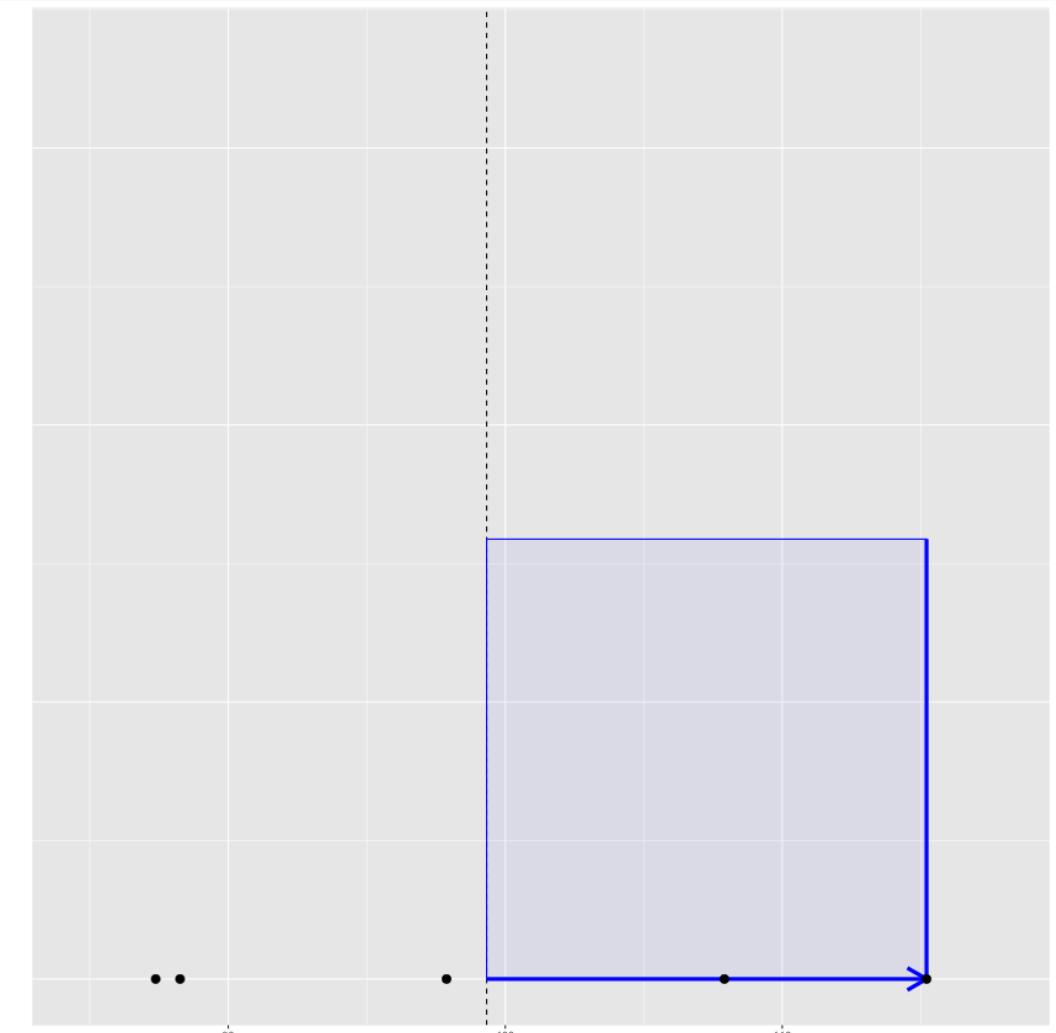


Variance (cont.)

Population Variance:

$$S^2 = \frac{\Sigma(x_i - \bar{x})^2}{N}$$

We end up with a square.

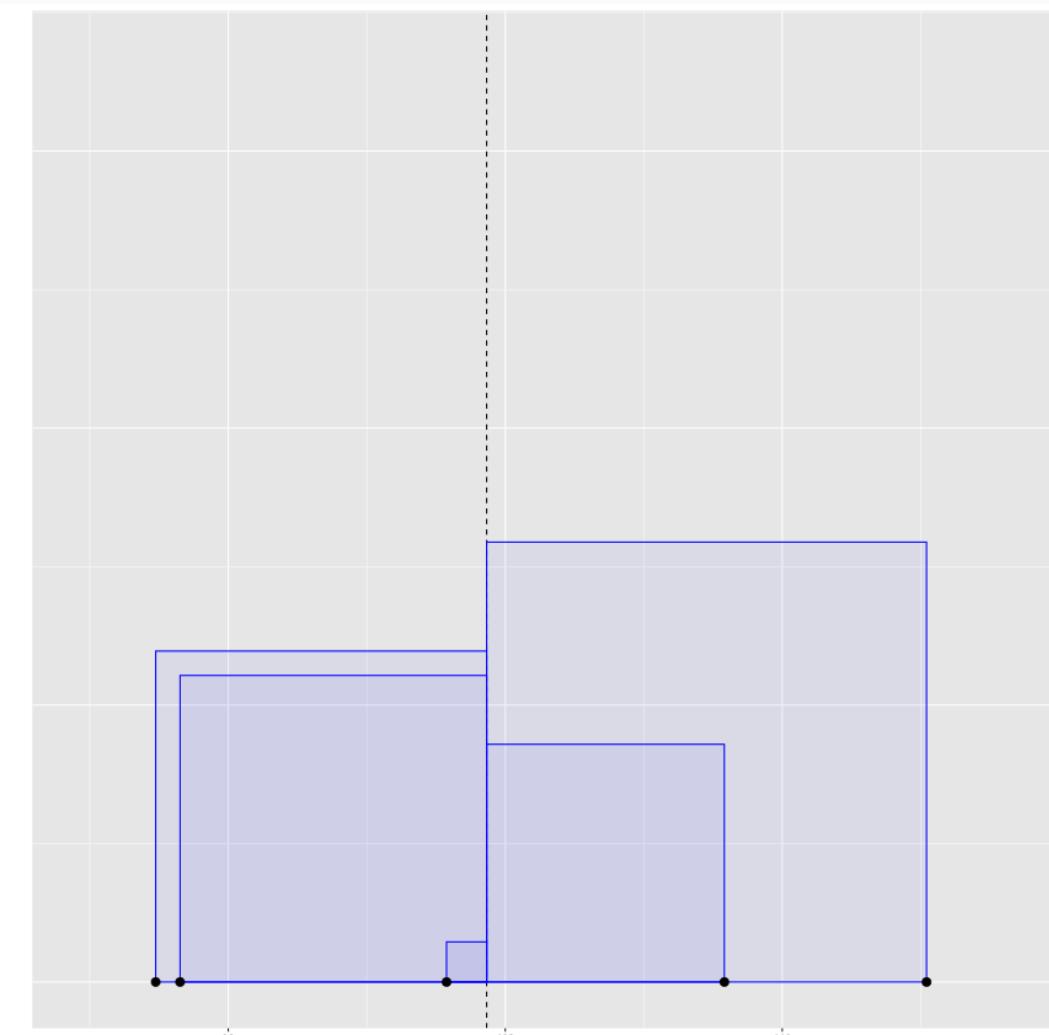


Variance (cont.)

Population Variance:

$$S^2 = \frac{\Sigma(x_i - \bar{x})^2}{N}$$

We can plot the squared deviance for all the data points. That is, each component in the numerator is the area of each of these squares.

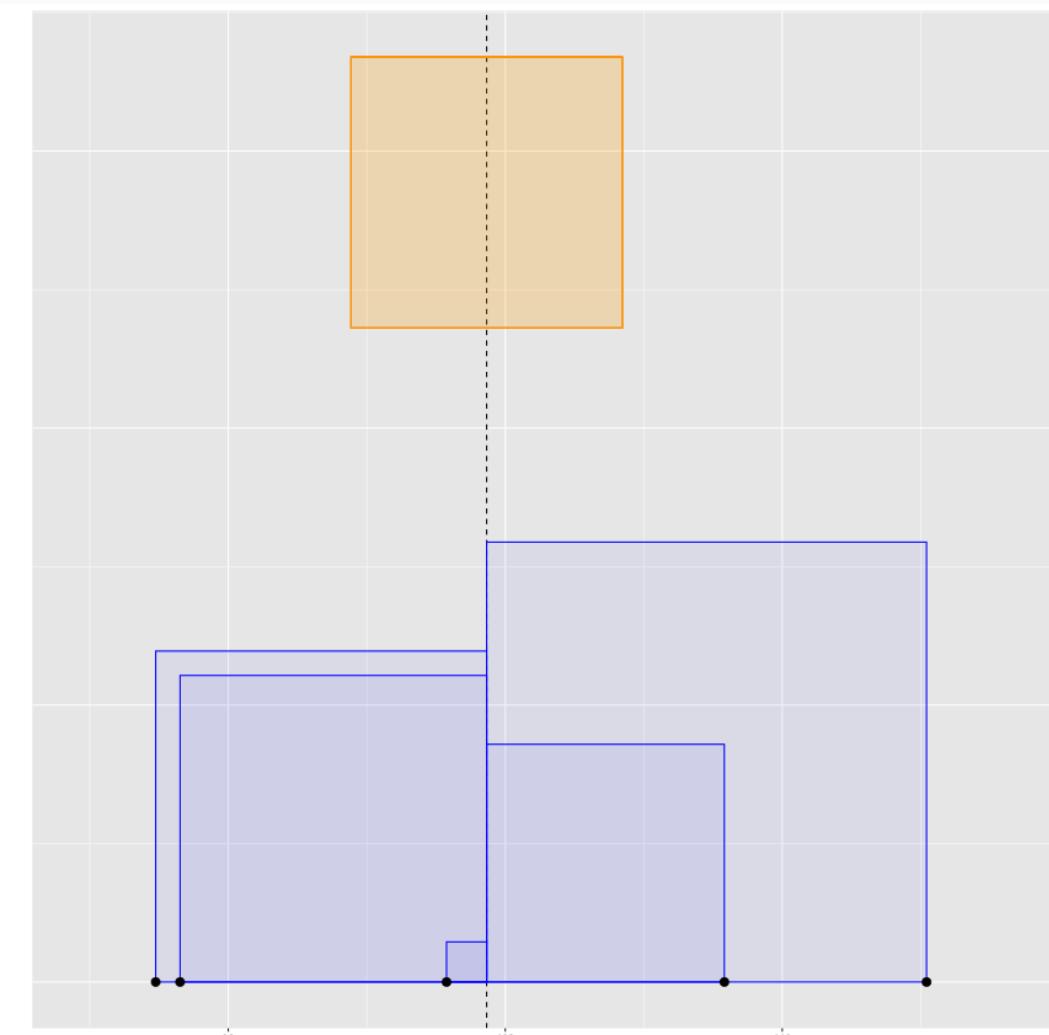


Variance (cont.)

Population Variance:

$$S^2 = \frac{\Sigma(x_i - \bar{x})^2}{N}$$

The variance is therefore the average of the area of all these squares, here represented by the orange square.



Population versus Sample Variance

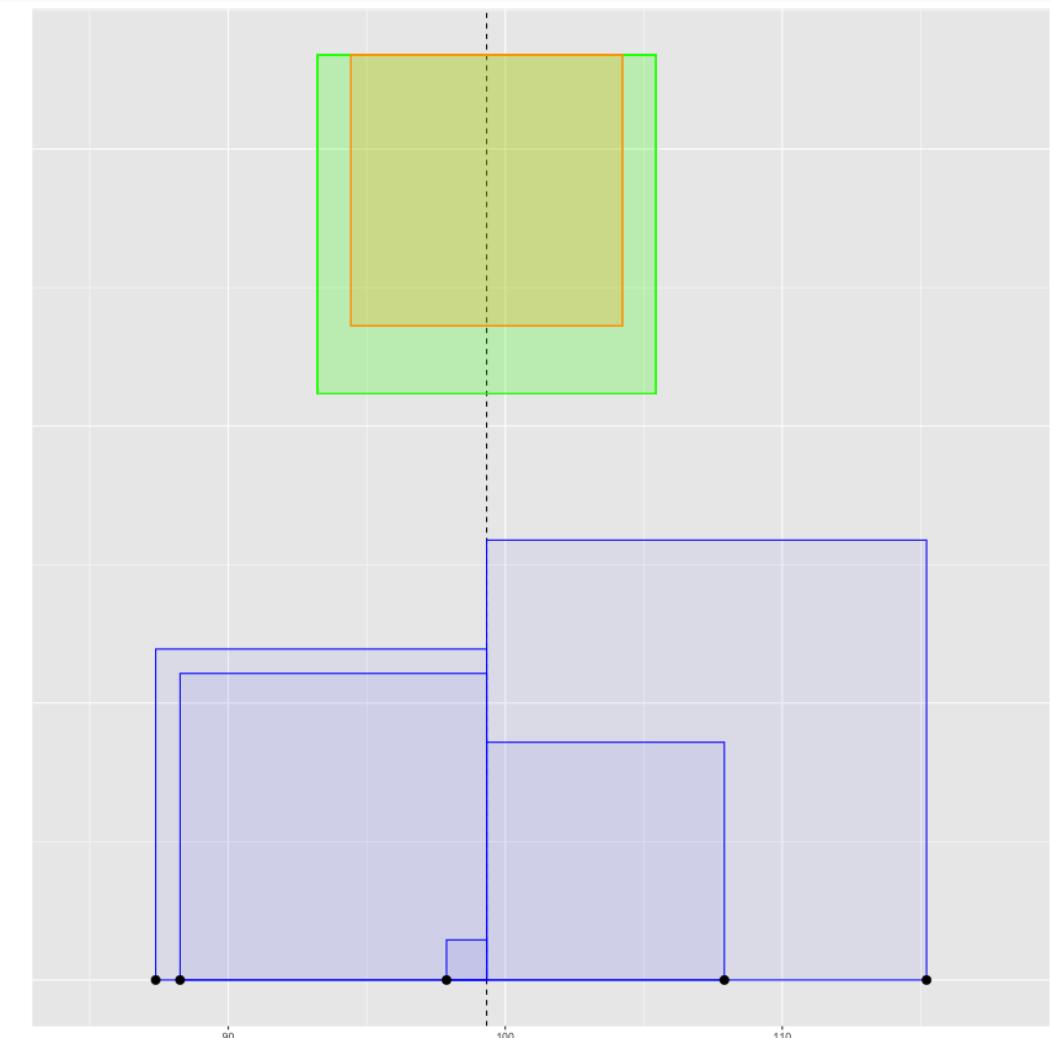
Typically we want the sample variance. The difference is we divide by $n - 1$ to calculate the sample variance. This results in a slightly larger area (variance) then if we divide by n .

Population Variance (yellow):

$$S^2 = \frac{\sum(x_i - \bar{x})^2}{N}$$

Sample Variance (green):

$$s^2 = \frac{\sum(x_i - \bar{x})^2}{n - 1}$$



Robust Statistics

Consider the following data randomly selected from the normal distribution:

```
set.seed(41)
x <- rnorm(30, mean = 100, sd = 15)
mean(x); sd(x)
```

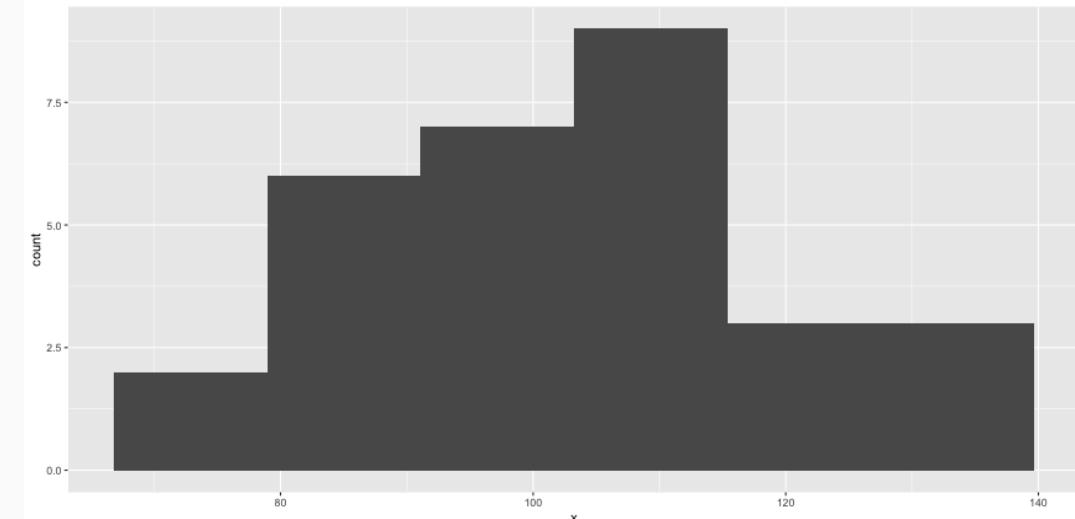
```
## [1] 103.1934
```

```
## [1] 16.8945
```

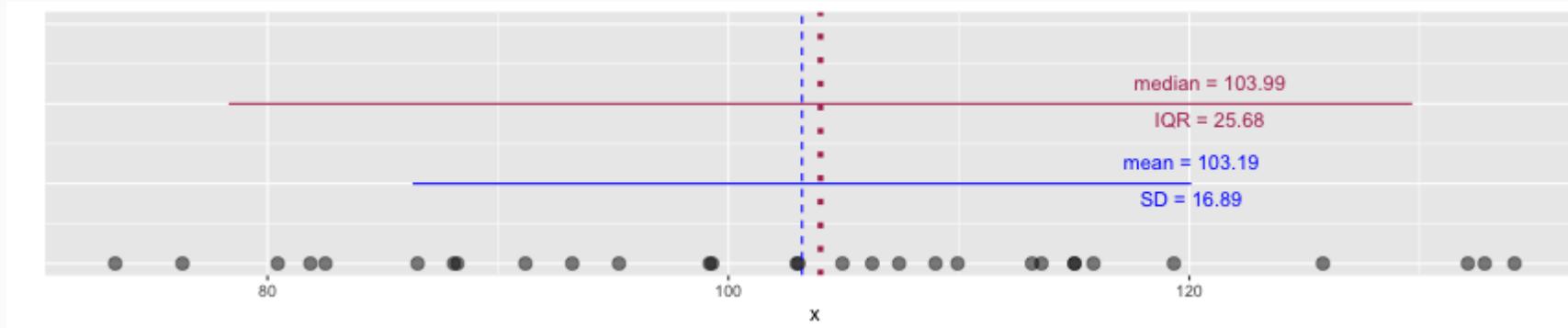
```
median(x); IQR(x)
```

```
## [1] 103.9947
```

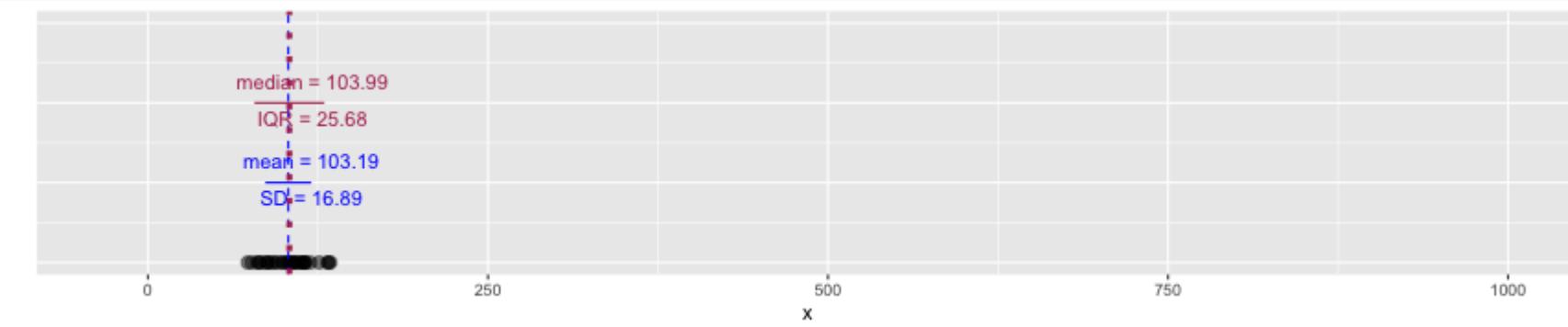
```
## [1] 25.68004
```



Robust Statistics

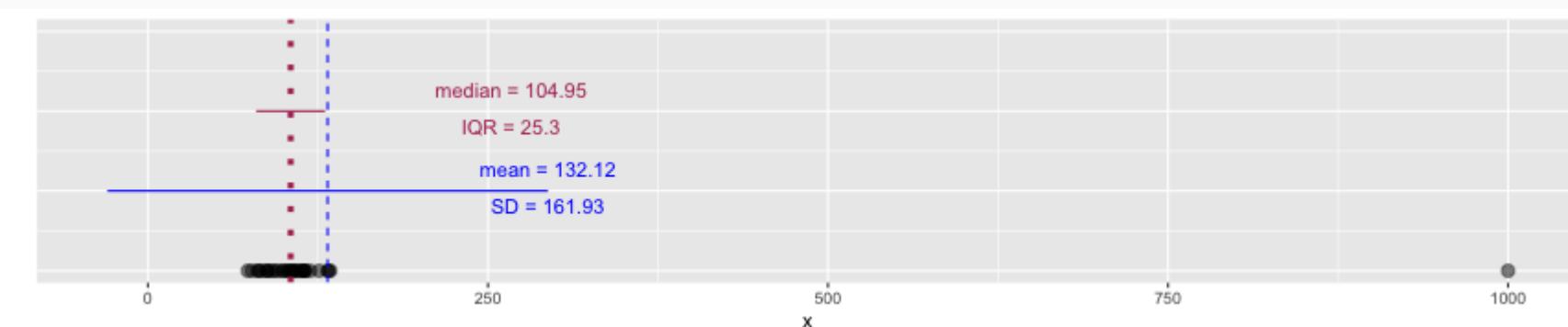


Robust Statistics



Let's add an extreme value:

```
x <- c(x, 1000)
```



Robust Statistics

Median and IQR are more robust to skewness and outliers than mean and SD. Therefore,

- for skewed distributions it is often more helpful to use median and IQR to describe the center and spread
- for symmetric distributions it is often more helpful to use the mean and SD to describe the center and spread



About legosets

To install the `brickset` package:

```
remotes::install_github('jbryer/brickset')
```

To load the `legosets` dataset.

```
data('legosets', package = 'brickset')
```

The `legosets` data has 19409 observations of 36 variables.

```
names(legosets)
```

```
## [1] "setID"                 "number"                "numberVariant"  
## [4] "name"                  "year"                  "theme"  
## [7] "themeGroup"             "subtheme"              "category"  
## [10] "released"               "pieces"                "minifigs"  
## [13] "bricksetURL"            "rating"                "reviewCount"  
## [16] "packagingType"          "availability"          "agerange_min"  
## [19] "thumbnailURL"           "imageURL"              "US_retailPrice"  
## [22] "US_dateFirstAvailable" "US_dateLastAvailable" "UK_retailPrice"  
## [25] "UK_dateFirstAvailable" "UK_dateLastAvailable" "CA_retailPrice"  
## [28] "CA_dateFirstAvailable" "CA_dateLastAvailable" "DE_retailPrice"  
## [31] "DE_dateFirstAvailable" "DE_dateLastAvailable" "height"  
## [34] "width"                  "depth"                 "weight"
```

Structure (str)

```
str(legosets)
```

```
## 'data.frame': 19409 obs. of 36 variables:
## $ setID      : int 7693 7695 7697 7698 25534 ...
## $ number     : chr "1" "2" "3" "4" ...
## $ numberVariant : int 8 8 6 4 6 1 1 1 3 4 ...
## $ name       : chr "Small house set" "Medium house set" "Medium house set" "Large house set" ...
## $ year        : int 1970 1970 1970 1970 1970 1970 1970 1970 1970 ...
## $ theme      : chr "Minitalia" "Minitalia" "Minitalia" "Minitalia" ...
## $ themeGroup : chr "Vintage" "Vintage" "Vintage" "Vintage" ...
## $ subtheme   : chr NA NA NA NA ...
## $ category   : chr "Normal" "Normal" "Normal" "Normal" ...
## $ released    : logi TRUE TRUE TRUE TRUE TRUE ...
## $ pieces      : int 67 109 158 233 NA 1 1 60 65 NA ...
## $ minifigs   : int NA NA NA NA NA NA NA NA NA ...
## $ bricksetURL: chr "https://brickset.com/sets/1-8" "https://brickset.com/sets/2-8" "https://brickset.com/sets/3-6" "https://brickset.com/sets/4-4" ...
## $ rating      : num 0 0 0 0 0 0 0 0 0 ...
## $ reviewCount: int 0 0 1 0 0 0 0 0 0 ...
## $ packagingType: chr "{Not specified}" "{Not specified}" "{Not specified}" "{Not specified}" ...
## $ availability: chr "{Not specified}" "{Not specified}" "{Not specified}" "{Not specified}" ...
## $ agerange_min: int NA NA NA NA NA NA NA NA NA ...
## $ thumbnailURL: chr "https://images.brickset.com/sets/small/1-8.jpg" "https://images.brickset.com/sets/small/2-8.jpg" "https://images.brickset.com/sets/small/3-6.jpg" "https://images.brickset.com/sets/small/4-4.jpg" ...
## $ imageURL    : chr "https://images.brickset.com/sets/images/1-8.jpg" "https://images.brickset.com/sets/images/2-8.jpg" "https://images.brickset.com/sets/images/3-6.jpg" "https://images.brickset.com/sets/images/4-4.jpg" ...
## $ US_retailPrice: num NA NA NA NA NA NA NA NA NA ...
## $ US_dateFirstAvailable: Date, format: NA NA ...
## $ US_dateLastAvailable: Date, format: NA NA ...
## $ UK_retailPrice   : num NA NA NA NA NA NA NA NA NA ...
## $ UK_dateFirstAvailable: Date, format: NA NA ...
## $ UK_dateLastAvailable: Date, format: NA NA ...
## $ CA_retailPrice   : num NA NA NA NA NA NA NA NA NA ...
## $ CA_dateFirstAvailable: Date, format: NA NA ...
## $ CA_dateLastAvailable: Date, format: NA NA ...
## $ DE_retailPrice   : num NA NA NA NA NA NA NA NA NA ...
## $ DE_dateFirstAvailable: Date, format: NA NA ...
## $ DE_dateLastAvailable: Date, format: NA NA ...
## $ height         : num NA NA NA NA NA ...
## $ width          : num NA NA NA NA NA ...
```

RStudio Environment tab can help

Environment History Connections Git Tutorial

Import Dataset | 

R Global Environment 

Data

legosets	16355 obs. of 34 variables
\$ setID	: int 7693 7695 7697 7698 25534 ...
\$ name	: chr "Small house set" "Medium house set" "Medium house set" "L...
\$ year	: int 1970 1970 1970 1970 1970 1970 1970 1970 1970 1970 1970 1970 ...
\$ theme	: chr "Minitalia" "Minitalia" "Minitalia" "Minitalia" ...
\$ themeGroup	: chr "Vintage" "Vintage" "Vintage" "Vintage" ...
\$ subtheme	: chr NA NA NA NA ...
\$ category	: chr "Normal" "Normal" "Normal" "Normal" ...
\$ released	: logi TRUE TRUE TRUE TRUE TRUE ...
\$ pieces	: int 67 109 158 233 NA 1 1 60 65 NA ...
\$ minifigs	: int NA NA NA NA NA NA NA NA NA ...
\$ bricksetURL	: chr "https://brickset.com/sets/1-8" "https://brickset.com/sets..."
\$ rating	: num 0 0 0 0 0 0 0 0 0 ...
\$ reviewCount	: int 0 0 1 0 0 0 0 1 0 0 ...
\$ packagingType	: chr "{Not specified}" "{Not specified}" "{No..."
\$ availability	: chr "{Not specified}" "{Not specified}" "{No..."
\$ agerange_min	: int NA NA NA NA NA NA NA NA NA ...
\$ US_retailPrice	: num NA NA NA NA NA 1.99 NA NA 4.99 NA ...
\$ US_dateFirstAvailable	: Date, format: NA NA NA NA ...
\$ US_dateLastAvailable	: Date, format: NA NA NA NA ...
\$ UK_retailPrice	: num NA NA NA NA NA NA NA NA NA ...
\$ UK_dateFirstAvailable	: Date, format: NA NA NA NA ...
\$ UK_dateLastAvailable	: Date, format: NA NA NA NA ...
\$ CA_retailPrice	: num NA NA NA NA NA NA NA NA NA ...
\$ CA_dateFirstAvailable	: Date, format: NA NA NA NA ...
\$ CA_dateLastAvailable	: Date, format: NA NA NA NA ...
\$ DE_retailPrice	: num NA NA NA NA NA NA NA NA NA ...
\$ DE_dateFirstAvailable	: Date, format: NA NA NA NA ...
\$ DE_dateLastAvailable	: Date, format: NA NA NA NA ...
\$ height	: num NA NA NA NA NA ...
\$ width	: num NA NA NA NA NA ...
\$ depth	: num NA NA NA NA NA NA NA 5.08 NA ...
\$ weight	: num NA NA NA NA NA NA NA NA NA ...
\$ thumbnailURL	: chr "https://images.brickset.com/sets/small/1-8.jpg" "https://..."
\$ imageURL	: chr "https://images.brickset.com/sets/images/1-8.jpg" "https:/..."

Table View

Table View											
Show		10	▼	entries		Search:					
setID	name		year	theme	themeGroup	category	US_retailPrice	pieces	minifigs	rating	
1	9712	Darth Maul	2012	Gear	Miscellaneous	Gear	4.99			3.7	
2	28411	TIE Fighter Attack	2019	Star Wars	Licensed	Normal	19.99	77	2	3.5	
3	24252	LEGO Minifigures - Series 14 - Monsters {Random bag}	2015	Collectable Minifigures	Miscellaneous	Random				0	
4	1448	Head Stand	1998	Town	Modern day	Normal		96	3	0	
5	32020	Mania Magazine March - April 1995	1995	Books	Miscellaneous	Book				0	
6	28352	Genius LEGO Inventions with Bricks You Already Have	2018	Books	Miscellaneous	Book				0	
7	34334	Friendship Flowers	2023	Friends	Modern day	Normal		84		3.8	
8	31865	BRICK KICKS Summer 1991	1991	Books	Miscellaneous	Book				0	
9	31061	LEGO Space Projects: 52 Galactic Models	2021	Books	Miscellaneous	Book				0	
10	30688	James Potter	2020	Collectable Minifigures	Miscellaneous	Normal		7	1	3.8	

Showing 1 to 10 of 100 entries

Previous 1 2 3 4 5 ... 10 Next



Data Wrangling 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**



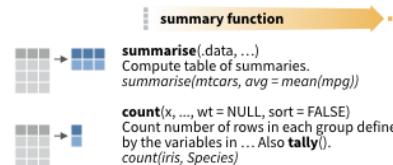
Each **observation**, or **case**, is in its own **row**



`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).

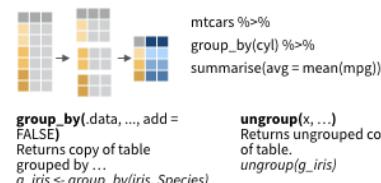


VARIATIONS

`summarise_all()` - Apply funs to every column.
`summarise_at()` - Apply funs to specific columns.
`summarise_if()` - Apply funs to all cols of one type.

Group Cases

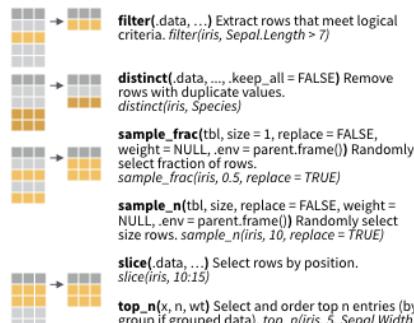
Use `group_by()` to create a "grouped" copy of a table. dplyr functions will manipulate each "group" separately and then combine the results.



Manipulate Cases

EXTRACT CASES

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

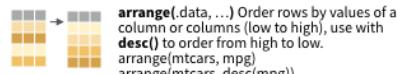


Logical and boolean operators to use with filter()

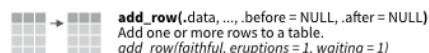
<	=	is.na()	%in%		xor()
>	==	!is.na()	!	&	

See `?base::logic` and `?Comparison` for help.

ARRANGE CASES



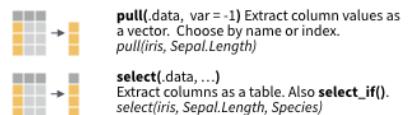
ADD CASES



Manipulate Variables

EXTRACT VARIABLES

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

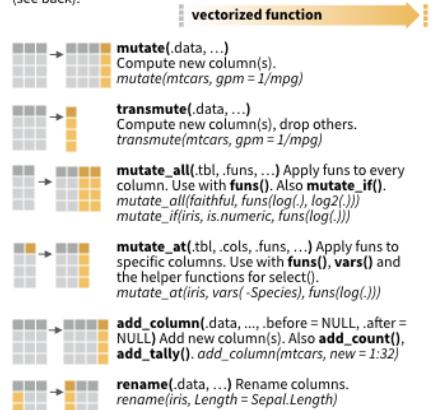


Use these helpers with `select()`, e.g. `select(iris, starts_with("Sepal"))`

<code>contains(match)</code>	<code>num_range(prefix, range)</code>	:	e.g. <code>mpg:cyl</code>
<code>ends_with(match)</code>	<code>one_of(..)</code>	:	e.g. <code>Species</code>
<code>matches(match)</code>	<code>starts_with(match)</code>		

MAKE NEW VARIABLES

These apply **vectorized functions** to columns. Vectorized funs take vectors as input and return vectors of the same length as output (see back).



Tidyverse vs Base R



R Syntax Comparison :: CHEAT SHEET

Dollar sign syntax

```
goal(data$x, data$y)
```

SUMMARY STATISTICS:

one continuous variable:
`mean(mtcars$mpg)`

one categorical variable:
`table(mtcars$cyl)`

two categorical variables:
`table(mtcars$cyl, mtcars$am)`

one continuous, one categorical:
`mean(mtcars$mpg[mtcars$cyl==4])`
`mean(mtcars$mpg[mtcars$cyl==6])`
`mean(mtcars$mpg[mtcars$cyl==8])`

PLOTTING:

one continuous variable:
`hist(mtcars$disp)`

`boxplot(mtcars$disp)`

one categorical variable:
`barplot(table(mtcars$cyl))`

two continuous variables:
`plot(mtcars$disp, mtcars$mpg)`

two categorical variables:
`mosaicplot(table(mtcars$am, mtcars$cyl))`

one continuous, one categorical:
`histogram(mtcars$disp[mtcars$cyl==4])`
`histogram(mtcars$disp[mtcars$cyl==6])`
`histogram(mtcars$disp[mtcars$cyl==8])`

`boxplot(mtcars$disp[mtcars$cyl==4])`
`boxplot(mtcars$disp[mtcars$cyl==6])`
`boxplot(mtcars$disp[mtcars$cyl==8])`

WRANGLING:

subsetting:
`mtcars[mtcars$mpg>30,]`

making a new variable:
`mtcars$efficient[mtcars$mpg>30] <- TRUE`
`mtcars$efficient[mtcars$mpg<30] <- FALSE`

Formula syntax

```
goal(y~x|z, data=data, group=w)
```

SUMMARY STATISTICS:

one continuous variable:
`mosaic::mean(~mpg, data=mtcars)`

one categorical variable:
`mosaic::tally(~cyl, data=mtcars)`

two categorical variables:
`mosaic::tally(cyl~am, data=mtcars)`

one continuous, one categorical:
`mosaic::mean(mpg~cyl, data=mtcars)`

tilde

PLOTTING:

one continuous variable:
`lattice::histogram(~disp, data=mtcars)`

`lattice::bwplot(~disp, data=mtcars)`

one categorical variable:
`mosaic::bargraph(~cyl, data=mtcars)`

two continuous variables:
`lattice::xyplot(mpg~disp, data=mtcars)`

two categorical variables:
`mosaic::bargraph(~am, data=mtcars, group=cyl)`

one continuous, one categorical:
`lattice::histogram(~disp|cyl, data=mtcars)`

`lattice::bwplot(cyl~disp, data=mtcars)`

The variety of R syntaxes give
you many ways to “say” the
same thing

read across the cheatsheet to see how different
syntaxes approach the same problem

Tidyverse syntax

```
data %>% goal(x)
```

SUMMARY STATISTICS:

one continuous variable:
`mtcars %>% dplyr::summarize(mean(mpg))`

one categorical variable:
`mtcars %>% dplyr::group_by(cyl) %>%
dplyr::summarize(n())`

the pipe

two categorical variables:
`mtcars %>% dplyr::group_by(cyl, am) %>%
dplyr::summarize(n())`

one continuous, one categorical:
`mtcars %>% dplyr::group_by(cyl) %>%
dplyr::summarize(mean(mpg))`

PLOTTING:
one continuous variable:
`ggplot2::qplot(x=mpg, data=mtcars, geom = "histogram")`

`ggplot2::qplot(y=disp, x=1, data=mtcars, geom="boxplot")`

one categorical variable:
`ggplot2::qplot(x=cyl, data=mtcars, geom="bar")`

two continuous variables:
`ggplot2::qplot(x=disp, y=mpg, data=mtcars, geom="point")`

two categorical variables:
`ggplot2::qplot(x=factor(cyl), data=mtcars, geom="bar") +
facet_grid(.~am)`

one continuous, one categorical:
`ggplot2::qplot(x=disp, data=mtcars, geom = "histogram") +
facet_grid(.~cyl)`

`ggplot2::qplot(y=disp, x=factor(cyl), data=mtcars,
geom="boxplot")`

WRANGLING:
subsetting:
`mtcars %>% dplyr::filter(mpg>30)`

making a new variable:
`mtcars <- mtcars %>%
dplyr::mutate(efficient = if_else(mpg>30, TRUE, FALSE))`

Pipes %>% and |>



The pipe operator (`%>%`) introduced with the `magrittr` R package allows for the chaining of R operations. Base R has now added their own pipe operator (`|>`). They take the output from the left-hand side and passes it as the first parameter to the function on the right-hand side.



You can do this in two steps:

```
tab_out <- table(legosets$category)
prop.table(tab_out)
```

Or as nested function calls.

```
prop.table(table(legosets$category))
```

Using the pipe (`|>`) operator we can chain these calls in a what is arguably a more readable format:

```
table(legosets$category) |> prop.table()
```

```
##          Book Collection Extended      Gear      Normal       Other
## 0.034468546 0.031377196 0.028749549 0.154515946 0.684682364 0.062599825
```

dplyr::filter()

KEEP ROWS THAT
satisfy
your CONDITIONS

keep rows from... this data... ONLY IF... type MATCHES "otter" AND site MATCHES "bay"
filter(df, type == "otter" & site == "bay")



A cartoon illustration featuring three characters: an orange circle with arms and legs pointing at a map, a purple circle with arms and legs standing next to a green circle, and a green circle with arms and legs pointing at the table. A table with columns 'type', 'food', and 'site' is shown, with the first row ('otter', 'urchin', 'bay') highlighted in pink.

type	food	site
otter	urchin	bay
Shark	seal	channel
otter	abalone	bay
otter	crab	wharf

@allisonhorst

Logical Operators

- `!a` - TRUE if a is FALSE
- `a == b` - TRUE if a and be are equal
- `a != b` - TRUE if a and b are not equal
- `a > b` - TRUE if a is larger than b, but not equal
- `a >= b` - TRUE if a is larger or equal to b
- `a < b` - TRUE if a is smaller than be, but not equal
- `a <= b` - TRUE if a is smaller or equal to b
- `a %in% b` - TRUE if a is in b where b is a vector

```
which( letters %in% c('a','e','i','o','u') )
```

```
## [1] 1 5 9 15 21
```

- `a | b` - TRUE if a or b are TRUE
- `a & b` - TRUE if a and b are TRUE
- `isTRUE(a)` - TRUE if a is TRUE

Filter



dplyr

```
mylego <- legosets %>% filter(themeGroup == 'Educational' & year > 2015)
```

Base R

```
mylego <- legosets[legosets$themeGroups == 'Educaitonal' & legosets$year > 2015,]
```

```
nrow(mylego)
```

```
## [1] 99
```

Select



dplyr

```
mylego <- mylego %>% select(setID, pieces, theme, availability, US_retailPrice, minifigs)
```

Base R

```
mylego <- mylego[,c('setID', 'pieces', 'theme', 'availability', 'US_retailPrice', 'minifigs')]
```

```
head(mylego, n = 4)
```

```
##   setID pieces    theme availability US_retailPrice minifigs
## 1 26803     103 Education {Not specified}        NA         6
## 2 26689     142 Education {Not specified}        NA         4
## 3 26804      98 Education {Not specified}        NA         6
## 4 26277     188 Education Educational       94.95       NA
```

Relocate



dplyr::**relocate()**
move COLUMNS around!

Default: move to FRONT
or move to
.before or .after
A SPECIFIED COLUMN!



Relocate



dplyr

```
mylego %>% relocate(where(is.numeric), .after = where(is.character)) %>% head(n = 3)
```

```
##      theme availability setID pieces US_retailPrice minifigs
## 1 Education {Not specified} 26803     103          NA       6
## 2 Education {Not specified} 26689     142          NA       4
## 3 Education {Not specified} 26804      98          NA       6
```

Base R

```
mylego2 <- mylego[,c('theme', 'availability', 'setID', 'pieces', 'US_retailPrice', 'minifigs')]
head(mylego2, n = 3)
```

```
##      theme availability setID pieces US_retailPrice minifigs
## 1 Education {Not specified} 26803     103          NA       6
## 2 Education {Not specified} 26689     142          NA       4
## 3 Education {Not specified} 26804      98          NA       6
```

Rename



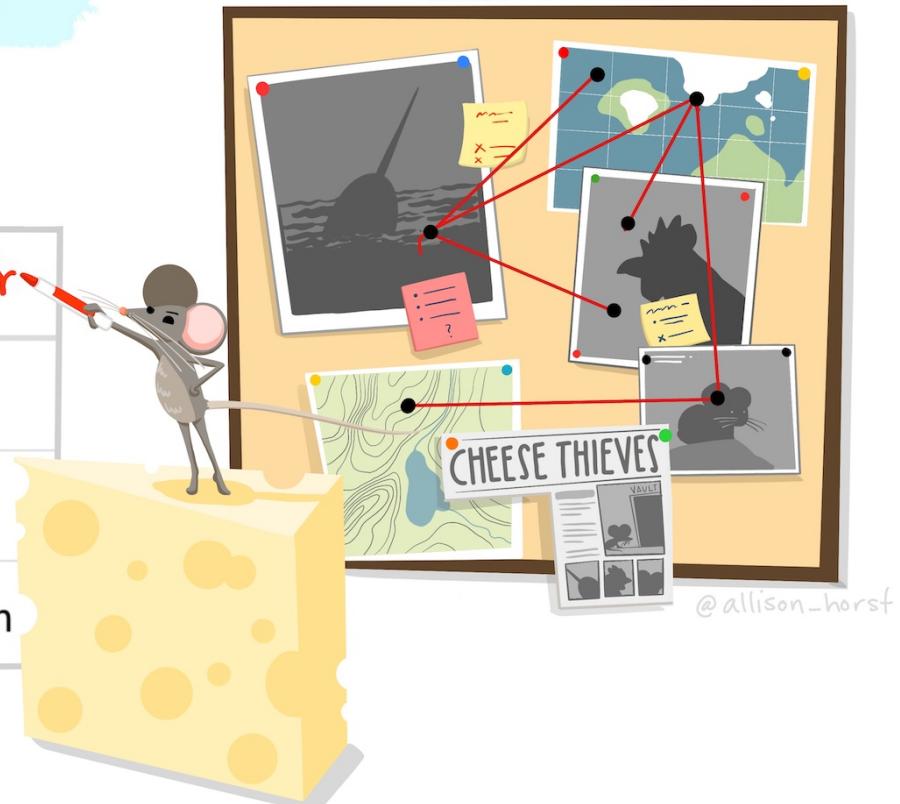
dplyr::rename()

RENAME COLUMNS*

df %>% rename(lair=site)

species nemesis	status	site lair
narwhal	unknown	ocean
chicken	active	coop
pika	active	mountain

*See `rename_with()` to rename using a function.



Rename



dplyr

```
mylego %>% dplyr::rename(USD = US_retailPrice) %>% head(n = 3)
```

```
## #> #> #> #>
```

	setID	pieces	theme	availability	USD	minifigs
## 1	26803	103	Education	{Not specified}	NA	6
## 2	26689	142	Education	{Not specified}	NA	4
## 3	26804	98	Education	{Not specified}	NA	6

Base R

```
names(mylego2)[5] <- 'USD'  
head(mylego2, n = 3)
```

```
## #> #> #> #>
```

	theme	availability	setID	pieces	USD	minifigs
## 1	Education	{Not specified}	26803	103	NA	6
## 2	Education	{Not specified}	26689	142	NA	4
## 3	Education	{Not specified}	26804	98	NA	6

Mutate



Mutate



dplyr

```
mylego %>% filter(!is.na(pieces) & !is.na(US_retailPrice)) %>%  
  mutate(Price_per_piece = US_retailPrice / pieces) %>% head(n = 3)
```

```
## #> #> setID pieces theme availability US_retailPrice minifigs Price_per_piece  
## #> 1 26277 188 Education Educational 94.95 NA 0.5050532  
## #> 2 25949 280 Education Educational 224.95 NA 0.8033929  
## #> 3 25954 1 Education Educational 14.95 NA 14.9500000
```

Base R

```
mylego2 <- mylego[!is.na(mylego$US_retailPrice) & !is.na(mylego$Price_per_piece),]  
mylego2$Price_per_piece <- mylego2$Price_per_piece / mylego2$US_retailPrice  
head(mylego2, n = 3)
```

```
## [1] setID pieces theme availability  
## [5] US_retailPrice minifigs Price_per_piece  
## <0 rows> (or 0-length row.names)
```



Group By and Summarize

```
legosets %>% group_by(themeGroup) %>% summarize(mean_price = mean(US_retailPrice, na.rm = TRUE),  
                                sd_price = sd(US_retailPrice, na.rm = TRUE),  
                                median_price = median(US_retailPrice, na.rm = TRUE),  
                                n = n(),  
                                missing = sum(is.na(US_retailPrice)))
```

```
## # A tibble: 17 × 6  
##   themeGroup     mean_price    sd_price median_price      n missing  
##   <chr>          <dbl>       <dbl>      <dbl> <int>    <int>  
## 1 Action/Adventure  40.2        38.9      30.0  1474     779  
## 2 Art and crafts   34.9        47.7      17.5   97      9  
## 3 Basic             21.6        19.2      15.0   873     733  
## 4 Constraction     16.4        12.4      13.0   502     284  
## 5 Educational       182.        188.      130.   503     465  
## 6 Girls              35.8        24.0      23.0   240     227  
## 7 Historical         34.2        32.4      20.0   473     400  
## 8 Junior             22.0        10.1      20.0   228     165  
## 9 Licensed            53.3        71.7      30.0  2775    1066  
## 10 Miscellaneous      20.7        29.2      13.0  6253    3961  
## 11 Model making       74.3        92.1      40.0   771     384  
## 12 Modern day          38.2        35.6      30.0  2469    1535  
## 13 Pre-school          30.8        22.7      25.0  1562    1103  
## 14 Racing              26.8        26.5      15.0   270     176
```

Describe and Describe By

```
library(psych)
```

```
describe(legosets$US_retailPrice)
```

```
##      vars     n   mean    sd median trimmed    mad    min    max range skew kurtosis
## X1      1 7483 38.96 56.5  19.99    27.7 17.79 1.49 849.99 848.5 5.32    44.74
##          se
## X1 0.65
```

```
describeBy(legosets$US_retailPrice, group = legosets$availability, mat = TRUE, skew = FALSE)
```

```
##      item           group1 vars     n   mean    sd    min    max range     se
## X11     1 {Not specified}  1 1831 26.84733 39.96747 1.49 789.99 788.5 0.9340335
## X12     2 Educational     1   12 212.86667 105.88283 14.95 399.95 385.0 30.5657410
## X13     3 LEGO exclusive  1 1039 57.21203 106.63125 1.99 849.99 848.0 3.3080857
## X14     4 LEGOLAND exclusive 1    2  4.99000  0.00000  4.99    4.99  0.0 0.0000000
## X15     5 Not sold       1    1 12.99000        NA 12.99    12.99  0.0        NA
## X16     6 Promotional     1    5  4.79000  0.83666  3.99    5.99  2.0 0.3741657
## X17     7 Promotional (Airline) 1    0      NaN        NA Inf -Inf -Inf        NA
## X18     8 Retail           1 4290 37.55889 38.44918 1.99 699.99 698.0 0.5870275
## X19     9 Retail - limited 1   302 63.54381 70.91908 2.49 449.99 447.5 4.0809343
## X110   10 Unknown         1    1  3.99000        NA 3.99    3.99  0.0        NA
```

Additional Resources

For data wrangling:

- `dplyr` website: <https://dplyr.tidyverse.org>
- R for Data Science book: <https://r4ds.had.co.nz/wrangle-intro.html>
- Wrangling penguins tutorial: <https://allisonhorst.shinyapps.io/dplyr-learnr/#section-welcome>
- Data transformation cheat sheet: <https://github.com/rstudio/cheatsheets/raw/master/data-transformation.pdf>

One Minute Paper

Complete the one minute paper:

<https://forms.gle/CD5Qxkq3xtdxSheW8>

1. What was the most important thing you learned during this class?

2. What important question remains unanswered for you?



Good luck with the semester!

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 github.com/jbryer/DAV5300-2024-Spring