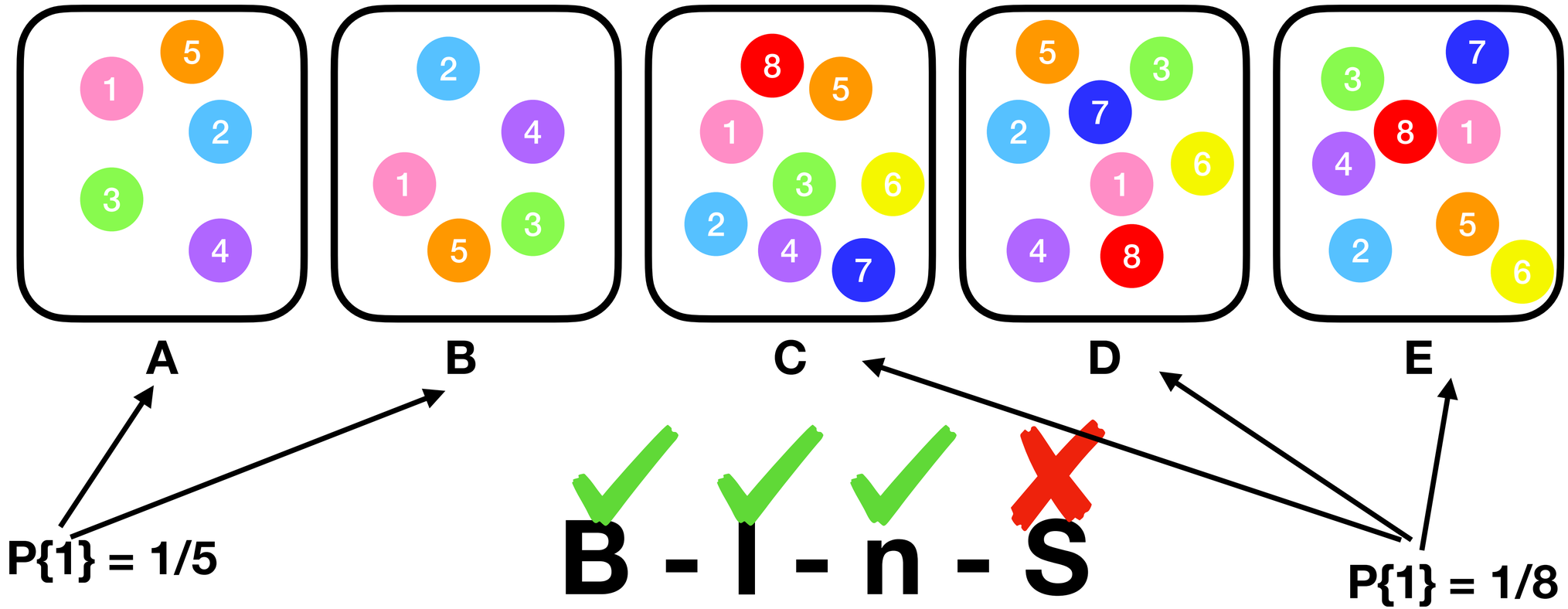
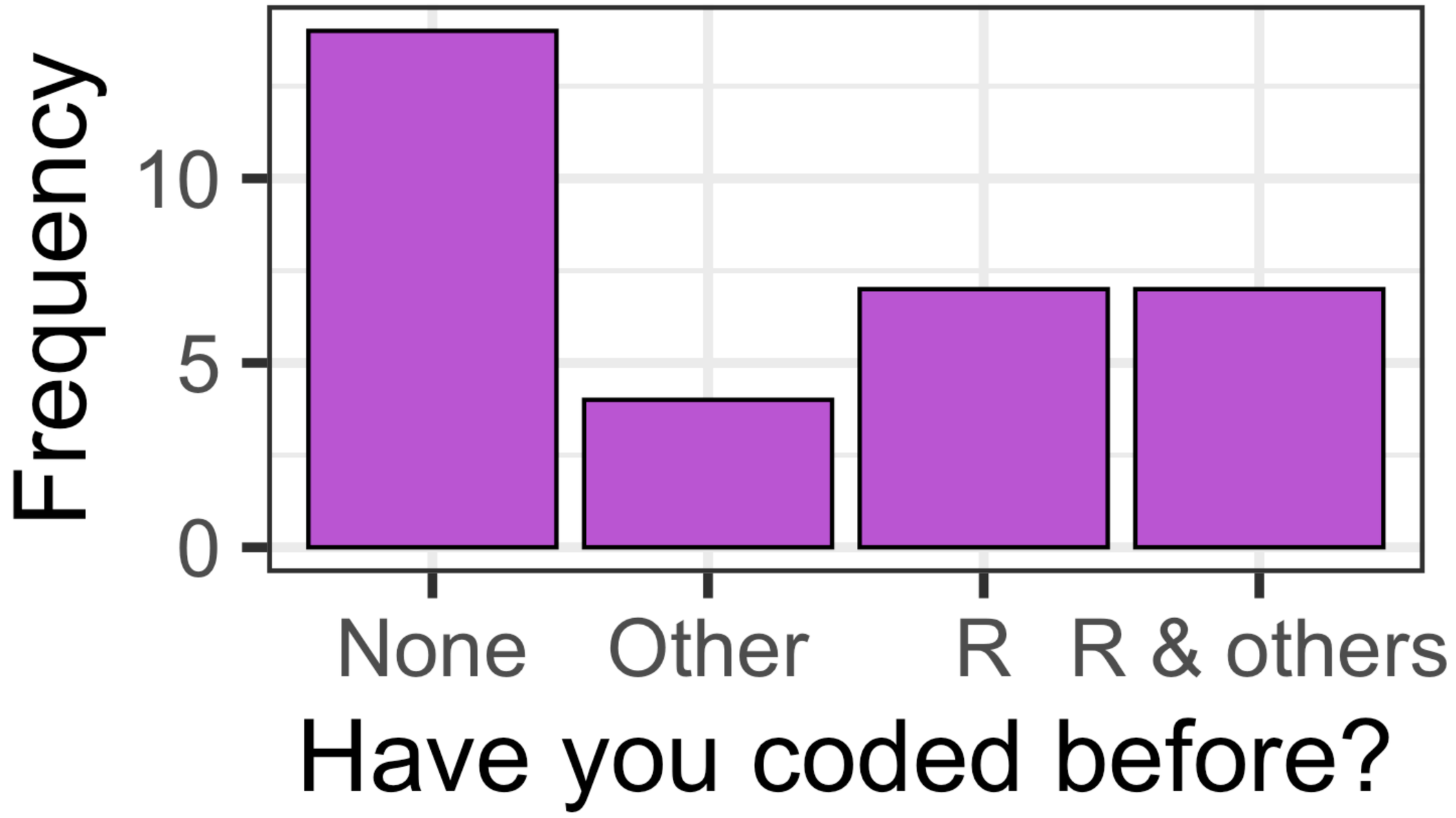
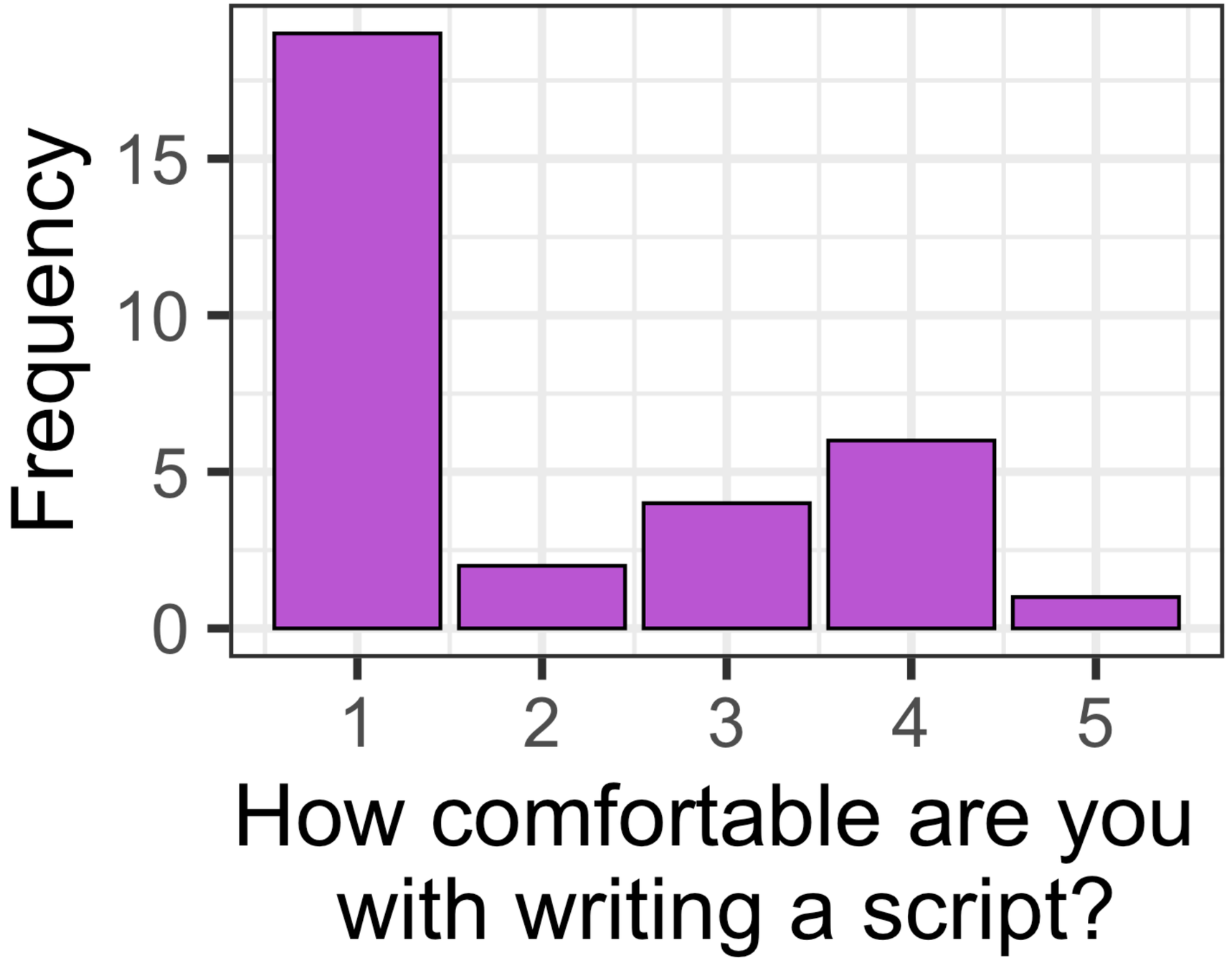
Practicum 01

10.05.2021

You have 5 urns: A, B, C, D, E. Urns A and B have balls numbered 1 through 5; urns C, D, E have ball numbers 1 through 8. There are five trials. In each trial, you draw a ball from an urn. In the first trial you draw from urn A, in the second trial you draw from urn B, etc. Let X be the number of times you draw a ball numbered 1.




Frequency
10
5
0
None
Other
R
R & others
Have you coded before?


Frequency
15
10
5
0
1
2
3
4
5
How comfortable are you with writing a script?

A general and basic knowledge of programming and how to use it to analyze data.

To become comfortable with using R to analyze data rather than being scared.

Becoming more comfortable with R data analysis

Become more comfortable writing code

Coding and R

I want to learn how to code!

Become more comfortable/fluent with de novo writing of analysis scripts and using appropriate plug-ins within the R coding language.

Basic Script Writing

How to use R and how to perform useful statistical analyses

how to use R to analyze my data

I would love to be more comfortable with writing and use code to analyze data

How to better analyze my data.

get comfortable with using r

R

Learn R and hopefully use R to generate data during PhD ! That's the goal!

computational skills

how to use R in a meaningful way that can benefit my research

Learn programming skills specifically applicable to biology

More hands-on experience with R and scripting

how to be proficient in R

Become proficient in R so that I can try and join a Bioinformatics lab.

Becoming more comfortable with R

Learn how to use R or other tools like SPSS or Python, and writing a script to analyze my data

How to analyze my data

analyzing sequencing data

Tools to work on my dataset!

Python

How to be comfortable with writing a script to perform data analysis

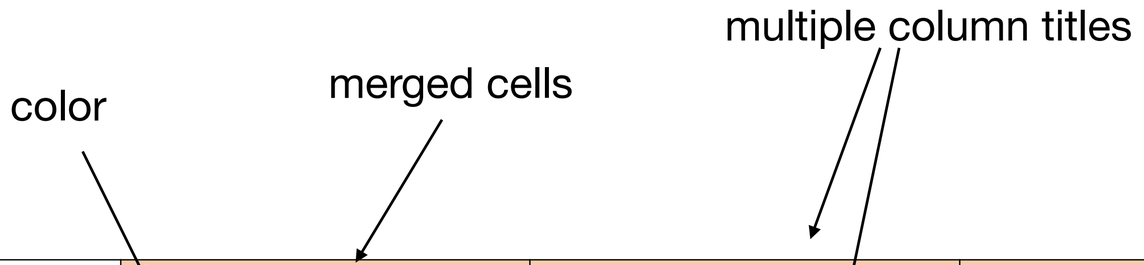
Intro to the Tidyverse for clean data

- Collection of packages for data manipulation, exploration, and visualization that share a common syntax
- Intended to make data scientists more productive by guiding them through workflows
- Allows for connections between tools

“Happy families are all alike; every unhappy family is unhappy in its own way.” — Leo Tolstoy

“Tidy datasets are all alike, but every messy dataset is messy in its own way.” — Hadley Wickham

Intro to the Tidyverse for clean data



	Replicate1			Replicate2			Replicate3			Replicate4		
PLATE1	day0	day2	day2/day0	day0	day2	day2/day0	day0	day2	day2/day0	day0	day2	day2/day0
BRC20067	229	2	0.8733624454148	138	0	0	234	0	0	136	0	0
DL238	285	183	64.210526315789	334	161	48.2035928143713	179	71	39.6648044692737	224	110	49.1071428571429
A3	166	0	0	104	0	0	231	0	0	251	0	0
A6_R1	57	0	0	62	0	0	60	0	0	75	0	0
A6_R2	150	0	0	256	6	2.34375	265	4	1.50943396226415	236	0	0
B2	187	2	1.0695187165775	165	1	0.606060606060606	183	0	0	171	4	2.33918128654971
B3	179	12	6.703910614525	202	26	12.8712871287129	251	22	8.76494023904382	243	26	10.6995884773663
B6	128	15	11.71875	113	9	7.9646017699115	220	10	4.54545454545455	214	14	6.54205607476636
B8	268	0	0	155	0	0	164	1	0.60975609756097	175	0	0
B9	93	2	2.1505376344086	118	2	1.69491525423729	132	0	0	111	2	1.8018018018018
B10	188	2	1.0638297872340	379	2	0.527704485488127	225	0	0			
C6	169	0	0	129	1	0.775193798449611	130	0	0	115	1	0.869565217391304

Q: Clean or messy?

Intro to the Tidyverse for clean data

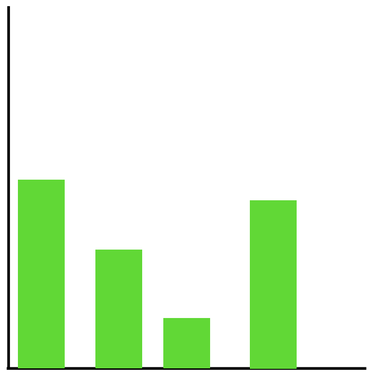
strain	survival	rep	day
BRC20067	2.873362445	A	1
DL238	54.21052631	A	1
A3		A	1
A6_R1		A	1
A6_R2		A	1
B2	1.069518716	A	1
B3	6.703910614	A	1
B6	11.7187	A	1
B8		A	1
B9	2.150537634	A	1
B10	1.063829787	A	1
C6		A	1
BRC20067		B	1
DL238	48.20359281	B	1
A3		B	1
A6_R1		B	1
A6_R2	2.34375	B	1
B2	0.606060606	B	1
B3	12.87128712	B	1
B6	7.964601769	B	1
B8		B	1

Rules for tidy data

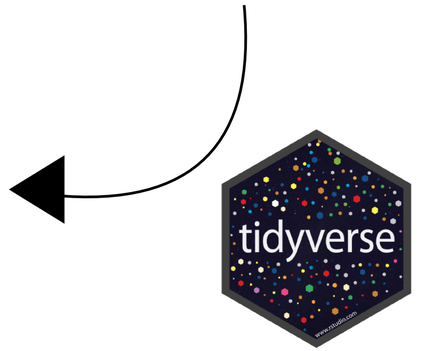
- Each **variable** must have its own **column**
- Each **observation** must have its own **row**
- Each **value** must have its own **cell**

Intro to the Tidyverse for clean data

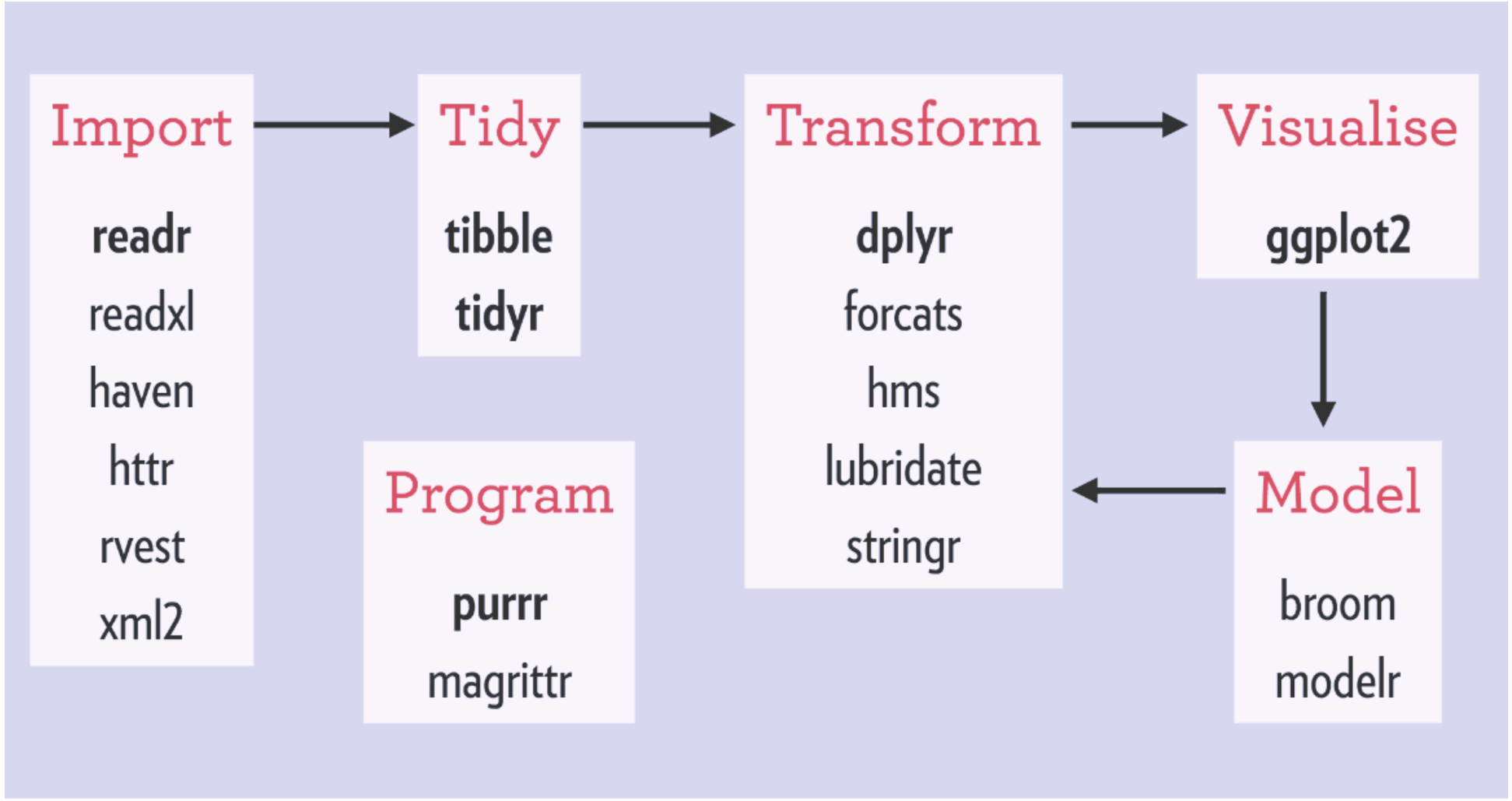
	Replicate1			Replicate2			Replicate3			Replicate4		
PLATE1	day0	day2	day2/day0	day0	day2	day2/day0	day0	day2	day2/day0	day0	day2	day2/day0
BRC20067	229	2	0.8733624454148	138	0	0	234	0	0	136	0	0
DL238	285	183	64.21052631578	334	161	48.2035928143713	179	71	39.6648044692737	224	110	49.1071428571429
A3	166	0	0	104	0	0	231	0	0	251	0	0
A6_R1	57	0	0	62	0	0	60	0	0	75	0	0
A6_R2	150	0	0	256	6	2.34375	265	4	1.50943396226415	236	0	0
B2	187	2	1.0695187165775	165	1	0.60606060606060	183	0	0	171	4	2.33918128654971
B3	179	12	6.703910614525	202	26	12.8712871287129	251	22	8.76494023904382	243	26	10.6995884773663
B6	128	15	11.71875	113	9	7.9646017699115	220	10	4.54545454545455	214	14	6.54205607476636
B8	268	0	0	155	0	0	164	1	0.60975609756097	175	0	0
B9	93	2	2.150537634408	118	2	1.69491525423729	132	0	0	111	2	1.8018018018018
B10	188	2	1.0638297872340	379	2	0.52770448548812	225	0	0			
C6	169	0	0	129	1	0.775193798449611	130	0	0	115	1	0.869565217391304



strain	survival	rep	day
BRC20067	0.873362445414	A	1
DL238	64.21052631578	A	1
A3	0	A	1
A6_R1	0	A	1
A6_R2	0	A	1
B2	1.069518716577	A	1
B3	6.703910614525	A	1
B6	11.71875	A	1
B8	0	A	1
B9	2.150537634408	A	1
B10	1.063829787234	A	1
C6	0	A	1



Intro to the Tidyverse for clean data

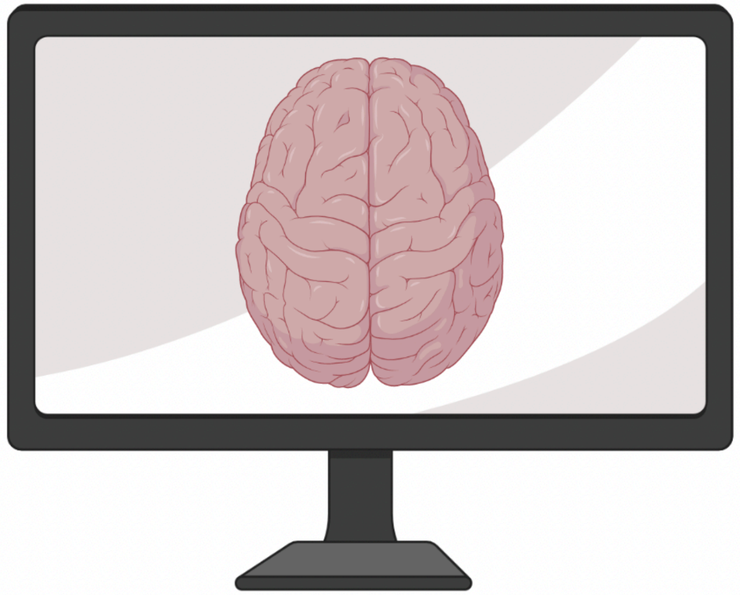


Coding: thinking like a computer

1. Figure out what you want to do

2. Describe those tasks words

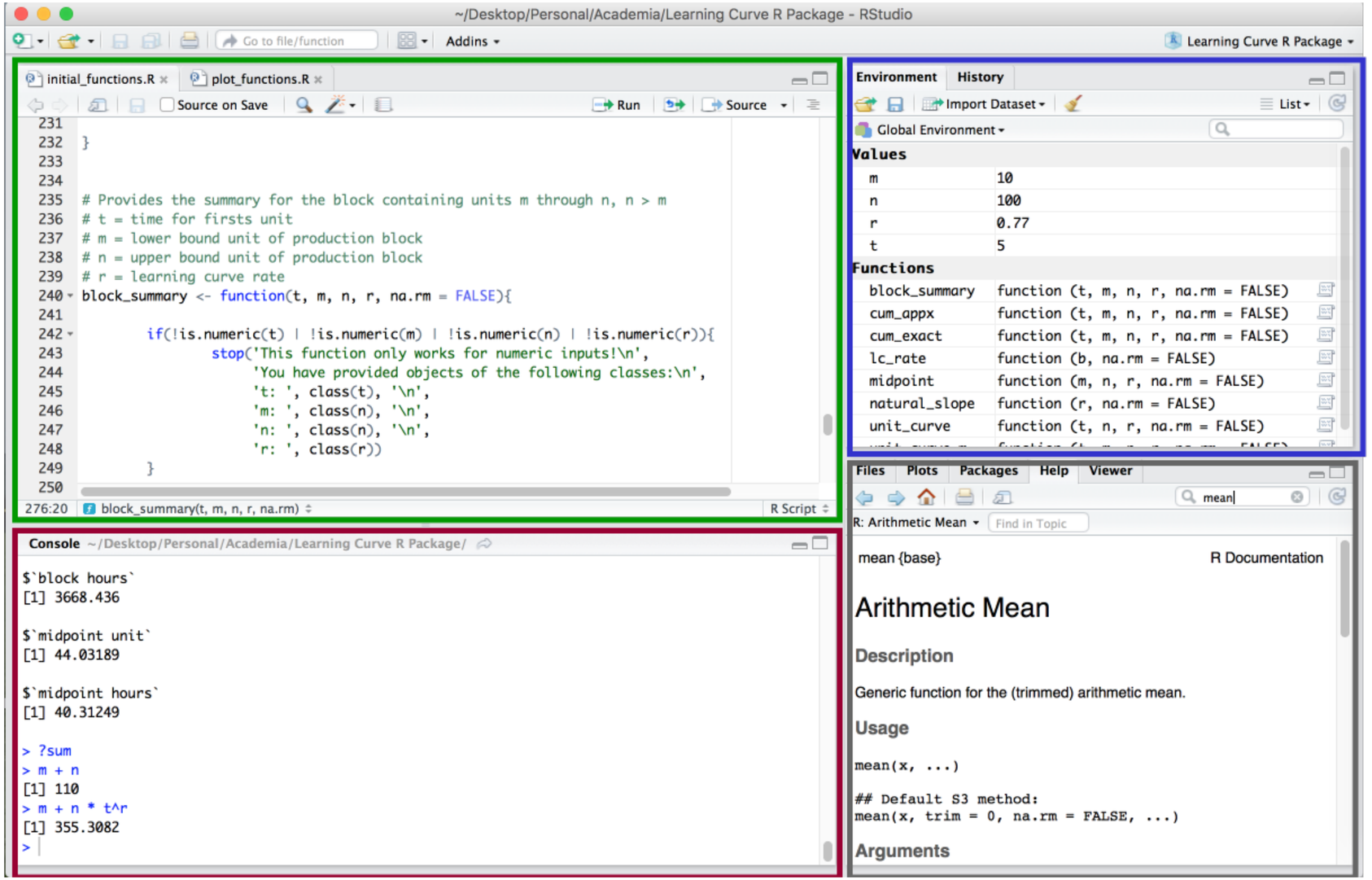
3. Describe those tasks in code



R Studio

Script files
- Saves your script
- Allows code & comments
- Can have multiple files open at a time

Console/Command line
- Can use as calculator
- Does not save code
- This is where your output is displayed



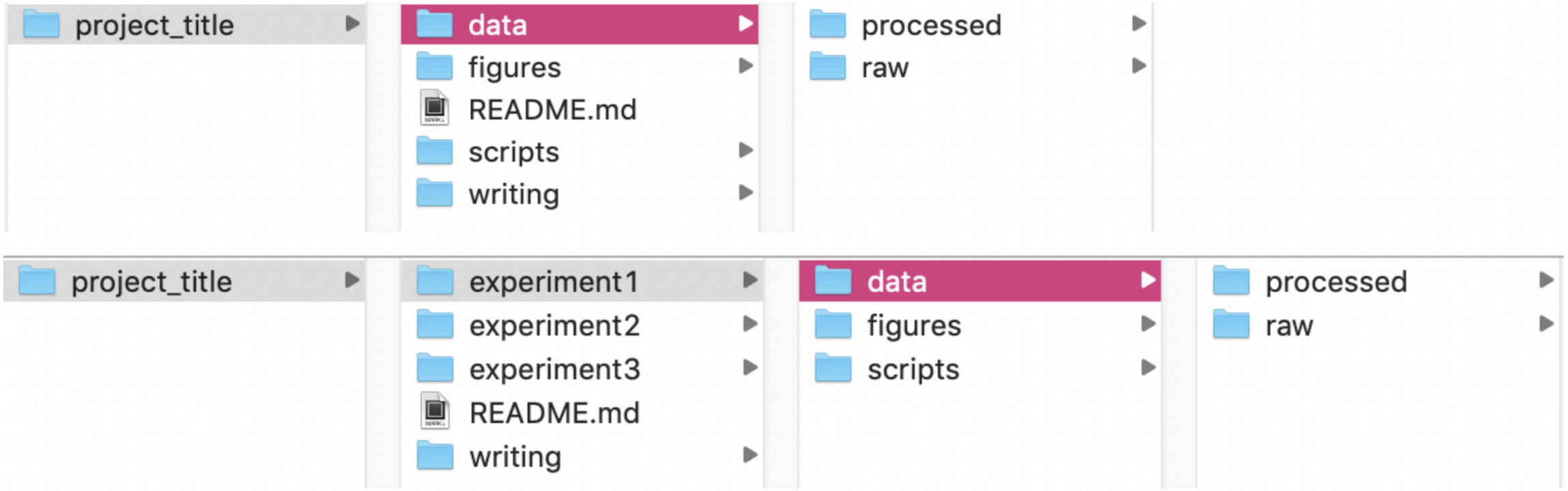
Workspace environment
- Holds your objects
- Can review history

Misc - Displays:
- files in working directory
- plots when produced
- help files/search

Data analysis 101

- Do not use spaces in names of files/folders. Try also to not use spaces in column names (although sometimes necessary)
    - Computers often have a hard time reading spaces and code used to ignore spaces can differ between programs. Instead, try using “-“ or “_” or “.” Or capitalization (i.e. fileName.txt)
- NEVER replace raw data!!!!!!!!!
    - Save data in rawest form, write a script to analyze it, and save the processed data (if you want)
- Comment your code! I promise, you will forget what you were doing one day (maybe sooner than you hope…)
- For R specifically: please please please ALWAYS use namespaces (i.e. **dplyr::**filter())

Data analysis 101



Follow along coding

commented_script.R

Source on Save | Run | Source

```
1  ##################################
2  # Intro to R - quick
3  ##################################
4
5  # create a vector
6
7
8  # create a dataframe
9
10
11
12 # types of variables
13 # numeric
14
15
16
```

GitHub.com/katiesevans/IGP_biostatistics/tree/main/lectures/practicum01/commented_script.R

Basic R things to know before we start

Variable

Stores a value that might change

Vector

Collection of elements

```
c(3, 5, 10)
```

Data frame

Collection of vectors (tabular format)

```
data.frame(color = c("red", "white"),
           count = c(45, 80))
```

color	count
red	45
white	80

{swirl}

Learn R, in R.

Lists

A special type of vector

Basic R things to know before we start

Character

```
x <- "gene-A"
```

Integer/numeric

```
x <- 5
```

Logical

```
x <- TRUE
```

R logic expressions (returns TRUE or FALSE)

```
x <- 5
x == 5
x != 4
x > 2
x <= 10
x > 4 & x < 6
x > 6 | x < 7
is.na(x)
```

```
x <- c(4, 6, 10)
x == 6
x > 5
10 %in% x
x[1]
x[2:3]
x[-1]
x[4] <- 15
which(x > 5)
```

{swirl}

Learn R, in R.

Basic R things to know before we start

```
x <- c(2, 5, 10, 12)
```

Get the first element

```
x[1]
```

Change the first element

```
x[1] <- 9
```

Remove the second element

```
x[-2]
```

Keep the 2nd and 3rd elements

```
x[2:3]
```

Get the elements > 5

```
x[x > 5]
```

{swirl}

Learn R, in R.

Basic R things to know before we start

```
ifelse(condition, what to do if TRUE, what to do if FALSE)
```

```
x <- c(2, 5, 10, 12)
```

```
# Write an ‘ifelse' statement to print “less than 9” if the element is less than 9 or “greater than 9” if the element is greater than 9
```

```
ifelse(x < 9, ”less than 9”, ”greater than 9”)
```

Basic R things to know before we start

```
if(condition) {

    what to do if TRUE

} else {

   what to do if FALSE

}
```

Basic R things to know before we start

```
if(condition) {
    what to do if TRUE
} else {
  what to do if FALSE
}
```

What is the difference between `ifelse` and `if/else`?

`ifelse` is element-wise!

```
x <- 10

# Write an 'if' statement to print "less than 9" if the variable is less than 9 or "greater than 9" if the variable is greater than 9

if(x < 9) {
    print("less than 9")
} else {
  print("greater than 9")
}
```

Basic R things to know before we start

```
for(element in start:end) {

    function(s)

}

    x <- c(2, 5, 10, 12)

# Write an ‘for loop’ to add 5 to each element of vector x

  for(i in 1:length(x)) {
     print(x[i] + 5)
  }
```

What is a package?

- Contains functions useful for certain tasks
- Can download and load them easily
  - `install.packages("dplyr")`
  - `library(dplyr)`
- Can specifically direct R to use a function within a package using a namespace (*e.g.* `dplyr::filter()`)
- **Try downloading and loading `dplyr()`**

Starwars dataset


```
library(dplyr)
data(starwars)
View(starwars)
```

variables

name	height	mass	hair_color	skin_color	eye_color	birth_year	gender	homeworld	species	films	vehicles	starships
Luke Skywalker	172	77.0	blond	fair	blue	19.0	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	c("Snowspeeder", "Imperial Speeder Bike")	c("X-wing", "Imperial shuttle")
C-3PO	167	75.0	*NA*	gold	yellow	112.0	*NA*	Tatooine	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
R2-D2	96	32.0	*NA*	white, blue	red	33.0	*NA*	Naboo	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
Darth Vader	202	136.0	none	white	yellow	41.9	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	character(0)	TIE Advanced x1
Leia Organa	150	49.0	brown	light	brown	19.0	female	Alderaan	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	Imperial Speeder Bike	character(0)
Owen Lars	178	120.0	brown, grey	light	blue	52.0	male	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
R5-D4	97	32.0	*NA*	white, red	red	*NA*	*NA*	Tatooine	Droid	A New Hope	character(0)	character(0)
Biggs Darklighter	183	84.0	black	light	brown	24.0	male	Tatooine	Human	A New Hope	character(0)	X-wing
Obi-Wan Kenobi	182	77.0	auburn, white	fair	blue-gray	57.0	male	Stewjon	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	Tribubble bongo	c("Jedi starfighter", "Trade Federation cruiser", "Naboo...
Anakin Skywalker	188	84.0	blond	fair	blue	41.9	male	Tatooine	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	c("Zephyr-G swoop bike", "XJ-6 airspeeder")	c("Trade Federation cruiser", "Jedi Interceptor", "Nabo...
Wilhuff Tarkin	180	*NA*	auburn, grey	fair	blue	64.0	male	Eriadu	Human	c("Revenge of the Sith", "A New Hope")	character(0)	character(0)
Chewbacca	228	112.0	brown	unknown	blue	200.0	male	Kashyyyk	Wookiee	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	AT-ST	c("Millennium Falcon", "Imperial shuttle")
Han Solo	180	80.0	brown	fair	brown	29.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	character(0)	c("Millennium Falcon", "Imperial shuttle")
Greedo	173	74.0	*NA*	green	black	44.0	male	Rodia	Rodian	A New Hope	character(0)	character(0)
Jabba Desilijic Tiure	175	1358.0	*NA*	green-tan, brown	orange	600.0	hermaphrodite	Nal Hutta	Hutt	c("The Phantom Menace", "Return of the Jedi", "A New ...	character(0)	character(0)
Wedge Antilles	170	77.0	brown	fair	hazel	21.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	Snowspeeder	X-wing
Jek Tono Porkins	180	110.0	brown	fair	blue	*NA*	male	Bestine IV	Human	A New Hope	character(0)	X-wing
Yoda	66	17.0	white	green	brown	896.0	male	*NA*	Yoda's species	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
Palpatine	170	75.0	grey	pale	yellow	82.0	male	Naboo	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
Boba Fett	183	78.2	black	fair	brown	31.5	male	Kamino	Human	c("Attack of the Clones", "Return of the Jedi", "The Em...	character(0)	Slave 1
IG-88	200	140.0	none	metal	red	15.0	none	*NA*	Droid	The Empire Strikes Back	character(0)	character(0)
Bossk	190	113.0	none	green	red	53.0	male	Trandosha	Trandoshan	The Empire Strikes Back	character(0)	character(0)
Lando Calrissian	177	79.0	black	dark	brown	31.0	male	Socorro	Human	c("Return of the Jedi", "The Empire Strikes Back")	character(0)	Millennium Falcon

observations

values

Starwars dataset


```
library(dplyr)
data(starwars)
View(starwars)
```

MESSY DATA

variables

name	height	mass	hair_color	skin_color	eye_color	birth_year	gender	homeworld	species	films	vehicles	starships
Luke Skywalker	172	77.0	blond	fair	blue	19.0	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	c("Snowspeeder", "Imperial Speeder Bike")	c("X-wing", "Imperial shuttle")
C-3PO	167	75.0	*NA*	gold	yellow	112.0	*NA*	Tatooine	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
R2-D2	96	32.0	*NA*	white, blue	red	33.0	*NA*	Naboo	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
Darth Vader	202	136.0	none	white	yellow	41.9	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	character(0)	TIE Advanced x1
Leia Organa	150	49.0	brown	light	brown	19.0	female	Alderaan	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	Imperial Speeder Bike	character(0)
Owen Lars	178	120.0	brown, grey	light	blue	52.0	male	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
R5-D4	97	32.0	*NA*	white, red	red	*NA*	*NA*	Tatooine	Droid	A New Hope	character(0)	character(0)
Biggs Darklighter	183	84.0	black	light	brown	24.0	male	Tatooine	Human	A New Hope	character(0)	X-wing
Obi-Wan Kenobi	182	77.0	auburn, white	fair	blue-gray	57.0	male	Stewjon	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	Tribubble bongo	c("Jedi starfighter", "Trade Federation cruiser", "Naboo...
Anakin Skywalker	188	84.0	blond	fair	blue	41.9	male	Tatooine	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	c("Zephyr-G swoop bike", "XJ-6 airspeeder")	c("Trade Federation cruiser", "Jedi Interceptor", "Nabo...
Wilhuff Tarkin	180	*NA*	auburn, grey	fair	blue	64.0	male	Eriadu	Human	c("Revenge of the Sith", "A New Hope")	character(0)	character(0)
Chewbacca	228	112.0	brown	unknown	blue	200.0	male	Kashyyyk	Wookiee	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	AT-ST	c("Millennium Falcon", "Imperial shuttle")
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Jabba Desilijic Tiure	175	1358.0	*NA*	green-tan, brown	orange	600.0	hermaphrodite	Nal Hutta	Hutt	c("The Phantom Menace", "Return of the Jedi", "A New ...	character(0)	character(0)
Wedge Antilles	170	77.0	brown	fair	hazel	21.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	Snowspeeder	X-wing
Jek Tono Porkins	180	110.0	brown	fair	blue	*NA*	male	Bestine IV	Human	A New Hope	character(0)	X-wing
Yoda	66	17.0	white	green	brown	896.0	male	*NA*	Yoda's species	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
Palpatine	170	75.0	grey	pale	yellow	82.0	male	Naboo	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
Boba Fett	183	78.2	black	fair	brown	31.5	male	Kamino	Human	c("Attack of the Clones", "Return of the Jedi", "The Em...	character(0)	Slave 1
IG-88	200	140.0	none	metal	red	15.0	none	*NA*	Droid	The Empire Strikes Back	character(0)	character(0)
Bossk	190	113.0	none	green	red	53.0	male	Trandosha	Trandoshan	The Empire Strikes Back	character(0)	character(0)
Lando Calrissian	177	79.0	black	dark	brown	31.0	male	Socorro	Human	c("Return of the Jedi", "The Empire Strikes Back")	character(0)	Millennium Falcon

observations

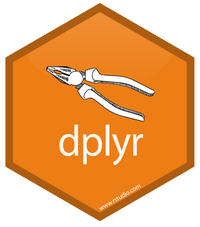
values

Introduction: **dplyr**

- Collection of functions as **verbs** to easily describe what you want to do with your data

Functions:

- `filter()` to keep rows based on values
- `select()` to keep columns based on names
- `mutate()` to add new (or change existing) columns
- `group_by()` to group rows by columns
- `summarize()` to condense multiple columns
- `arrange()` to reorder the rows
- `rename()` to give columns new names
- `xxx_join()` to combine data frames
- `bind_rows()` or `bind_cols()` to combine dataframes



dplyr::filter()

```
dplyr::filter(dataframe, condition(s))
```

starwars

only humans

1. Figure out what you want to do

2. Describe your goal in words

Filter the starwars dataframe to only include humans

3. Describe your goal in code

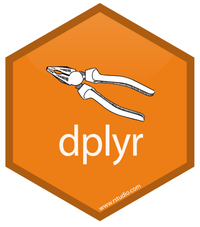
```
dplyr::filter(starwars, ? )
```

`dplyr::filter()` to keep rows based on values

dplyr::filter()

	name	height	mass	hair_color	skin_color	eye_color	birth_year	gender	homeworld	species	films	vehicles	starships
1	Luke Skywalker	172	77.0	blond	fair	blue	19.0	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	c("Snowspeeder", "Imperial Speeder Bike")	c("X-wing", "Imperial shuttle")
2	C-3PO	167	75.0	*NA*	gold	yellow	112.0	*NA*	Tatooine	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
3	R2-D2	96	32.0	*NA*	white, blue	red	33.0	*NA*	Naboo	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
4	Darth Vader	202	136.0	none	white	yellow	41.9	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	character(0)	TIE Advanced x1
5	Leia Organa	150	49.0	brown	light	brown	19.0	female	Alderaan	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	Imperial Speeder Bike	character(0)
6	Owen Lars	178	120.0	brown, grey	light	blue	52.0	male	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
7	Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
8	R5-D4	97	32.0	*NA*	white, red	red	*NA*	*NA*	Tatooine	Droid	A New Hope	character(0)	character(0)
9	Biggs Darklighter	183	84.0	black	light	brown	24.0	male	Tatooine	Human	A New Hope	character(0)	X-wing
10	Obi-Wan Kenobi	182	77.0	auburn, white	fair	blue-gray	57.0	male	Stewjon	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	Tribubble bongo	c("Jedi starfighter", "Trade Federation cruiser", "Naboo...
11	Anakin Skywalker	188	84.0	blond	fair	blue	41.9	male	Tatooine	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	c("Zephyr-G swoop bike", "XJ-6 airspeeder")	c("Trade Federation cruiser", "Jedi Interceptor", "Nabo...
12	Wilhuff Tarkin	180	*NA*	auburn, grey	fair	blue	64.0	male	Eriadu	Human	c("Revenge of the Sith", "A New Hope")	character(0)	character(0)
13	Chewbacca	228	112.0	brown	unknown	blue	200.0	male	Kashyyyk	Wookiee	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	AT-ST	c("Millennium Falcon", "Imperial shuttle")
14	Han Solo	180	80.0	brown	fair	brown	29.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	character(0)	c("Millennium Falcon", "Imperial shuttle")
15	Greedo	173	74.0	*NA*	green	black	44.0	male	Rodia	Rodian	A New Hope	character(0)	character(0)
16	Jabba Desilijic Tiure	175	1358.0	*NA*	green-tan, brown	orange	600.0	hermaphrodite	Nal Hutta	Hutt	c("The Phantom Menace", "Return of the Jedi", "A New ...	character(0)	character(0)
17	Wedge Antilles	170	77.0	brown	fair	hazel	21.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	Snowspeeder	X-wing
18	Jek Tono Porkins	180	110.0	brown	fair	blue	*NA*	male	Bestine IV	Human	A New Hope	character(0)	X-wing
19	Yoda	66	17.0	white	green	brown	896.0	male	*NA*	Yoda's species	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
20	Palpatine	170	75.0	grey	pale	yellow	82.0	male	Naboo	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
21	Boba Fett	183	78.2	black	fair	brown	31.5	male	Kamino	Human	c("Attack of the Clones", "Return of the Jedi", "The Em...	character(0)	Slave 1
22	IG-88	200	140.0	none	metal	red	15.0	none	*NA*	Droid	The Empire Strikes Back	character(0)	character(0)
23	Bossk	190	113.0	none	green	red	53.0	male	Trandosha	Trandoshan	The Empire Strikes Back	character(0)	character(0)
24	Lando Calrissian	177	79.0	black	dark	brown	31.0	male	Socorro	Human	c("Return of the Jedi", "The Empire Strikes Back")	character(0)	Millennium Falcon

`species == "Human"`



`dplyr::filter()` to keep rows based on values

dplyr::filter()

```
dplyr::filter(dataframe, condition(s))
```

starwars

only humans

1. Figure out what you want to do

2. Describe your goal in words

Filter the starwars dataframe to only include humans

3. Describe your goal in code

```
dplyr::filter(starwars, species == "Human")
```

`dplyr::filter()` to keep rows based on values

dplyr::filter()

	name	height	mass	hair_color	skin_color	eye_color	birth_year	gender	homeworld	species	films	vehicles	starships
1	Luke Skywalker	172	77.0	blond	fair	blue	19.0	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	c("Snowspeeder", "Imperial Speeder Bike")	c("X-wing", "Imperial shuttle")
2	Darth Vader	202	136.0	none	white	yellow	41.9	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	character(0)	TIE Advanced x1
3	Leia Organa	150	49.0	brown	light	brown	19.0	female	Alderaan	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	Imperial Speeder Bike	character(0)
4	Owen Lars	178	120.0	brown, grey	light	blue	52.0	male	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
5	Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)
6	Biggs Darklighter	183	84.0	black	light	brown	24.0	male	Tatooine	Human	A New Hope	character(0)	X-wing
7	Obi-Wan Kenobi	182	77.0	auburn, white	fair	blue-gray	57.0	male	Stewjon	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	Tribubble bongo	c("Jedi starfighter", "Trade Federation cruiser", "Naboo...
8	Anakin Skywalker	188	84.0	blond	fair	blue	41.9	male	Tatooine	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	c("Zephyr-G swoop bike", "XJ-6 airspeeder")	c("Trade Federation cruiser", "Jedi Interceptor", "Nabo...
9	Wilhuff Tarkin	180	NA	auburn, grey	fair	blue	64.0	male	Eriadu	Human	c("Revenge of the Sith", "A New Hope")	character(0)	character(0)
10	Han Solo	180	80.0	brown	fair	brown	29.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	character(0)	c("Millennium Falcon", "Imperial shuttle")
11	Wedge Antilles	170	77.0	brown	fair	hazel	21.0	male	Corellia	Human	c("Return of the Jedi", "The Empire Strikes Back", "A N...	Snowspeeder	X-wing
12	Jek Tono Porkins	180	110.0	brown	fair	blue	NA	male	Bestine IV	Human	A New Hope	character(0)	X-wing
13	Palpatine	170	75.0	grey	pale	yellow	82.0	male	Naboo	Human	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)
14	Boba Fett	183	78.2	black	fair	brown	31.5	male	Kamino	Human	c("Attack of the Clones", "Return of the Jedi", "The Em...	character(0)	Slave 1
15	Lando Calrissian	177	79.0	black	dark	brown	31.0	male	Socorro	Human	c("Return of the Jedi", "The Empire Strikes Back")	character(0)	Millennium Falcon
16	Lobot	175	79.0	none	light	blue	37.0	male	Bespin	Human	The Empire Strikes Back	character(0)	character(0)
17	Mon Mothma	150	NA	auburn	fair	blue	48.0	female	Chandrila	Human	Return of the Jedi	character(0)	character(0)
18	Arvel Crynyd	NA	NA	brown	fair	brown	NA	male	NA	Human	Return of the Jedi	character(0)	A-wing
19	Qui-Gon Jinn	193	89.0	brown	fair	blue	92.0	male	NA	Human	The Phantom Menace	Tribubble bongo	character(0)
20	Finis Valorum	170	NA	blond	fair	blue	91.0	male	Coruscant	Human	The Phantom Menace	character(0)	character(0)
21	Shmi Skywalker	163	NA	black	fair	brown	72.0	female	Tatooine	Human	c("Attack of the Clones", "The Phantom Menace")	character(0)	character(0)

```
dplyr::filter(starwars, species == "Human")
```

`dplyr::filter()` to keep rows based on values

dplyr::**filter**()

`dplyr::filter(`dataframe, condition(s)`)`

★ You can also filter based on multiple conditions

Filter the starwars dataframe to include only male humans.

```
dplyr::filter(starwars, species == "Human", gender == "male")
```

Filter the starwars dataframe to include humans and droids.

```
dplyr::filter(starwars, species %in% c("Human", "Droid"))
```

`dplyr::filter()` to keep rows based on values

dplyr::filter()

`dplyr::filter(dataframe, condition(s))`

Filter starwars to include only people with height less than 100.

```
dplyr::filter(starwars, height < 100)
```

Keep all non-humans

```
dplyr::filter(starwars, species != “Human”)
```

Remove characters with no known species

```
dplyr::filter(starwars, !is.na(species))
```

`dplyr::filter()` to keep rows based on values

Piping in Tidyverse

Filter the starwars dataframe to include only male humans.

Without pipes

```
dplyr::filter(starwars, species == "Human", gender == "male")
```

1. start with the starwars dataframe

2. filter to keep only humans

3. filter to keep only males

With pipes

```
starwars %>%
  dplyr::filter(species == "Human") %>%
  dplyr::filter(gender == "male")
```

Can be useful to combine several tidyverse "verbs" to one block of code

takes output of left side and makes it input of right side

`dplyr::select()`

```
dplyr::select(dataframe, columns_to_keep)
```

starwars

name, species, films

Select only name, species, and films variables from the starwars dataframe

```
dplyr::select(starwars, name, species, films)
```

★ Deselect a column with `-column_name`

Select all columns except the gender

```
dplyr::select(starwars, -gender)
```

`dplyr::select()` to keep columns based on names

`dplyr::select()`

```
dplyr::select(dataframe, columns_to_keep)
```

★ Select a range of columns with `column1:column2`

Select columns name, height, mass, hair color, and skin color

```
dplyr::select(starwars, name:skin_color)
```

Select all columns except hair color, skin color, and eye color

```
dplyr::select(starwars, -hair_color, -skin_color, -eye_color)
dplyr::select(starwars, -(hair_color:eye_color))
```

`dplyr::select()` to keep columns based on names

dplyr::select()

```
dplyr::select(dataframe, columns_to_keep)
```

★ Reorder columns with select too!

Select columns name, height, mass, hair color, and skin color

```
dplyr::select(starwars, name:skin_color)
```

Select columns name, mass, skin color, hair color, and height (in order)

```
dplyr::select(starwars, name, mass, skin_color, hair_color, height)
```

`dplyr::select()` to keep columns based on names

dplyr::select()

`dplyr::select(dataframe, new_name = old_name)`

You can also use `select()` to rename columns

Rename the “name” column to “character” and the “mass” column to “weight” using `select()`

```
renamed <- starwars %>%
  dplyr::select(character = name, weight = mass)
```

character	weight
Luke Skywalker	77.0
C-3PO	75.0
R2-D2	32.0
Darth Vader	136.0
Leia Organa	49.0
Owen Lars	120.0

`dplyr::select()` to keep columns based on names

Combine filter and select

`dplyr::filter(dataframe, condition(s))`

`dplyr::select(dataframe, columns_to_keep)`

Challenge OYO:

[Keep: height greater than 100 &
Keep: humans &
Remove: brown hair color &
Remove: vehicles &
Keep: name, homeworld, height, species, hair color]

`dplyr::filter()` to keep rows based on values

`dplyr::select()` to keep columns based on names

Combine filter and select

	name	homeworld	height	species	hair_color
1	Luke Skywalker	Tatooine	172	Human	blond
2	Darth Vader	Tatooine	202	Human	none
3	Owen Lars	Tatooine	178	Human	brown, grey
4	Biggs Darklighter	Tatooine	183	Human	black
5	Obi-Wan Kenobi	Stewjon	182	Human	auburn, white
6	Anakin Skywalker	Tatooine	188	Human	blond
7	Wilhuff Tarkin	Eriadu	180	Human	auburn, grey
8	Palpatine	Naboo	170	Human	grey
9	Boba Fett	Kamino	183	Human	black
10	Lando Calrissian	Socorro	177	Human	black
11	Lobot	Bespin	175	Human	none
12	Mon Mothma	Chandrila	150	Human	auburn
13	Finis Valorum	Coruscant	170	Human	blond
14	Shmi Skywalker	Tatooine	163	Human	black

```
starwars %>%
    dplyr::filter(height > 100) %>%
    dplyr::filter(species == "Human") %>%
    dplyr::filter(hair_color != "brown") %>%
    dplyr::select(-vehicles) %>%
    dplyr::select(name, homeworld, height, species, hair_color)
```

`dplyr::mutate()`

```
dplyr::mutate(dataframe, new_column = expression)
```

1. Figure out what you want to do

calculate BMI of all starwars characters

2. Describe your goal in words

cm

BMI = weight (kg) / [height (m)]^2

	name	height	mass	hair_color	skin_color	eye_color
1	Luke Skywalker	172	77.0	blond	fair	blue
2	C-3PO	167	75.0	*NA*	gold	yellow
3	R2-D2	96	32.0	*NA*	white, blue	red
4	Darth Vader	202	136.0	none	white	yellow

`?starwars`

`dplyr::mutate()` to add new (or change existing) columns

`dplyr::mutate()`

```
dplyr::mutate(dataframe,  new_column = expression)
```

1. Figure out what you want to do

calculate BMI of all starwars characters

2. Describe your goal in words

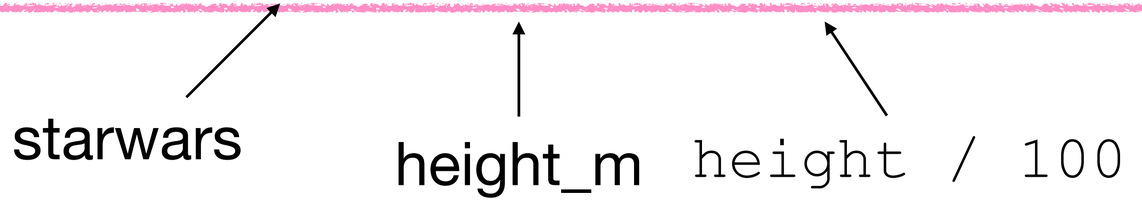
BMI = weight (kg) / [height (m)]^2

First: convert height in cm to height in meters
Second: calculate BMI as new column

`dplyr::mutate()` to add new (or change existing) columns

dplyr::mutate()

```
dplyr::mutate(dataframe, new_column = expression)
```



2. Describe your goal in words

BMI = weight (kg) / [height (m)]^2

First: convert height in cm to height in meters

Second: calculate BMI as new column

3. Describe your goal in code

```
new_starwars <- dplyr::mutate(starwars, height_m = height / 100)
```

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

```
dplyr::mutate(dataframe,  new_column = expression)
```

new_starwars

bmi `mass / height_m^2`

2. Describe your goal in words

BMI = weight (kg) / [height (m)]^2

First: convert height in cm to height in meters

Second: calculate BMI as new column

3. Describe your goal in code

```
new_starwars <- starwars %>%
  dplyr::mutate(height_m = height / 100) %>%
  dplyr::mutate(bmi = mass / height_m^2)
```

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Select only name, height, mass, height_m, and bmi and view dataframe

```
new_starwars <- new_starwars %>%
    dplyr::select(name, height, mass, height_m, bmi)

View(new_starwars)
```

name	height	mass	height_m	bmi
Luke Skywalker	172	77.0	1.72	26.02758
C-3PO	167	75.0	1.67	26.89232
R2-D2	96	32.0	0.96	34.72222
Darth Vader	202	136.0	2.02	33.33007
Leia Organa	150	49.0	1.50	21.77778
Owen Lars	178	120.0	1.78	37.87401
Beru Whitesun lars	165	75.0	1.65	27.54821
R5-D4	97	32.0	0.97	34.00999
Biggs Darklighter	183	84.0	1.83	25.08286

`dplyr::mutate()` to add new (or cha

dplyr::**mutate**()

```
dplyr::mutate(dataframe,  new_column = expression)
```

★ We can change existing columns if we use the same name

```
new_starwars <- starwars %>%
  dplyr::mutate(height = height / 100) %>%
  dplyr::mutate(bmi = mass / height^2)

View(new_starwars)
```

name	height	mass	bmi
Luke Skywalker	1.72	77.0	26.02758
C-3PO	1.67	75.0	26.89232
R2-D2	0.96	32.0	34.72222
Darth Vader	2.02	136.0	33.33007
Leia Organa	1.50	49.0	21.77778
Owen Lars	1.78	120.0	37.87401

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

```
dplyr::mutate(dataframe,  new_column = expression)
```

Make a new column to find the average height (in meters)

```
starwars %>%
  dplyr::mutate(height =
  dplyr::mutate(avg_heig

    ?mean
```

name	height	mass	avg_height
Palpatine	1.70	75.0	*NA*
Boba Fett	1.83	78.2	*NA*
IG-88	2.00	140.0	*NA*
Bossk	1.90	113.0	*NA*
Lando Calrissian	1.77	79.0	*NA*
Lobot	1.75	79.0	*NA*
Ackbar	1.80	83.0	*NA*
Mon Mothma	1.50	*NA*	*NA*
Arvel Crynyd	*NA*	*NA*	*NA*
Wicket Systri Warrick	0.88	20.0	*NA*
Nien Nunb	1.60	68.0	*NA*
Qui-Gon Jinn	1.93	89.0	*NA*
Nute Gunray	1.91	90.0	*NA*
Finis Valorum	1.70	*NA*	*NA*

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Make a new column to find the average height (in meters)

```
starwars %>%
  dplyr::muta
  dplyr::muta

?mean
```

Arithmetic Mean

Description

Generic function for the (trimmed) arithmetic mean.

Usage

```
mean(x, ...)

## Default S3 method:
mean(x, trim = 0, na.rm = FALSE, ...)
```

Arguments

`x`	An `R` object. Currently there are methods for numeric/logical vectors and date, date-time and time interval objects. Complex vectors are allowed for `trim = 0`, only.
`trim`	the fraction (0 to 0.5) of observations to be trimmed from each end of `x` before the mean is computed. Values of trim outside that range are taken as the nearest endpoint.
`na.rm`	a logical value indicating whether `NA` values should be stripped before the computation proceeds.
`...`	further arguments passed to or from other methods.

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Make a new column to find the average height (in meters)

```
starwars %>%
  dplyr::mutate(height = height / 100) %>%
  dplyr::mutate(avg_height = mean(height, na.rm = TRUE))
```

name	height	mass	avg_height
Luke Skywalker	172	77.0	1.74358
C-3PO	167	75.0	1.74358
R2-D2	96	32.0	1.74358
Darth Vader	202	136.0	1.74358
Leia Organa	150	49.0	1.74358
Owen Lars	178	120.0	1.74358
Beru Whitesun lars	165	75.0	1.74358
R5-D4	97	32.0	1.74358

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Standardize the heights of the starwars characters (height / avg_height)

```
starwars %>%
  dplyr::mutate(height = height / 100) %>%
  dplyr::mutate(avg_height = mean(height, na.rm = TRUE)) %>%
  dplyr::mutate(std_height = height / avg_height)
```

name	height	mass	avg_height	std_height
Luke Skywalker	1.72	77.0	1.74358	0.9864760
C-3PO	1.67	75.0	1.74358	0.9577993
R2-D2	0.96	32.0	1.74358	0.5505912
Darth Vader	2.02	136.0	1.74358	1.1585357
Leia Organa	1.50	49.0	1.74358	0.8602988
Owen Lars	1.78	120.0	1.74358	1.0208879
Beru Whitesun lars	1.65	75.0	1.74358	0.9463287
R5-D4	0.97	32.0	1.74358	0.5563266
Biggs Darklighter	1.83	84.0	1.74358	1.0495645

`dplyr::mutate()` t umns

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Make a new column to see if each character is above or below the average height

hint: try using `ifelse(condition, if_true_do_this, if_false_do_this)`

```
test <- starwars %>%
    dplyr::mutate(height = height / 100) %>%
    dplyr::mutate(avg_height = mean(height, na.rm = TRUE)) %>%
    dplyr::mutate(std_height = height / avg_height) %>%
    dplyr::select(name, height, mass, avg_height, std_height) %>%
    dplyr::mutate(relative_height =
                      ifelse(std_height > 1, "above", "below"))      %>%
     dplyr::filter(relative_height == "below")
```

Bonus: make a new dataframe that only keeps characters with heights BELOW average

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Make a new column to see if each character is above or below the average height

hint: try using `ifelse(condition, if_true_do_this, if_false_do_this)`

```
test <- starwars %>%
    dplyr::mutate(height = height / 100) %>%
    dplyr::mutate(avg_height = mean(height, na.rm = TRUE)) %>%
    dplyr::mutate(std_height = height / avg_height) %>%
    dplyr::select(name, height, mass, avg_height, std_height) %>%
    dplyr::mutate(relative_height =
                      ifelse(std_height > 1, "above", "below"))      %>%
     dplyr::filter(std_height < 1)
```

Bonus: make a new dataframe that only keeps characters with heights BELOW average

`dplyr::mutate()` to add new (or change existing) columns

dplyr::**mutate**()

`dplyr::mutate(dataframe, new_column = expression)`

Make a new column to see if each character is above or below the average height

hint: try using `ifelse(condition, if_true_do_this, if_false_do_this)`

```
test <- starwars %>%
    dplyr::mutate(height = height / 100) %>%
    dplyr::mutate(avg_height = mean(height, na.rm = TRUE)) %>%
    dplyr::mutate(std_height = height / avg_height) %>%
    dplyr::select(name, height, mass, avg_height, std_height) %>%
    dplyr::mutate(relative_height =
                      ifelse(std_height > 1, "above", "below"))      %>%
     dplyr::filter(height < avg_height)
```

Bonus: make a new dataframe that only keeps characters with heights BELOW average

`dplyr::mutate()` to add new (or change existing) columns

dplyr::group_by()

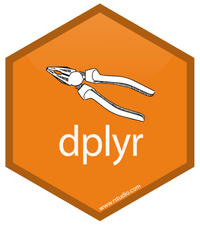
```
dplyr::group_by(dataframe, column_to_group_by)
```

Doesn't change how the data looks, changes how the data interacts with other dplyr verbs

Group starwars dataframe by gender

```
grouped_starwars <- starwars %>%
  dplyr::group_by(gender)
```

```
View(starwars)
View(grouped_starwars)
```



`dplyr::group_by()` to group rows by columns

dplyr::group_by()

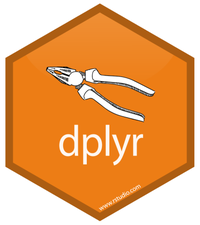
```
dplyr::group_by(dataframe, column_to_group_by)
```

ungrouped

	name	height	mass	hair_color	skin_color	eye_color	birth_year	gender
1	Luke Skywalker	172	77.0	blond	fair	blue	19.0	male
2	C-3PO	167	75.0	*NA*	gold	yellow	112.0	*NA*
3	R2-D2	96	32.0	*NA*	white, blue	red	33.0	*NA*
4	Darth Vader	202	136.0	none	white	yellow	41.9	male
5	Leia Organa	150	49.0	brown	light	brown	19.0	female
6	Owen Lars	178	120.0	brown, grey	light	blue	52.0	male
7	Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female
8	R5-D4	97	32.0	*NA*	white, red	red	*NA*	*NA*
9	Biggs Darklighter	183	84.0	black	light	brown	24.0	male
10	Obi-Wan Kenobi	182	77.0	auburn, white	fair	blue-gray	57.0	male
11	Anakin Skywalker	188	84.0	blond	fair	blue	41.9	male
12	Wilhuff Tarkin	180	*NA*	auburn, grey	fair	blue	64.0	male
13	Chewbacca	228	112.0	brown	unknown	blue	200.0	male
14	Han Solo	180	80.0	brown	fair	brown	29.0	male
15	Greedo	173	74.0	*NA*	green	black	44.0	male
16	Jabba Desilijic Tiure	175	1358.0	*NA*	green-tan, brown	orange	600.0	hermaphrodite
17	Wedge Antilles	170	77.0	brown	fair	hazel	21.0	male
18	Jek Tono Porkins	180	110.0	brown	fair	blue	*NA*	male
19	Yoda	66	17.0	white	green	brown	896.0	male
20	Palpatine	170	75.0	grey	pale	yellow	82.0	male
21	Boba Fett	183	78.2	black	fair	brown	31.5	male
22	IG-88	200	140.0	none	metal	red	15.0	none
23	Bossk	190	113.0	none	green	red	53.0	male
24	Lando Calrissian	177	79.0	black	dark	brown	31.0	male

grouped by gender

	name	height	mass	hair_color	skin_color	eye_color	birth_year	gender
1	Luke Skywalker	172	77.0	blond	fair	blue	19.0	male
2	C-3PO	167	75.0	*NA*	gold	yellow	112.0	*NA*
3	R2-D2	96	32.0	*NA*	white, blue	red	33.0	*NA*
4	Darth Vader	202	136.0	none	white	yellow	41.9	male
5	Leia Organa	150	49.0	brown	light	brown	19.0	female
6	Owen Lars	178	120.0	brown, grey	light	blue	52.0	male
7	Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female
8	R5-D4	97	32.0	*NA*	white, red	red	*NA*	*NA*
9	Biggs Darklighter	183	84.0	black	light	brown	24.0	male
10	Obi-Wan Kenobi	182	77.0	auburn, white	fair	blue-gray	57.0	male
11	Anakin Skywalker	188	84.0	blond	fair	blue	41.9	male
12	Wilhuff Tarkin	180	*NA*	auburn, grey	fair	blue	64.0	male
13	Chewbacca	228	112.0	brown	unknown	blue	200.0	male
14	Han Solo	180	80.0	brown	fair	brown	29.0	male
15	Greedo	173	74.0	*NA*	green	black	44.0	male
16	Jabba Desilijic Tiure	175	1358.0	*NA*	green-tan, brown	orange	600.0	hermaphrodite
17	Wedge Antilles	170	77.0	brown	fair	hazel	21.0	male
18	Jek Tono Porkins	180	110.0	brown	fair	blue	*NA*	male
19	Yoda	66	17.0	white	green	brown	896.0	male
20	Palpatine	170	75.0	grey	pale	yellow	82.0	male
21	Boba Fett	183	78.2	black	fair	brown	31.5	male
22	IG-88	200	140.0	none	metal	red	15.0	none
23	Bossk	190	113.0	none	green	red	53.0	male
24	Lando Calrissian	177	79.0	black	dark	brown	31.0	male



`dplyr::group_by()` to group rows by columns

dplyr::group_by()

```
dplyr::group_by(dataframe, column_to_group_by)
```

Doesn't change how the data looks, changes how the data interacts with other dplyr verbs

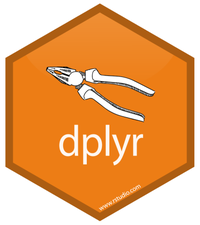
Group starwars dataframe by gender

```
grouped_starwars <- starwars %>%
  dplyr::group_by(gender)
```

Calculate average height *PER GENDER*

hint: group by gender FIRST

```
grouped_starwars <- starwars %>%
  dplyr::group_by(gender) %>%
  dplyr::mutate(avg_height = mean(height, na.rm = TRUE))
```



`dplyr::group_by()` to group rows by columns

dplyr::group_by()

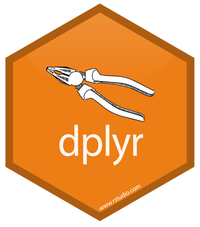
```
dplyr::group_by(dataframe, column_to_group_by)
```

Calculate average height *PER GENDER*

name	gender	height	avg_height
Luke Skywalker	male	1.72	1.792373
C-3PO	*NA*	1.67	1.200000
R2-D2	*NA*	0.96	1.200000
Darth Vader	male	2.02	1.792373
Leia Organa	female	1.50	1.654706
Owen Lars	male	1.78	1.792373
Beru Whitesun lars	female	1.65	1.654706
R5-D4	*NA*	0.97	1.200000
Biggs Darklighter	male	1.83	1.792373
Obi-Wan Kenobi	male	1.82	1.792373
Anakin Skywalker	male	1.88	1.792373
Wilhuff Tarkin	male	1.80	1.792373
Chewbacca	male	2.28	1.792373
Han Solo	male	1.80	1.792373

Calculate average height

name	gender	height	avg_height
Luke Skywalker	male	1.72	1.74358
C-3PO	*NA*	1.67	1.74358
R2-D2	*NA*	0.96	1.74358
Darth Vader	male	2.02	1.74358
Leia Organa	female	1.50	1.74358
Owen Lars	male	1.78	1.74358
Beru Whitesun lars	female	1.65	1.74358
R5-D4	*NA*	0.97	1.74358
Biggs Darklighter	male	1.83	1.74358
Obi-Wan Kenobi	male	1.82	1.74358
Anakin Skywalker	male	1.88	1.74358
Wilhuff Tarkin	male	1.80	1.74358
Chewbacca	male	2.28	1.74358
Han Solo	male	1.80	1.74358



`dplyr::group_by()` to group rows by columns

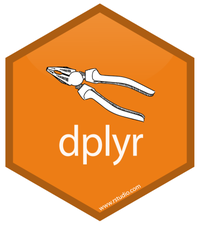
dplyr::group_by()

`dplyr::group_by(dataframe, column_to_group_by)`

★ `dplyr::ungroup()` removes all groups

Ungroup your grouped dataframe and re-calculate average height

```
ungrouped_starwars <- grouped_starwars %>%
  dplyr::ungroup() %>%
  dplyr::mutate(avg_height = mean(height, na.rm = TRUE))
```



`dplyr::group_by()` to group rows by columns

dplyr::group_by()

```
dplyr::group_by(dataframe, column_to_group_by)
```

★ You can also group by multiple columns

Calculate the average height per gender AND eye color

```
grouped_starwars <- starwars %>%
  dplyr::group_by(gender, eye_color) %>%
  dplyr::mutate(avg_height = mean(height, na.rm = TRUE))
```

`dplyr::group_by()` to group rows by columns

`dplyr::summarize()`

`dplyr::summarize(dataframe, new_column = expression)`

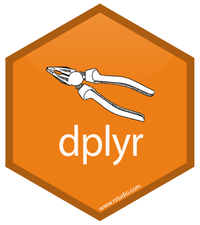
`summarize()` is similar to `mutate()` but only keeps grouped columns

Calculate average height *PER GENDER*

hint: group by gender FIRST

```
grouped_starwars <- starwars %>%
  dplyr::group_by(gender) %>%
  dplyr::summarize(avg_height = mean(height, na.rm = TRUE))
```

gender	avg_height
NA	120.0000
female	165.4706
hermaphrodite	175.0000
male	179.2373
none	200.0000



`dplyr::summarize()` to condense multiple columns

dplyr::summarize()

summarize() is similar to mutate() but only keeps grouped columns

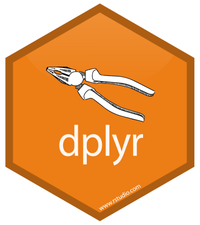
Compare `mutate()` and `summarize()` to calculate average height by gender

```
dplyr::mutate(avg_height = mean(height, na.rm = TRUE))
```

name	height	mass	hair_color	skin_color	eye_color	birth_year	gender	homeworld	species	films	vehicles	starships	avg_height
Luke Skywalker	172	77.0	blond	fair	blue	19.0	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	c("Snowspeeder", "Imperial Speeder Bike")	c("X-wing", "Imperial shuttle")	179.2373
C-3PO	167	75.0	*NA*	gold	yellow	112.0	*NA*	Tatooine	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)	120.0000
R2-D2	96	32.0	*NA*	white, blue	red	33.0	*NA*	Naboo	Droid	c("Attack of the Clones", "The Phantom Menace", "Rev...	character(0)	character(0)	120.0000
Darth Vader	202	136.0	none	white	yellow	41.9	male	Tatooine	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	character(0)	TIE Advanced x1	179.2373
Leia Organa	150	49.0	brown	light	brown	19.0	female	Alderaan	Human	c("Revenge of the Sith", "Return of the Jedi", "The Emp...	Imperial Speeder Bike	character(0)	165.4706
Owen Lars	178	120.0	brown, grey	light	blue	52.0	male	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)	179.2373
Beru Whitesun lars	165	75.0	brown	light	blue	47.0	female	Tatooine	Human	c("Attack of the Clones", "Revenge of the Sith", "A New...	character(0)	character(0)	165.4706
R5-D4	97	32.0	*NA*	white, red	red	*NA*	*NA*	Tatooine	Droid	A New Hope	character(0)	character(0)	120.0000

```
dplyr::summarize(avg_height = mean(height, na.rm = TRUE))
```

gender	avg_height
NA	120.0000
female	165.4706
hermaphrodite	175.0000
male	179.2373
none	200.0000



`dplyr::summarize()` to condense multiple columns

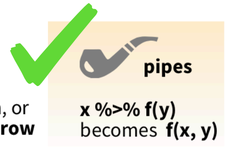
Data Transformation with dplyr : : **CHEAT SHEET**

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))

count(x, ..., wt = NULL, sort = FALSE)
Count number of rows in each group defined by the variables in … Also **tally**().
count(iris, Species)

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.

mtcars %>%
group_by(cyl) %>%
summarise(avg = mean(mpg))

group_by(.data, ..., add = FALSE)
Returns copy of table grouped by …
g_iris <- group_by(iris, Species)

ungroup(x, …)
Returns ungrouped copy of table.
ungroup(g_iris)

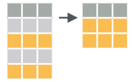
Manipulate Cases

EXTRACT CASES

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

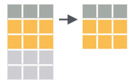
filter(.data, …) Extract rows that meet logical criteria. *filter(iris, Sepal.Length > 7)*

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)*



slice(.data, …) Select rows by position.
slice(iris, 10:15)

top_n(x, n, wt) Select and order top n entries (by group if grouped data). *top_n(iris, 5, Sepal.Width)*

Logical and boolean operators to use with filter()

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

See **?base::Logic** and **?Comparison** for help.

ARRANGE CASES

arrange(.data, …) Order rows by values of a column or columns (low to high), use with **desc()** to order from high to low.
arrange(mtcars, mpg)
arrange(mtcars, desc(mpg))

ADD CASES

add_row(.data, ..., .before = NULL, .after = NULL) Add one or more rows to a table.
add_row(faithful, eruptions = 1, waiting = 1)

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)	

MAKE NEW VARIABLES

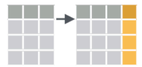
These apply **vectorized functions** to columns. Vectorized funs take vectors as input and return vectors of the same length as output (see back).

mutate(.data, …)
Compute new column(s).
mutate(mtcars, gpm = 1/mpg)

transmute(.data, …)
Compute new column(s), drop others.
transmute(mtcars, gpm = 1/mpg)

mutate_all(.tbl, .funs, …) Apply funs to every column. Use with **funs()**. Also **mutate_if()**.
mutate_all(faithful, funs(log(.), log2(.)))
mutate_if(iris, is.numeric, funs(log(.)))

mutate_at(.tbl, .cols, .funs, …) Apply funs to specific columns. Use with **funs()**, **vars()** and the helper functions for select().
mutate_at(iris, vars(-Species), funs(log(.)))



add_column(.data, ..., .before = NULL, .after = NULL) Add new column(s). Also **add_count()**, **add_tally()**. *add_column(mtcars, new = 1:32)*

rename(.data, …) Rename columns.
rename(iris, Length = Sepal.Length)

Vector Functions

TO USE WITH MUTATE ()

mutate() and **transmute()** apply vectorized functions to columns to create new columns. Vectorized functions take vectors as input and return vectors of the same length as output.

vectorized function →

OFFSETS

dplyr::**lag()** - Offset elements by 1
dplyr::**lead()** - Offset elements by -1

CUMULATIVE AGGREGATES

dplyr::**cumall()** - Cumulative all()
dplyr::**cumany()** - Cumulative any()
cummax() - Cumulative max()
dplyr::**cummean()** - Cumulative mean()
cummin() - Cumulative min()
cumprod() - Cumulative prod()
cumsum() - Cumulative sum()

RANKINGS

dplyr::**cume_dist()** - Proportion of all values <=
dplyr::**dense_rank()** - rank w ties = min, no gaps
dplyr::**min_rank()** - rank with ties = min
dplyr::**ntile()** - bins into n bins
dplyr::**percent_rank()** - min_rank scaled to [0,1]
dplyr::**row_number()** - rank with ties = "first"

MATH

+, - , *, /, ^, %/%, %% - arithmetic ops
log(), log2(), log10() - logs
<, <=, >, >=, !=, == - logical comparisons
dplyr::**between()** - x >= left & x <= right
dplyr::**near()** - safe == for floating point numbers

MISC

dplyr::**case_when()** - multi-case if_else()

```
iris %>% mutate(Species = case_when(
                Species == "versicolor" ~ "versi",
                Species == "virginica"  ~ "virgi",
                TRUE ~ Species))
```

dplyr::**coalesce()** - first non-NA values by element across a set of vectors
dplyr::**if_else()** - element-wise if() + else()
dplyr::**na_if()** - replace specific values with NA
pmax() - element-wise max()
pmin() - element-wise min()
dplyr::**recode()** - Vectorized switch()
dplyr::**recode_factor()** - Vectorized switch() for factors

Summary Functions

TO USE WITH SUMMARISE ()

summarise() applies summary functions to columns to create a new table. Summary functions take vectors as input and return single values as output.

summary function →

COUNTS

dplyr::**n()** - number of values/rows
dplyr::**n_distinct()** - # of uniques
sum(!is.na()) - # of non-NA's

LOCATION

mean() - mean, also **mean(!is.na())**
median() - median

LOGICALS

mean() - Proportion of TRUE's
sum() - # of TRUE's

POSITION/ORDER

dplyr::**first()** - first value
dplyr::**last()** - last value
dplyr::**nth()** - value in nth location of vector

RANK

quantile() - nth quantile
min() - minimum value
max() - maximum value

SPREAD

IQR() - Inter-Quartile Range
mad() - median absolute deviation
sd() - standard deviation
var() - variance

Row Names

Tidy data does not use rownames, which store a variable outside of the columns. To work with the rownames, first move them into a column.

rownames_to_column()
Move row names into col.
a <- rownames_to_column(iris, var = "C")

column_to_rownames()
Move col in row names.
column_to_rownames(a, var = "C")

Also **has_rownames()**, **remove_rownames()**

Combine Tables

COMBINE VARIABLES

Use **bind_cols()** to paste tables beside each other as they are.

bind_cols(…) Returns tables placed side by side as a single table.
BE SURE THAT ROWS ALIGN.

Use a "**Mutating Join**" to join one table to columns from another, matching values with the rows that they correspond to. Each join retains a different combination of values from the tables.

left_join(x, y, by = NULL, copy=FALSE, suffix=c(".x",".y"),…)
Join matching values from y to x.

right_join(x, y, by = NULL, copy = FALSE, suffix=c(".x",".y"),…)
Join matching values from x to y.

inner_join(x, y, by = NULL, copy = FALSE, suffix=c(".x",".y"),…)
Join data. Retain only rows with matches.

full_join(x, y, by = NULL, copy=FALSE, suffix=c(".x",".y"),…)
Join data. Retain all values, all rows.

Use **by = c("col1", "col2", …)** to specify one or more common columns to match on.
left_join(x, y, by = "A")

Use a named vector, **by = c("col1" = "col2")**, to match on columns that have different names in each table.
left_join(x, y, by = c("C" = "D"))

Use **suffix** to specify the suffix to give to unmatched columns that have the same name in both tables.
left_join(x, y, by = c("C" = "D"), suffix = c("1", "2"))

COMBINE CASES

Use **bind_rows()** to paste tables below each other as they are.

bind_rows(…, .id = NULL**)**
Returns tables one on top of the other as a single table. Set .id to a column name to add a column of the original table names (as pictured)

intersect(x, y, …)
Rows that appear in both x and y.

setdiff(x, y, …)
Rows that appear in x but not y.

union(x, y, …)
Rows that appear in x or y. (Duplicates removed). union_all() retains duplicates.

Use **setequal()** to test whether two data sets contain the exact same rows (in any order).

EXTRACT ROWS

Use a "**Filtering Join**" to filter one table against the rows of another.

semi_join(x, y, by = NULL, …)
Return rows of x that have a match in y.
USEFUL TO SEE WHAT WILL BE JOINED.

anti_join(x, y, by = NULL, …)
Return rows of x that do not have a match in y.
USEFUL TO SEE WHAT WILL NOT BE JOINED.

dplyr practice!

1. **Calculate the birth year of each character given the column 'birth_year' is actually age in 2021…**

Hint: rename "birth_year" as "age" first then calculate "birth_year"

2. **Calculate the number of characters with each hair color combination**

Note: "brown, grey" is different than "brown" or "grey"

Hint: the function `n()` *counts the number of observations in a group*

BONUS: Combine "blond" and "blonde" as one category and re-calculate

3. **Select all characters and their homeworld in the film "Return of the Jedi"**

Hint: try using `grepl()`

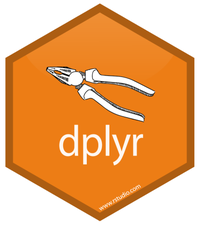
dplyr practice!

Calculate the birth year of each character given the column ‘birth_year’ is actually age in 2021…

GOAL:

name	age	birth_year
Luke Skywalker	19.0	2000.0
C-3PO	112.0	1907.0
R2-D2	33.0	1986.0
Darth Vader	41.9	1977.1
Leia Organa	19.0	2000.0
Owen Lars	52.0	1967.0
Beru Whitesun lars	47.0	1972.0
Biggs Darklighter	24.0	1995.0
Obi-Wan Kenobi	57.0	1962.0
Anakin Skywalker	41.9	1977.1
Wilhuff Tarkin	64.0	1955.0
Chewbacca	200.0	1819.0
Han Solo	29.0	1990.0
Greedo	44.0	1975.0
Jabba Desilijic Tiure	600.0	1419.0
Wedge Antilles	21.0	1998.0
Yoda	896.0	1123.0
Palpatine	82.0	1937.0
Boba Fett	31.5	1987.5
IG-88	15.0	2004.0

Hint: rename “birth_year” as “age” first then calculate “birth_year”



dplyr practice!

Calculate the birth year of each character given the column 'birth_year' is actually age in 2021…

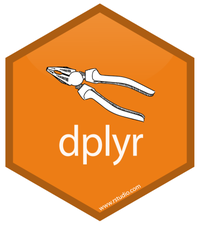
GOAL:

name	age	birth_year
Luke Skywalker	19.0	2000.0
C-3PO	112.0	1907.0
R2-D2	33.0	1986.0
Darth Vader	41.9	1977.1
Leia Organa	19.0	2000.0
Owen Lars		
Beru Whitesun lars		
Biggs Darklighter		
Obi-Wan Kenobi		
Anakin Skywalker		
Wilhuff Tarkin		
Chewbacca		
Han Solo		
Greedo		
Jabba Desilijic Tiure		
Wedge Antilles		
Yoda	896.0	1123.0
Palpatine	82.0	1937.0
Boba Fett	31.5	1987.5
IG-88	15.0	2004.0

Hint: rename "birth_year" as "age" first then calculate "birth_year"

CODE:

```
practice1 <- starwars %>%
    dplyr::select(name, age = birth_year) %>%
    dplyr::mutate(birth_year = 2019 - age) %>%
    dplyr::filter(!is.na(age))
```



dplyr practice!

Calculate the number of characters with each hair color combination

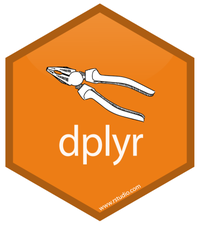
GOAL:

hair_color	number
auburn	1
auburn, grey	1
auburn, white	1
black	13
blond	3
blonde	1
brown	18
brown, grey	1
grey	1
none	37
unknown	1
white	4
NA	5

Note: "brown, grey" is different than "brown" or "grey"

Hint: the function `n()` *counts the number of observations in a group*

BONUS: Combine "blond" and "blonde" as one category and re-calculate



dplyr practice!

Calculate the number of characters with each hair color combination

GOAL:

hair_color	number
auburn	1
auburn, grey	1
auburn, white	1
black	
blond	
blonde	
brown	
brown, grey	
grey	
none	
unknown	
white	4
NA	5

Note: "brown, grey" is different than "brown" or "grey"

CODE:

```
practice2 <- starwars %>%
    dplyr::select(name, hair_color) %>%
    dplyr::group_by(hair_color) %>%
    dplyr::summarize(number = n())
```

calculate

dplyr practice!

Calculate the number of characters with each hair color combination

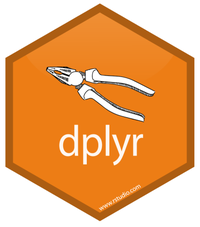
GOAL:

hair_color	number
auburn	1
auburn, grey	1
auburn, white	1
NA	5

Note: “brown, grey” is different than “brown” or “grey”

CODE:

```
practice2 <- starwars %>%
    dplyr::select(name, hair_color) %>%
    dplyr::mutate(hair_color = ifelse(hair_color == “blond”,
                                      “blonde”, hair_color)) %>%
    dplyr::group_by(hair_color) %>%
    dplyr::summarize(number = n())
```



dplyr practice!

Calculate the number of characters with each hair color combination
Note: Keep ALL characters

GOAL:

name	hair_color	number
Luke Skywalker	blond	3
C-3PO	*NA*	5
R2-D2	*NA*	5
Darth Vader	none	37
Leia Organa	brown	18
Owen Lars	brown, grey	1
Beru Whitesun lars	brown	18
R5-D4	*NA*	5
Biggs Darklighter	black	13
Obi-Wan Kenobi	auburn, white	1
Anakin Skywalker	blond	3
Wilhuff Tarkin	auburn, grey	1
Chewbacca	brown	18
Han Solo	brown	18
Greedo	*NA*	5
Jabba Desilijic Tiure	*NA*	5
Wedge Antilles	brown	18
Jek Tono Porkins	brown	18

Note: "brown, grey" is different than "brown" or "grey"

Hint: the function `n()` *counts the number of observations in a group*

dplyr practice!

Calculate the number of characters with each hair color combination
Note: Keep ALL characters

GOAL:

name	hair_color	number
Luke Skywalker	blond	3
C-3PO	*NA*	5
R2-D2	*NA*	5
Darth Vader	none	37
Leia Organa	brown	18
Owen Lars	brown, grey	1
Beru Whitesun lars	brown	
R5-D4	*NA*	
Biggs Darklighter	black	
Obi-Wan Kenobi	auburn, white	
Anakin Skywalker	blond	
Wilhuff Tarkin	auburn, grey	
Chewbacca	brown	
Han Solo	brown	
Greedo	*NA*	
Jabba Desilijic Tiure	*NA*	
Wedge Antilles	brown	18
Jek Tono Porkins	brown	18

Note: "brown, grey" is different than "brown" or "grey"

Hint: the function **`n()`** *counts the*

CODE:

```
practice3 <- starwars %>%
    dplyr::select(name, hair_color) %>%
    dplyr::group_by(hair_color) %>%
    dplyr::mutate(number = n())
```

dplyr practice!

Select all characters and their homeworld in the film “Return of the Jedi”

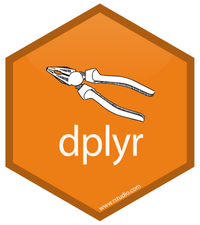
GOAL:

name	homeworld
Luke Skywalker	Tatooine
C-3PO	Tatooine
R2-D2	Naboo
Darth Vader	Tatooine
Leia Organa	Alderaan
Obi-Wan Kenobi	Stewjon
Arvel Crynyd	*NA*
Wicket Systri Warrick	Endor
Nien Nunb	Sullust
Bib Fortuna	Ryloth

Hint: try using `grepl()`

CODE:

```
practice4 <- starwars %>%
    dplyr::filter(grepl("Return of the Jedi", films)) %>%
    dplyr::select(name, homeworld)
```



Summary statistics and general math

```
vec <- c(1, 1, 3, 4, 5, 5, 7, 8, 9, 9)
```

```
# calculate sum of vector
> sum(vec)
52
```

```
# calculate product of vector
> prod(vec)
1360800
```

```
# calculate mean of vector
> mean(vec)
5.2
```

```
# calculate summary statistics
> summary(vec)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   1.00    3.25    5.00    5.20    7.75    9.00 
```

```
# calculate sd of vector
> sd(vec)
3.01
```

```
# calculate table of values
> table(vec)
1 3 4 5 7 8 9 
2 1 1 2 1 1 2 
```

Sampling from a distribution

```
vec <- c(1, 1, 3, 4, 5, 5, 7, 8, 9, 9)
```

```
# sample without replacement
> sample(vec, 3, replace = FALSE)
[1] 7 9 3

# sample with replacement
> sample(vec, 3, replace = TRUE)
[1] 8 5 5

# set random generator seed
> set.seed(192)
```

```
# sample with set probabilities
> sample(c("Yes", "No"),
         10,
         replace = TRUE,
         prob = c(0.7, 0.3))
[1] "Yes" "Yes" "No"  "Yes" "Yes"
[6] "Yes" "Yes" "Yes" "Yes" "Yes"
```

Generating a random distribution

```
# generate NORMAL distribution
> rnorm(5, mean = 0, sd = 1)
  0.8838757  1.8028252 -1.4362813  0.6163822 -0.6357746

# generate UNIFORM distribution
> runif(5, min = 1, max = 10)
9.294435 1.518637 5.570818 5.031591 6.430223

# generate BINOMIAL distribution
> rbinom(10, size = 1, prob = 0.5)
1 0 1 1 1 1 0 0 0 1
```

Practicing with the distribution functions

The probability of having blood type A is 0.4. There are 50 people in this room, what is the probability that 30 have type A?

```
> dbinom(x = 30, size = 50, prob = 0.4)
```

Consider a random sample of five children, and suppose that the chance of an individual child catching chickenpox during a given year is 0.10. What is the probability that at least two of the children get the chickenpox?

```
> 1 - (dbinom(0, 5, 0.1) + dbinom(1, 5, 0.1))
```

```
> 1 - pbinom(1, 5, 0.1)
```

Practicing with the distribution functions

In a certain population of fish, individual lengths follow a normal distribution. The mean length of the fish is 54.0 mm, and the standard deviation is 4.5 mm. What percentage of the fish are longer than 51 mm?

```
> 1 - pnorm(51, 54, 4.5)
```

What percentage of the fish are between 51-60 mm?

```
> pnorm(60, 54, 4.5) - pnorm(51, 54, 4.5)
```

What is the 20th percentile of fish length distributions?

```
> qnorm(0.2, 54, 4.5)
```

(Check with pnorm())

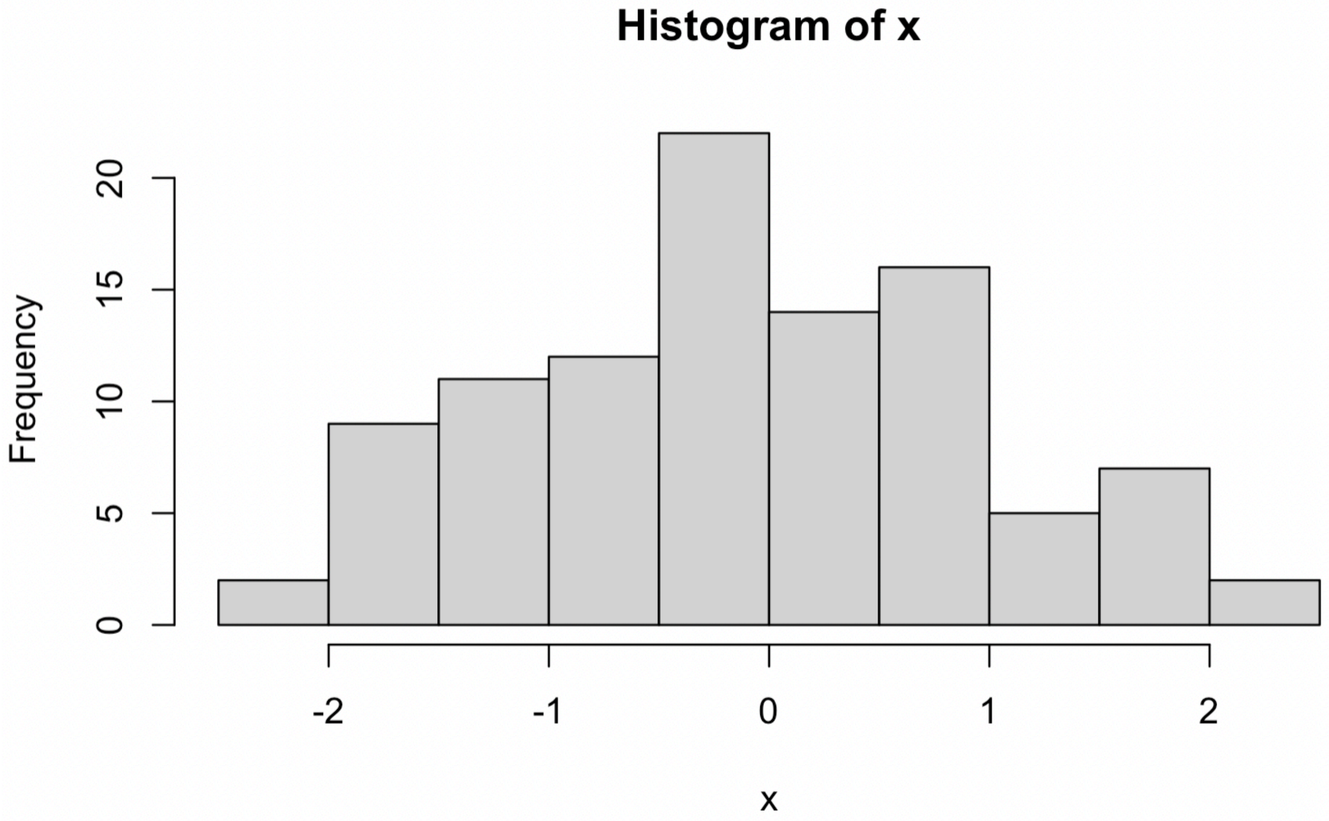
Plotting — Histograms

```
# generate NORMAL distribution

> x <- rnorm(100, mean = 0, sd = 1)

# plot with base R

> hist(x)
```



Plotting — Histograms

```
# generate NORMAL distribution

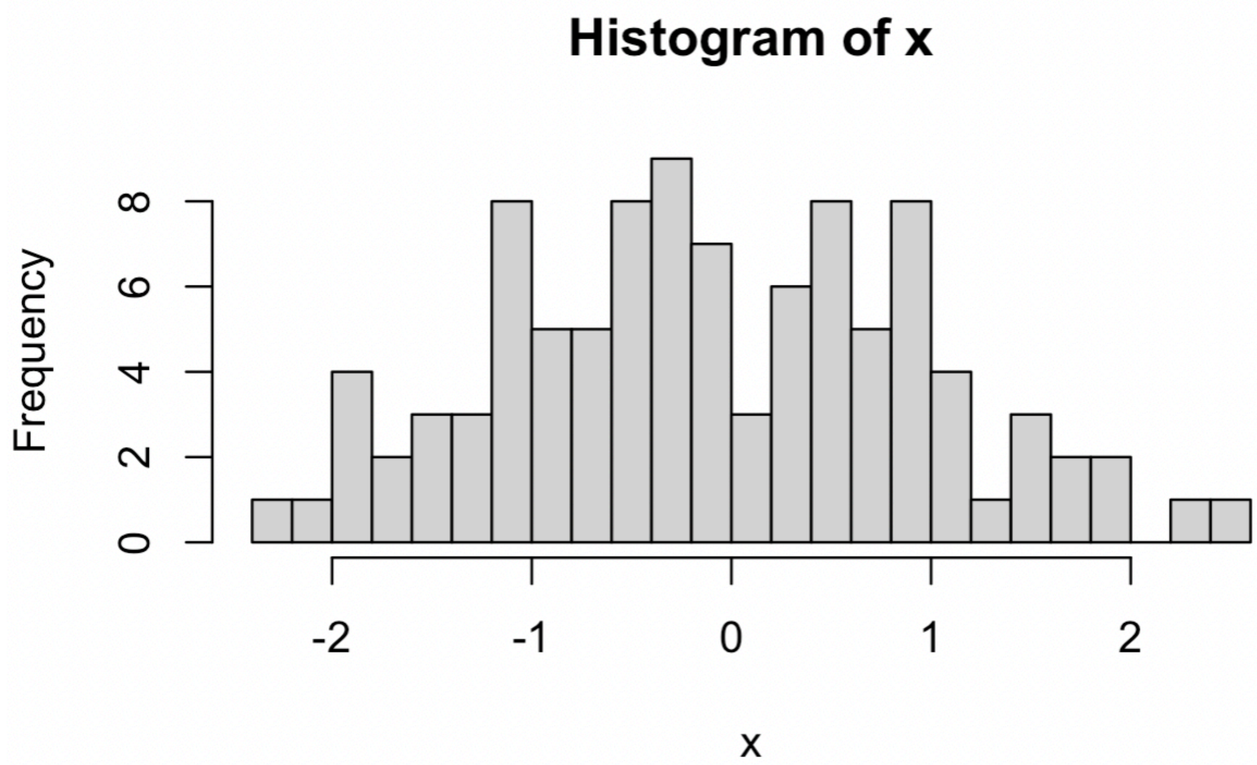
> x <- rnorm(100, mean = 0, sd = 1)

# plot with base R

> hist(x)

# change number of bins

> hist(x, breaks = 20)
```



Plotting with `ggplot2`

Plotting with ggplot2

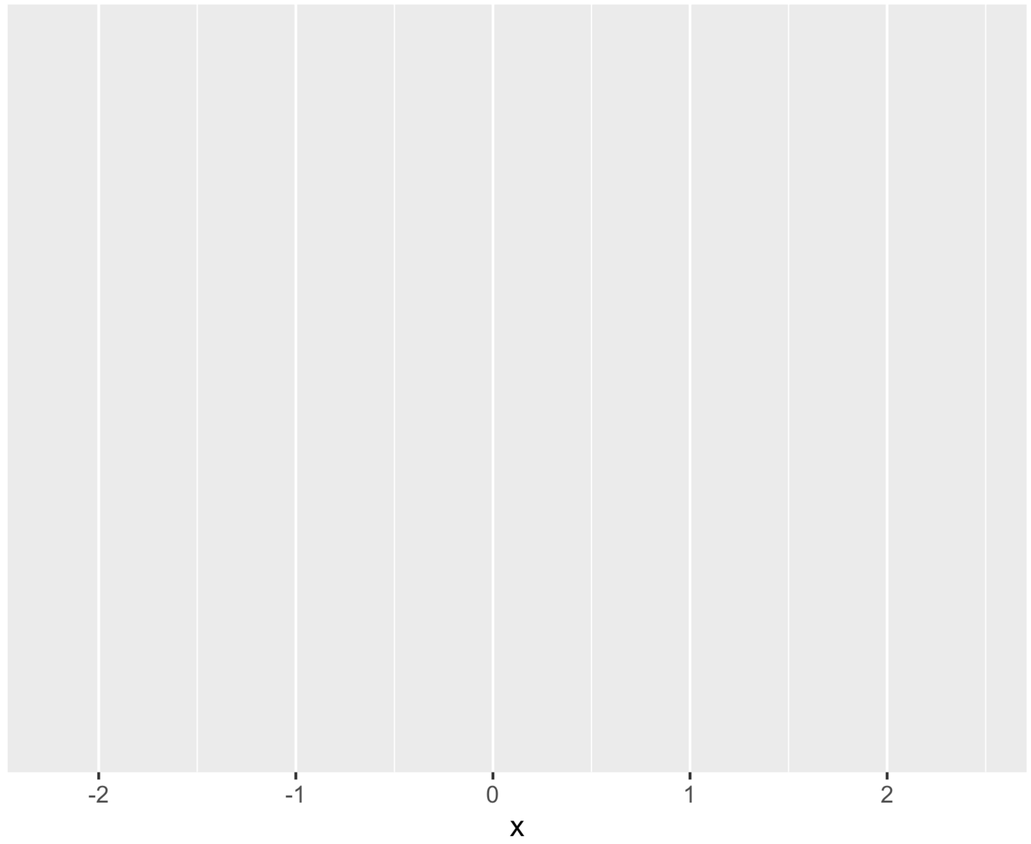
```
# generate NORMAL distribution
> x <- rnorm(100, mean = 0, sd = 1)

# make a ggplot object
> ggplot2::ggplot(data.frame(x))
```

Plotting with ggplot2

```
# generate NORMAL distribution
> x <- rnorm(100, mean = 0, sd = 1)

# make a ggplot object
> ggplot2::ggplot(data.frame(x)) +
# add x and y axes
      ggplot2::aes(x = x)
```



Plotting with ggplot2

```
# generate NORMAL distribution

> x <- rnorm(100, mean = 0, sd = 1)


# make a ggplot object

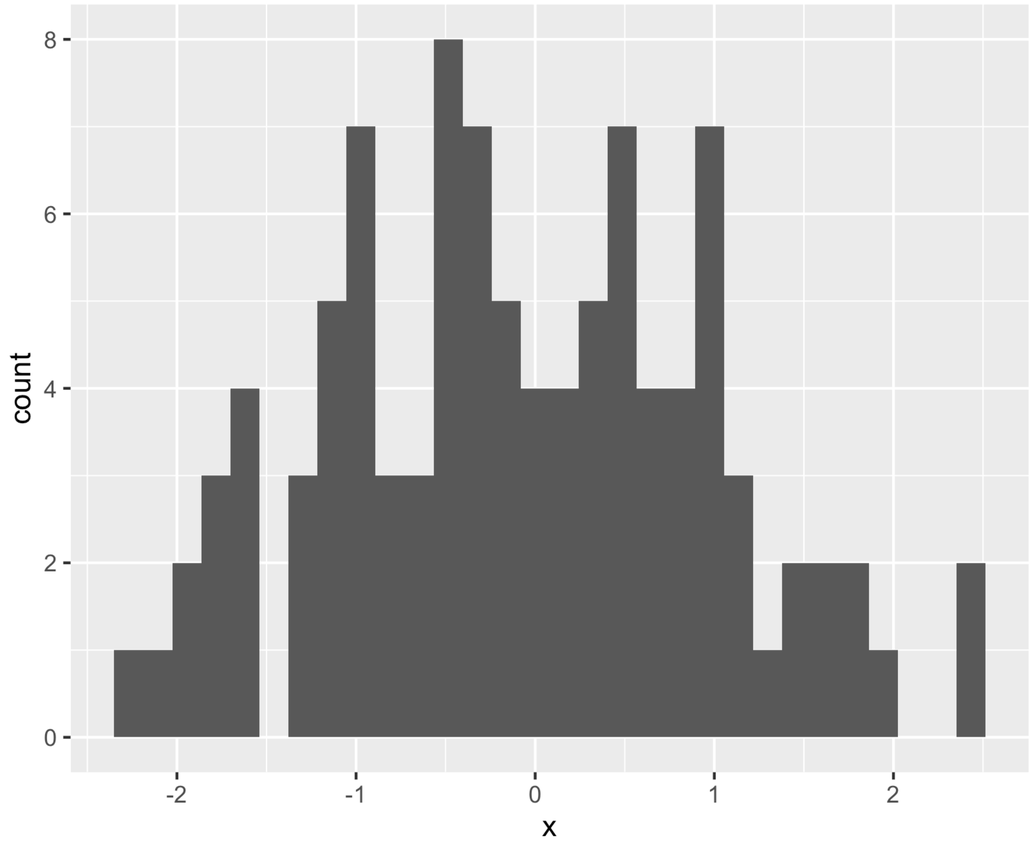
> ggplot2::ggplot(data.frame(x)) +

# add x and y axes

      ggplot2::aes(x = x) +

# add how to plot data

      ggplot2::geom_histogram()
```



Plotting with ggplot2

```
# generate NORMAL distribution

> x <- rnorm(100, mean = 0, sd = 1)


# make a ggplot object

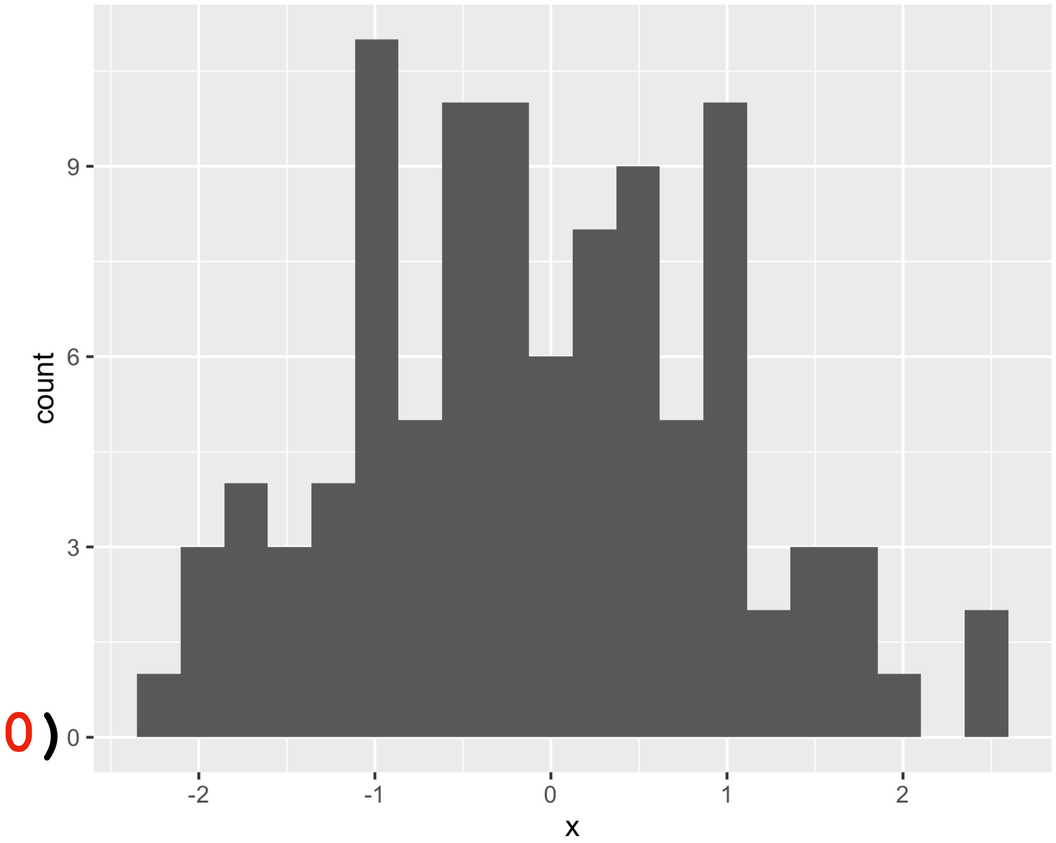
> ggplot2::ggplot(data.frame(x)) +

# add x and y axes

    ggplot2::aes(x = x) +

# add how to plot data

    ggplot2::geom_histogram(bins = 20)
```

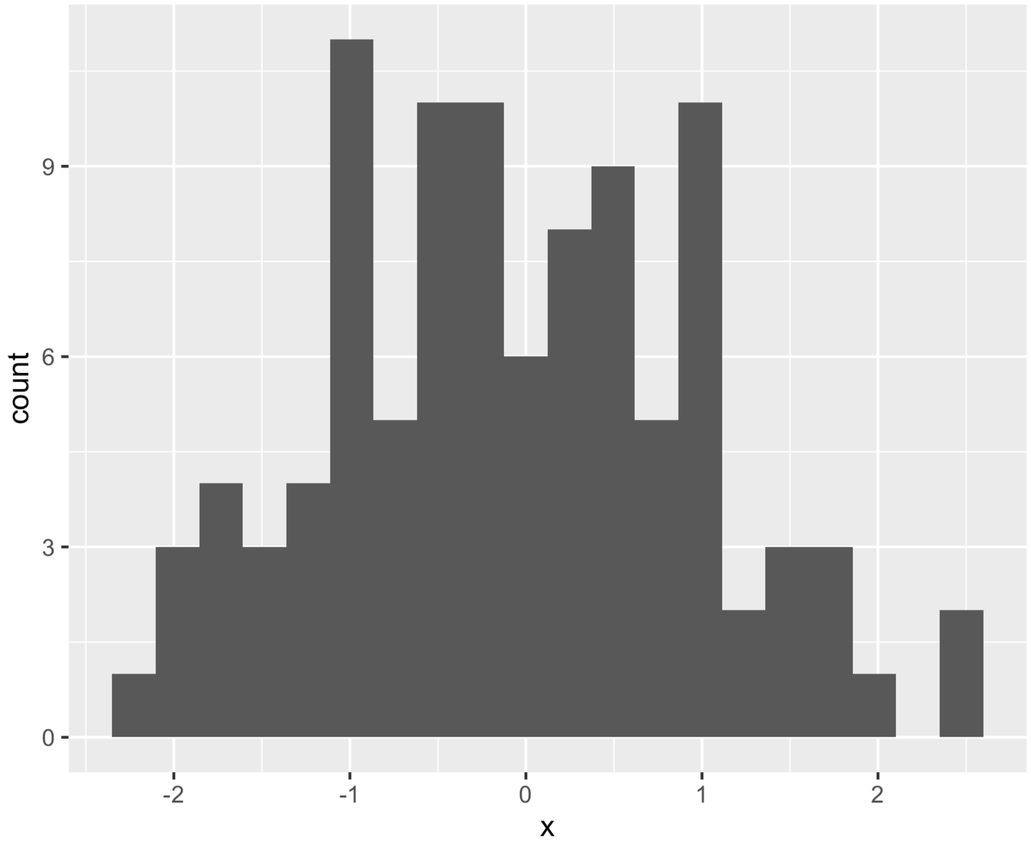


Plotting with ggplot2

```
# generate NORMAL distribution

> x <- rnorm(100, mean = 0, sd = 1)


 # make a ggplot object
 > ggplot2::ggplot(data.frame(x)) +
     # add x and y axes
     ggplot2::aes(x = x) +
     # add how to plot data
     ggplot2::geom_histogram(bins = 20)
     # add pre-set theme
     ggplot2::theme_bw()
```

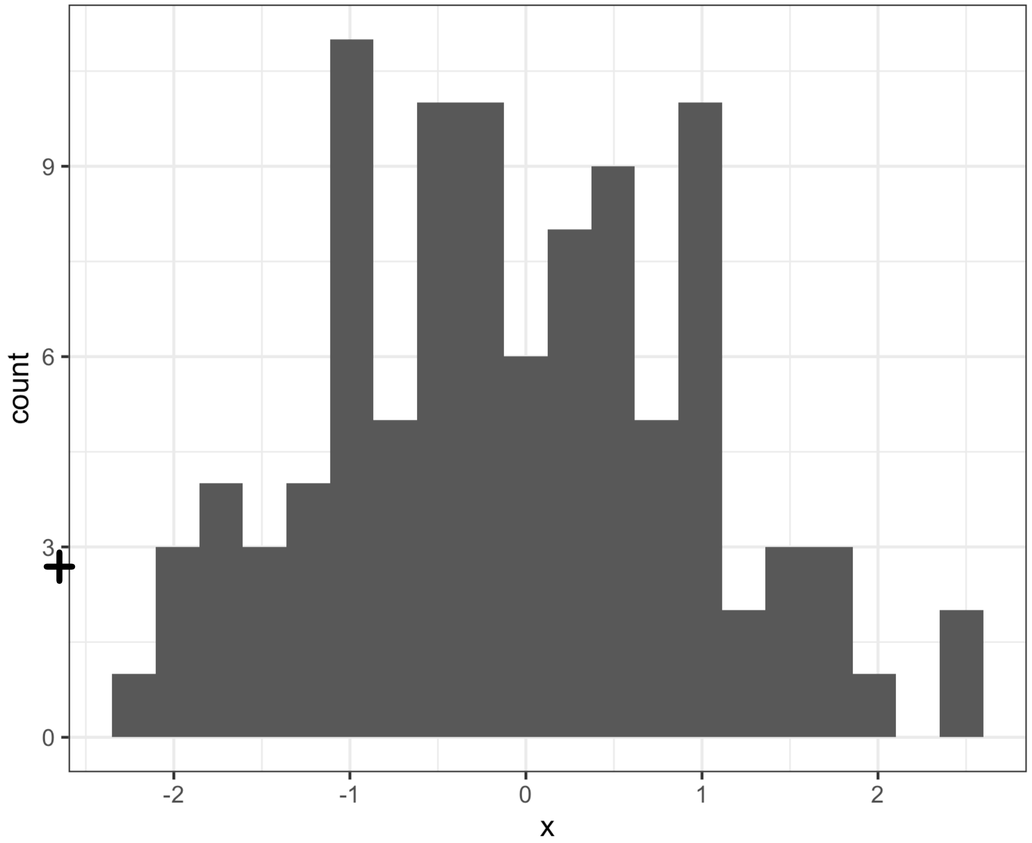


Plotting with ggplot2

```
# generate NORMAL distribution

> x <- rnorm(100, mean = 0, sd = 1)

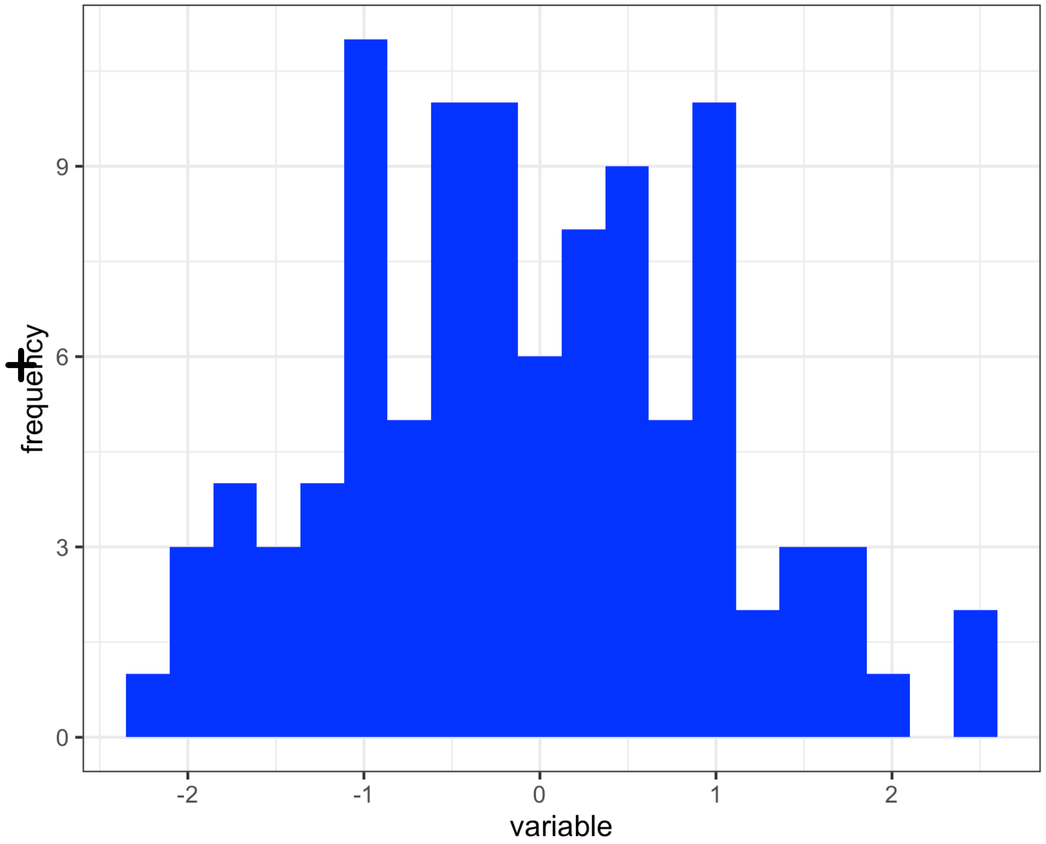

 # make a ggplot object
 > ggplot2::ggplot(data.frame(x)) +
     # add x and y axes
     ggplot2::aes(x = x) +
     # add how to plot data
     ggplot2::geom_histogram(bins = 20) +
     # add pre-set theme
     ggplot2::theme_bw()
```



Plotting with ggplot2

```
# make a ggplot object
> ggplot2::ggplot(data.frame(x)) +
    # add x and y axes
    ggplot2::aes(x = x) +
    # add how to plot data
    ggplot2::geom_histogram(bins = 20,
                            fill = "blue") +
    # add pre-set theme
    ggplot2::theme_bw() +
    # change labels
    ggplot2::labs(x = "variable",
                  y = "frequency")
```

Unlimited modifications!!!



Data Visualization with ggplot2 : : CHEAT SHEET

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and geoms—visual marks that represent data points.

To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

Complete the template below to build a graph.

required

```
ggplot (data = <DATA>) +
<GEOM_FUNCTION>(mapping = aes(<MAPPINGS>),
 stat = <STAT> , position = <POSITION> ) +
<COORDINATE_FUNCTION> +
<FACET_FUNCTION> +
<SCALE_FUNCTION> +
<THEME_FUNCTION>
```

Not required, sensible defaults supplied

ggplot(data = mpg, **aes(**x = cty, y = hwy**))** Begins a plot that you finish by adding layers to. Add one geom function per layer.

aesthetic mappings · data · geom

qplot(x = cty, y = hwy, data = mpg, geom = "point**)** Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

last_plot() Returns the last plot

ggsave("plot.png", width = 5, height = 5) Saves last plot as 5' x 5' file named "plot.png" in working directory. Matches file type to file extension.

Geoms

Use a geom function to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer.

GRAPHICAL PRIMITIVES

```
a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))
```

a + geom_blank()
(Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)**)** - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + geom_path(lineend="butt", linejoin="round", linemitre=1**)**
x, y, alpha, color, group, linetype, size

a + geom_polygon(aes(group = group)**)**
x, y, alpha, color, fill, group, linetype, size

b + geom_rect(aes(xmin = long, ymin=lat, xmax= long + 1, ymax = lat + 1)**)** - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + geom_ribbon(aes(ymin=unemploy - 900, ymax=unemploy + 900)**)** - x, ymax, ymin, alpha, color, fill, group, linetype, size

LINE SEGMENTS

common aesthetics: x, y, alpha, color, linetype, size

b + geom_abline(aes(intercept=0, slope=1)**)**
b + geom_hline(aes(yintercept = lat)**)**
b + geom_vline(aes(xintercept = long)**)**

b + geom_segment(aes(yend=lat+1, xend=long+1)**)**
b + geom_spoke(aes(angle = 1:1155, radius = 1)**)**

ONE VARIABLE continuous

```
c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)
```

c + geom_area(stat = "bin")
x, y, alpha, color, fill, linetype, size

c + geom_density(kernel = "gaussian"**)**
x, y, alpha, color, fill, group, linetype, size, weight

c + geom_dotplot()
x, y, alpha, color, fill

c + geom_freqpoly() x, y, alpha, color, group, linetype, size

c + geom_histogram(binwidth = 5**)** x, y, alpha, color, fill, linetype, size, weight

c2 + geom_qq(aes(sample = hwy)**)** x, y, alpha, color, fill, linetype, size, weight

discrete

```
d <- ggplot(mpg, aes(fl))
```

d + geom_bar()
x, alpha, color, fill, linetype, size, weight

TWO VARIABLES

continuous x , continuous y

```
e <- ggplot(mpg, aes(cty, hwy))
```

e + geom_label(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE**)** x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + geom_jitter(height = 2, width = 2**)**
x, y, alpha, color, fill, shape, size

e + geom_point(), x, y, alpha, color, fill, shape, size, stroke

e + geom_quantile(), x, y, alpha, color, group, linetype, size, weight

e + geom_rug(sides = "bl"**)**, x, y, alpha, color, linetype, size

e + geom_smooth(method = lm**)**, x, y, alpha, color, fill, group, linetype, size, weight

e + geom_text(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE**)**, x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

```
f <- ggplot(mpg, aes(class, hwy))
```

f + geom_col(), x, y, alpha, color, fill, group, linetype, size

f + geom_boxplot(), x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + geom_dotplot(binaxis = "y", stackdir = "center"**)**, x, y, alpha, color, fill, group

f + geom_violin(scale = "area"**)**, x, y, alpha, color, fill, group, linetype, size, weight

discrete x , discrete y

```
g <- ggplot(diamonds, aes(cut, color))
```

g + geom_count(), x, y, alpha, color, fill, shape, size, stroke

continuous bivariate distribution

```
h <- ggplot(diamonds, aes(carat, price))
```

h + geom_bin2d(binwidth = c(0.25, 500)**)**
x, y, alpha, color, fill, linetype, size, weight

h + geom_density2d()
x, y, alpha, colour, group, linetype, size

h + geom_hex()
x, y, alpha, colour, fill, size

continuous function

```
i <- ggplot(economics, aes(date, unemploy))
```

i + geom_area()
x, y, alpha, color, fill, linetype, size

i + geom_line()
x, y, alpha, color, group, linetype, size

i + geom_step(direction = "hv")
x, y, alpha, color, group, linetype, size

visualizing error

```
df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit-se, ymax = fit+se))
```

j + geom_crossbar(fatten = 2**)**
x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + geom_errorbar(), x, ymax, ymin, alpha, color, group, linetype, size, width (also **geom_errorbarh()**)

j + geom_linerange()
x, ymin, ymax, alpha, color, group, linetype, size

j + geom_pointrange()
x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

maps

```
data <- data.frame(murder = USArrests$Murder,
state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))
```

k + geom_map(aes(map_id = state), map = map**)**
+ expand_limits(x = map$long, y = map$lat**)**,
map_id, alpha, color, fill, linetype, size

THREE VARIABLES

```
seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2))l <- ggplot(seals, aes(long, lat))
```

l + geom_contour(aes(z = z))
x, y, z, alpha, colour, group, linetype, size, weight

l + geom_raster(aes(fill = z**)**, hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

l + geom_tile(aes(fill = z**))**, x, y, alpha, color, fill, linetype, size, width

R Markdown

(Open a new R Markdown file)

```
---
title: "test"
author: "Katie Evans"
date: "7/23/2018"
output: html_document
---

```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```

R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see <http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

```{r cars}
summary(cars)
```

Including Plots

You can also embed plots, for example:

```{r pressure, echo=FALSE}
plot(pressure)
```

Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.
```

HTML or PDF

Great for data analysis summary

Try pressing "knit" at the top of your script

test

Katie Evans

7/23/2018

R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com.

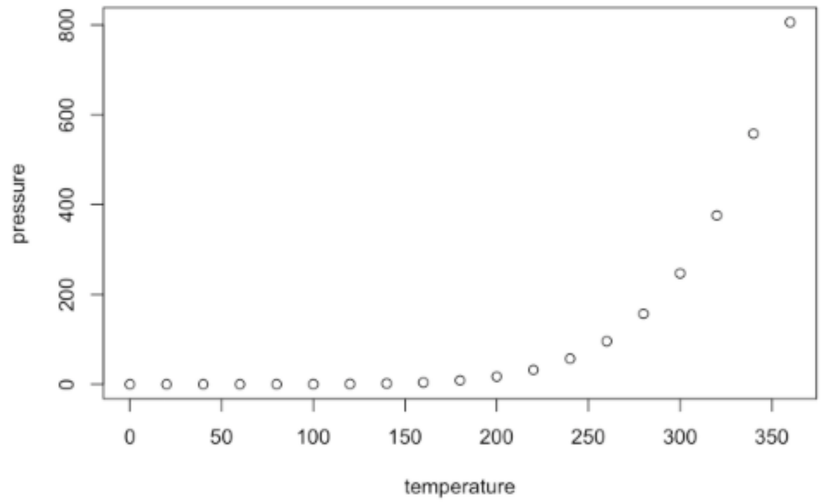
When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

```
summary(cars)
```

```
##      speed           dist       
##  Min.   : 4.0   Min.   :  2.00  
##  1st Qu.:12.0   1st Qu.: 26.00  
##  Median :15.0   Median : 36.00  
##  Mean   :15.4   Mean   : 42.98  
##  3rd Qu.:19.0   3rd Qu.: 56.00  
##  Max.   :25.0   Max.   :120.00
```

Including Plots

You can also embed plots, for example:



Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.