BOOTSTRAP
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Workbook v1.4

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Unit 1

Intro to Computational Data Science

Many important questions ("What's the best restaurant in town?", "Is this law good for citizens?", etc.) are answered with data. Data Scientists try and answer these questions by writing *programs that ask questions about data.*

Data of all types can be organized into **Tables**

- Every Table has a **header row**, and some number of **data rows**
- **Quantitative data** is numeric, and measures *quantity*, such as a person's height, a score on test, a measure of distance, etc. A list of quantitative data can be ordered from smallest to largest.
- **Categorical data** is data that specifies *categories*, such as eye color, country of origin, etc. Categorical data is not subject to the laws of arithmetic – for example, we cannot take the "average" of a list of colors.

Programming languages involve different *datatypes*, such as Numbers, Strings, Booleans and Images. Numbers are usually used for quantitative data, and other values are used as categorical data.

- **Operators** (like +, -, *, <, etc.) are written between values. For example: `4 + 2`
- We can use **functions** (like triangle, star, string-repeat, etc.) by writing the function name first, followed by a list of **arguments** in parentheses. For example: `star(50, "solid", "red")`
- Functions have **contracts**, which specify the *Name, Domain and Range* of each function. The Domain tells us what type of data the function consumes, and the Range tells us what it produces.

The Animals Dataset

name	Species	Gender	Age (years)	Fixed	Legs	Weight (lbs)	Time to Adoption (weeks)
Sasha	cat	female	1	FALSE	4	6.5	3
Mittens	cat	female	2	TRUE	4	7.4	1
Sunflower	cat	female	5	TRUE	4	8.1	6
Sheba	cat	female	7	TRUE	4	8.4	6
Felix	cat	male	16	TRUE	4	9.2	5
Snowcone	cat	female	2	TRUE	4	6.5	5
Wade	cat	male	1	FALSE	4	3.2	1
Hercules	cat	male	3	FALSE	4	13.4	2
Toggle	dog	female	3	TRUE	4	48	1
Boo-boo	dog	male	11	TRUE	4	123	24
Fritz	dog	male	4	TRUE	4	92	3
Maple	dog	female	3	TRUE	4	51.6	4
Bo	dog	male	8	TRUE	4	76.1	10
Midnight	dog	female	5	FALSE	4	112	4
Rex	dog	male	1	FALSE	4	28.9	9
Gir	dog	male	8	FALSE	4	88	5
Max	dog	male	3	FALSE	4	52.8	8
Nori	dog	female	3	TRUE	4	35.3	1
Mr. Peanutbutter	dog	male	10	FALSE	4	161	6
Lucky	dog	male	3	TRUE	3	45.4	9
Kujo	dog	male	8	FALSE	4	172	30
Buddy	lizard	male	2	FALSE	4	0.3	3
Gila	lizard	female	3	TRUE	4	1.2	4
Snuffles	rabbit	female	3	TRUE	4	3.5	8
Nibblet	rabbit	male	6	FALSE	4	4.3	2
Snuggles	tarantula	female	2	FALSE	8	0.1	1
Daisy	dog	female	5	TRUE	4	68	8
Ada	dog	female	2	TRUE	4	32	3
Miaulis	cat	male	7	FALSE	4	8.8	4
Heathcliff	cat	male	1	TRUE	4	2.1	2
Tinkles	cat	female	1	TRUE	4	1.7	3

The Animals Dataset

What do you NOTICE about this dataset?	What do you WONDER about this dataset?	*Question Type*
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate

1. This dataset is Animals from an animal shelter, which contains 31 data rows.
2. Some of the columns are:
   a) species, which contains categorical data. Some example values from this column are: "cat", "dog", and "rabbit".
   b) _____, which contains _____ data. Some example values from this column are: _____.
   c) _____, which contains _____ data. Some example values from this column are: _____.

Numbers and Strings

Make sure you've loaded the Unit 1 Starter File, and clicked "Run".

1. Try typing `42` into the Interactions Area and hitting "Enter". What happens?

2. Try typing in other Numbers. What happens if you try a decimal like `0.5`? A fraction like `1/3`? Try really big Numbers, and really small ones.

3. String values are always in quotes. Try typing your name (in quotes!). What happens when you hit "Enter"?

4. Try typing your name with the opening quote, but *without* the closing quote. What happens? Now try typing it without *any* quotes.

5. Is `42` the same as `"42"`? Why or why not? Write your answer below:

They are different data types: 42 (without quotes) is a Number, and "42" (with quotes) is a string.

Operators

6. Just like in math, Pyret has *operators* like `+` and `-`. Try typing in `4 + 2`, and then `4+2` (without the spaces). What can you conclude from this? Write your answer below:

Operators (like +) need whitespace separating them from their operands.

7. Typing in the following expressions, one at a time: `4 + 2 + 6`, `4 + 2 * 6`, and `4 + (2 * 6)`. What do you notice? Write your answer below:

You can use the same operator multiple times without parentheses, but you need parentheses to group order of operations if using different operators (like + and *) together.

8. Try typing in `4 + "cat"`, and then `"dog" + "cat"`. What can you conclude from this? Write your answer below:

The + operator can only be used with Numbers, not Strings.

Booleans

Boolean expressions are yes-or-no questions, and will always evaluate to either `true` ("yes") or `false` ("no"). What will each of the expressions below evaluate to? Write down the result in the blanks provided, and type them into Pyret if you're not sure.

`3 <= 4`	True	`"a" > "b"`	False
`3 == 2`	False	`"a" <> "b"`	True
`2 <> 4`	True	`"a" == "b"`	False
`3 <> 3`	False	`"a" <> "a"`	False

Boolean Operators

Pyret also has operators that work on *Booleans*. For each expression below, *write down your guess* about what it will evaluate to. Then type them in and see if you were right!

`(3 <= 4) and (3 == 2)`	False
`("a" == "b") and (3 <> 4)`	False
`(3 <= 4) or (3 == 2)`	True
`("a" == "b") or (3 <> 4)`	True

1. How many different Number values are there in Pyret? Infinite
2. How many different String values are there in Pyret? Infinite
3. How many different Boolean values are there in Pyret? Two

What's on your mind?

Unit 2

Questions and Definitions

Answering Questions from Data can take many forms. Here are a few types of questions, each requiring a different kind of analysis:

- **Lookup Questions** can be answered just by finding the right row and column a table. (e.g. – "How old is Toggle?")

- **Compute Questions** can be answered by computing over a single row or column. (e.g. – "What is the heaviest animal at the shelter?")

- **Relate Questions** require looking for trends across multiple rows or columns. (e.g. – "Do cats tend to be adopted sooner than dogs?")

Methods are special functions that are attached to pieces of data. We use them to manipulate Tables. They are different from functions in several ways:

- Their names can't be used alone: they can only be used as part of data, separated by a dot. (For example, `shapes.row-n(2)`)
- Their contracts are different: they include the type of the data as part of their names. (eg, `<table>.row-n :: (index :: Number) → Row`)
- They have a "secret" argument, which is the data they are attached to.
- In this course, the methods we'll be using are `row-n, order-by, filter,` and `build-column`.

We can **define our own functions**, using a technique called the **Design Recipe**.

- We use the Design Recipe to help us define functions **and think through problems clearly.**

- The first step is to write a **Contract** and **Purpose Statement** for the function, which specify the Name, Domain and Range of the function and give a summary of what it does.

- The second step is to **write at least two examples**, which show how the function should work for specific inputs. These examples help us see patterns, and we express those patterns by **circling and labeling** what changes.

- The final step is to **define the function**, which generalizes our examples.

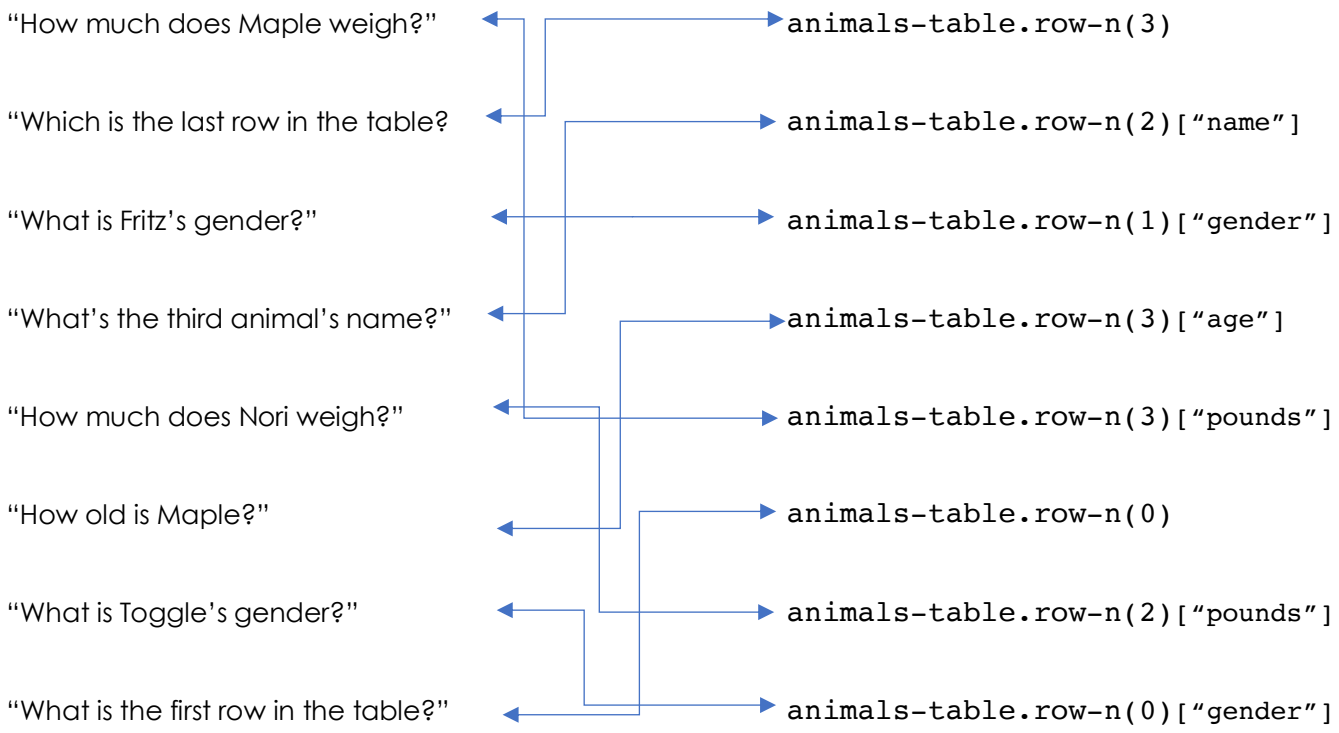
Lookup Questions

The table below represents four pets at an animal shelter:

animals-table

name	gender	age	pounds
"Toggle"	"female"	3	48
"Fritz"	"male"	4	92
"Nori"	"female"	6	35.3
"Maple"	"female"	3	51.6

1. Match each Lookup Question (left) to the code that will give the answer (right).



2. Fill in the blanks (left) with code that will produce the value (right).

animals-table.row-n(3)["name"]	"Maple"
animals-table.row-n(1)["gender"]	"male"
animals-table.row-n(1)["age"]	4
animals-table.row-n(0)["pounds"]	48
animals-table.row-n(2)["name"]	"Nori"

More Practice with Lookups

Consider the table below, and the four value definitions that follow:

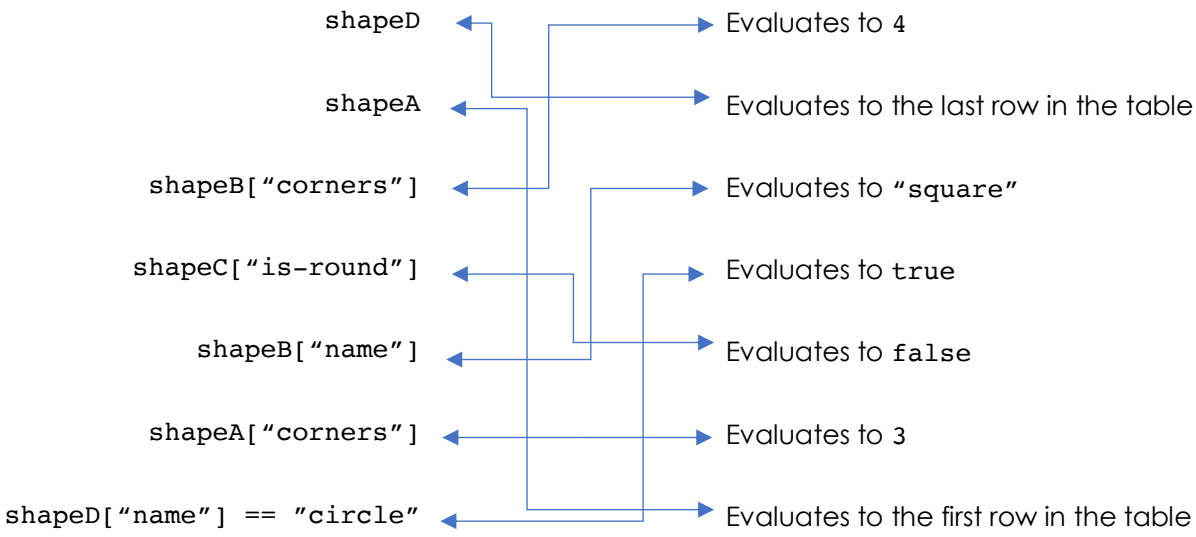
shapes-table

name	corners	is-round
"triangle"	3	false
"square"	4	false
"rectangle"	4	false
"circle"	0	true

```
shapeA = shapes-table.row-n(0)
shapeB = shapes-table.row-n(1)
shapeC = shapes-table.row-n(2)
shapeD = shapes-table.row-n(3)
```

---

1. ***Match*** each Pyret expression (left) to the description of what it looks up (right).



2. Fill in the blanks (left) with the Pyret lookup code that will produce the value (right).

a. *shapeC["name"]* — "rectangle"

b. *shapeA["name"]* — "triangle"

c. *shapeB["corners"]* — 4

d. *shapeD["corners"]* — 0

e. *shapeD["is-round"]* — true

The Design Recipe

For the word problems below, assume you have `animalA` and `animalB` defined in your code.

Define a function called `is-fixed`, which <u>looks up</u> whether or not an animal is fixed.

```
# is-fixed :: (r :: Row) → Boolean
  name       domain        range
# Consumes an animal, and looks up the value in the fixed column
examples:
  is-fixed(animalA) is false
  is-fixed(animalB) is true
end

fun is-fixed(r):
  r["fixed"]
end
```

Define a function called `gender`, which consumes a Row of the animals table and <u>looks up</u> the gender of that animal.

```
# gender :: (r :: Row) → Boolean
  name     domain        range
# Consumes an animal, and looks up the value in the fixed column
examples:
  gender(animalA) is "female"
  gender(animalB) is "male"
end

fun gender(r):
  r["gender"]
end
```

The Design Recipe

For the word problems below, assume you have `animalA` and `animalB` defined in your code.

Define a function called `is-cat`, which consumes a Row of the animals table and <u>computes</u> whether the animal is a cat.

```
# is-cat :: (r :: Row) → Boolean
  name      domain       range
# Consumes an animal, looks up the species column, and computes if species is "cat"
examples:
  is-cat(animalA) is true
  is-cat(animalB) is false
end
fun is-cat(r):
  r["species"] == "cat"
end
```

Define a function called `is-young`, which consumes a Row of the animals table and <u>computes</u> whether it is less than four years old.

```
# is-young :: (r :: Row) → Boolean
  name       domain       range
# Consumes an animal, looks up the age, and computes if age is less than 4
examples:
  is-cat(animalA) is true
  is-cat(animalB) is false
end
fun is-cat(r):
  r["age"] < 4
end
```

What's on your mind?

Unit 3

Exploring Datasets

Computer Scientists may take **samples** that are subsets of a data set. If their sample is well chosen, they can use it to test if their code does what it's supposed to do. However, choosing a good sample can be tricky!

Samples from the Animals Dataset

How can we define subsets? For a given row *r*, what function body will identify if that row is in the subset? We've given you the solution for the first subset, to get you started.

Subset	A single row *r* is in the subset if…
Kittens (<2 years old)	`(r["age"] < 2) and (r["species"] == "cat")`
Puppies (<2 years old)	`(r["age"] < 2) and (r["species"] == "dog")`
Fixed Cats	`r["fixed"] and (r["species"] == "cat")`
Fixed Kittens	`r["fixed"] and (r["age"] < 2) and (r["species"] == "cat")`
Heavy Dogs (>50 pounds)	`(r["pounds"] > 50) and (r["species"] == "dog")`
Heavy Fixed Dogs	`r["fixed"] and (r["pounds"] > 50) and (r["species"] == "dog")`
Cats with "s" in their name	`string-contains(r["name"], "s") and (r["species"] == "cat")`

My Dataset

What do you NOTICE?	What do you WONDER?	Question Type
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate
		Lookup Compute Relate

1. This dataset is _____, which contains _____ data rows.
2. Some of the columns are:
    1. _____, which contains _____ data, and is of type _____. Some example values from this column are: _____.
    2. _____, which contains _____ data, and is of type _____. Some example values from this column are: _____.
    3. _____, which contains _____ data, and is of type _____. Some example values from this column are: _____.

Samples from My Dataset

How can we define subsets? For a given row `r`, what function body will identify if that row is in the subset? We've given you the solution for the first subset, to get you started.

Subset	A single row `r` is in the subset if…

Design Recipes – Filtering Rows

Write filter functions for **your** dataset, which you can use to define subsets.

Define a function called _____ , which consumes a Row of the _____ table and _____

_____

```
# ____________________::____________(r :: Row)____________ → ____________Boolean____________
      name                          domain                          range
# ____________________________________________________________________________
examples:
    ____________(_________) is ____________________________
    ____________(_________) is ____________________________
end
fun ____________ (________) : ____________________________

end
```

Define a function called _____ , which consumes a Row of the _____ table and _____

_____

```
# ____________________::____________(r :: Row)____________ → ____________Boolean____________
      name                          domain                          range
# ____________________________________________________________________________
examples:
    ____________(_________) is ____________________________
    ____________(_________) is ____________________________
end
fun ____________ (________) : ____________________________

end
```

Design Recipes – Filtering Rows

Write your own word problems below, and solve them using the Design Recipe.

Define a function called _____ , which consumes a Row of the _____ table and _____

_____

```
# ______________::_____(r :: Row)_____ → _____Boolean_____
      name                domain                range
# ____________________________________________________________
examples:
    ____________(_________) is ____________________________

    ____________(_________) is ____________________________
end

fun ____________ (________) : ____________________________
end
```

Define a function called _____ , which consumes a Row of the _____ table and _____

_____

```
# ______________::_____(r :: Row)_____ → _____Boolean_____
      name                domain                range
# ____________________________________________________________
examples:
    ____________(_________) is ____________________________

    ____________(_________) is ____________________________
end

fun ____________ (________) : ____________________________
end
```

What's on your mind?

Unit 4

Visualizing the "Shape" of Data

Bar charts show the number of rows belonging to a given category. The more rows in each category, the longer the bar.

- *Bar charts provide a visual representation of the frequency of values in a* ***categorical*** *column.*

- There's no strict numerical way to order these bars, but **sometimes there's an order** that makes sense. For example, bars for the number of orders for different t-Shirt sizes might be presented in order of smallest to largest shirt.

Histograms show the number of rows that fall within certain intervals, or "bins" on a horizontal axis. The more rows that that fall within a particular "bin", the taller the bar.

- *Histograms provide a visual representation of the frequencies of values in a* ***quantitative*** *column.*

- Quantitative data can **always be ordered**, so the bars of a histogram always progress from smallest (on the left) to largest (on the right).

- When dealing with histograms, it's important to select a good **bin size**. If the bins are too small or too large, it is difficult to see the shape of the dataset.

Design Recipe

For the word problems below, assume you have `animalA` and `animalB` defined in your code.

Define a function called `kilos`, which consumes a Row of the animals table and divides the pounds column by 2.2 to <u>compute</u> the animal's weight in kilograms.

```
# kilos :: (r :: Row) → ____
  name      domain      range
# Consumes a row r, and multiplies the pounds by 2.2 to produce weight in kilos
examples:
    kilos ( animalA ) is 6.5 * 2.2
    kilos ( animalB ) is 172 * 2.2
end
fun kilos ( r ): r["pounds"] * 2.2
end
```

Define a function called `nametag`, which consumes a Row of the animals table and <u>computes</u> an image that shows the animal's name in big, red letters.

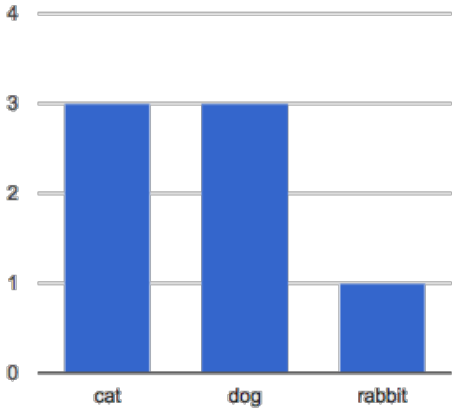
```
# nametag :: ____ → Image
  name      domain      range
# Consumes an animal, and produces an image of their name in big, red letters
examples:
    nametag ( animalB ) is text("sasha", 20, "red")
    nametag ( animalB ) is text("kujo", 20, "red")
end
fun nametag ( r ): text(r["name"], 20, "red")
end
```

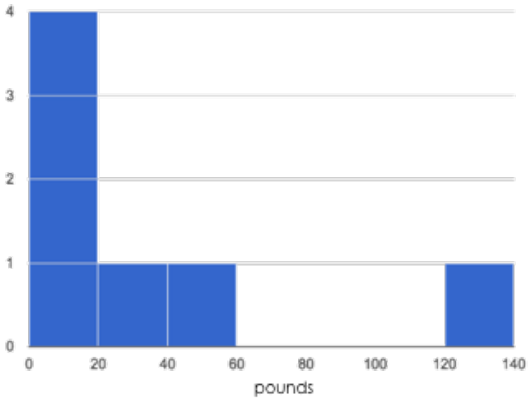
Summarizing Columns

name	species	age	pounds
"Sasha"	"cat"	1	6.5
"Boo-boo"	"dog"	11	123
"Felix"	"cat"	16	9.2
"Nori"	"dog"	6	35.3
"Wade"	"cat"	1	3.2
"Nibblet"	"rabbit"	6	4.3
"Maple"	"dog"	3	51.6

1. How many cats are there in the table above? *3*
2. How many dogs are there? *3*
3. How many animals weigh between 0-20 pounds? *4*
4. How many animals weigh between 20-40 pounds? *1*
5. Are there more animals weighing 40-60 than 60-140 pounds? *no*

The charts below are both based on this table. What is similar about them? What is different?

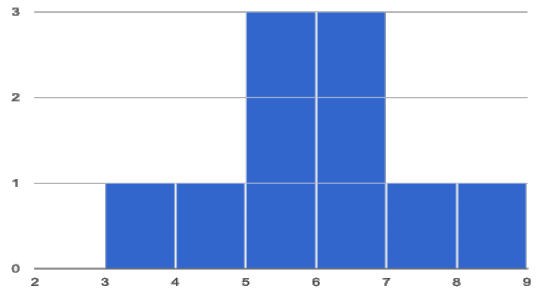
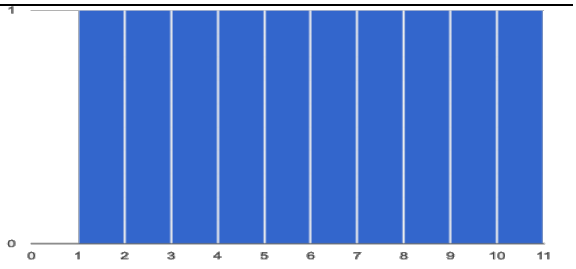
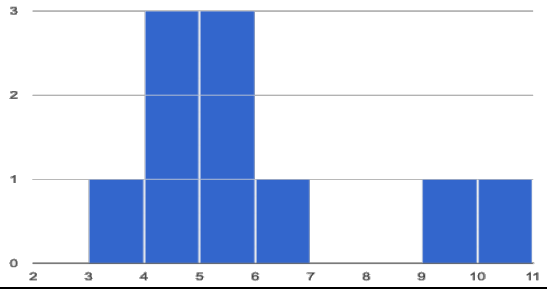
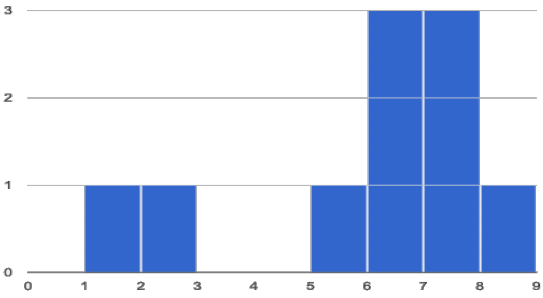
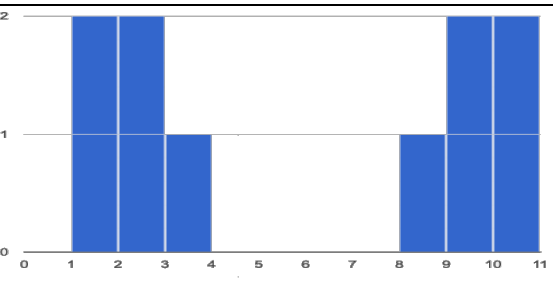




Similarities	Differences
Both use height to show amount	*Group by species vs. Group by pounds*
Data is grouped into bars	*The chart on the right has "ranges"*
Bars are blue	*Measuring different columns*

Reading Histograms

Students watched 5 videos, and rated them on a scale of 1 to 10. While the **average score** for every video is the same (5.5), the **shapes** of the ratings distributions were very different! Match the summary description (left) with the histogram of student ratings (right). For each histogram, **the x-axis is the score, and the y-axis is the number of students who gave it that score.**

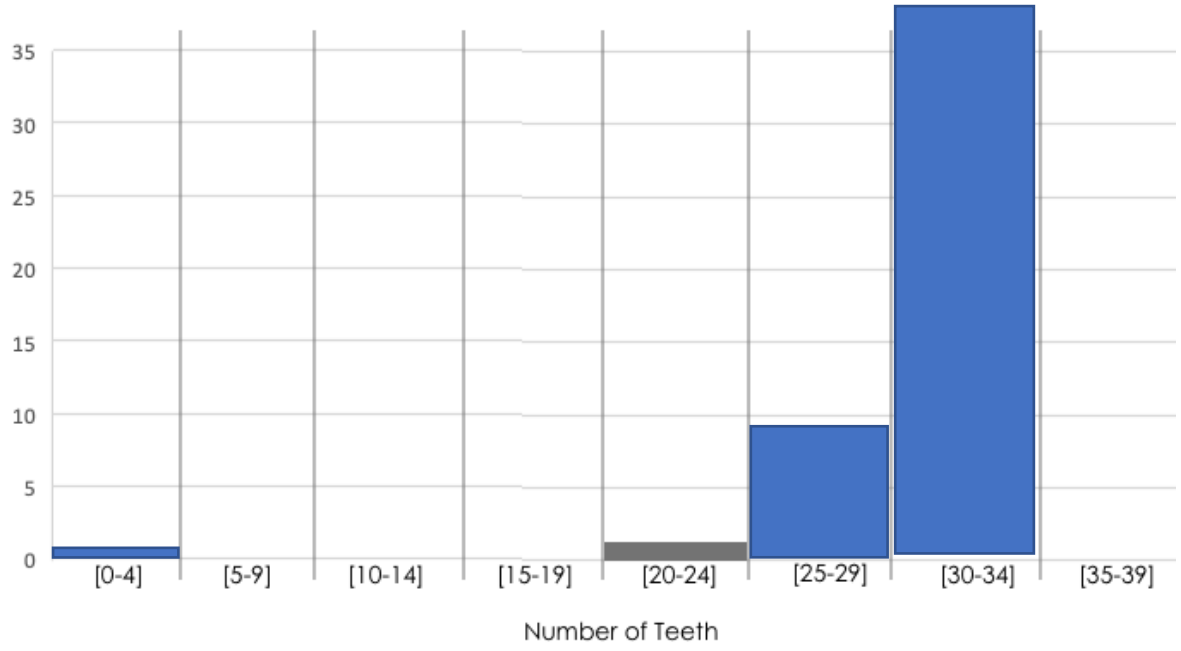
Most of the students were fine with the video, but a couple of them gave it an unusually low rating.	**1 (D)**	**A** 
Most of the students were okay with the video, but a couple students gave it an unusually high rating.	**2 (C)**	**B** 
Students tended to give the video an average rating, and they weren't likely to stray far from the average.	**3 (A)**	**C** 
Students either really liked or really disliked the video.	**4 (E)**	**D** 
Reactions to the video were all over the place: high ratings and low ratings and in-between ratings were all equally likely.	**5 (B)**	**E** 

Making Histograms

Suppose we have a data set for number of teeth in a group of 50 adults:

Number of teeth	Count
0	1
22	1
26	1
27	1
28	4
29	3
30	3
31	3
32	33

Draw a histogram for the table in the space below. For each row, find which interval (or "bin") on the x-axis represents the right number of teeth. Then fill in the box so that the height of the box is equal to the sum of the counts that fit into that interval. One of the intervals has been completed for you.



The Shape of the `Animals` Dataset

Describe two of the histograms you made from your dataset.

1) I made a histogram, showing the distribution of _____pounds_____ for
column in your dataset
_____animals at the shelter_____.
your subset (for example, "fixed dogs at the shelter")

2) I made a histogram, showing the distribution of _____ for
column in your dataset
_____.
your subset (for example, "fixed dogs at the shelter")

In the table below, describe the histograms. Are they symmetric? Do they show left skewness and/or low outliers? Right skewness and/or high outliers?

What do you NOTICE about these displays?	What do you WONDER about these displays?

The Shape of My Dataset

Describe two of the histograms you made from your dataset.

3) I made a histogram, showing the distribution of _____ for
column in your dataset

_____.
your subset (for example, "fixed dogs at the shelter")

4) I made a histogram, showing the distribution of _____ for
column in your dataset

_____.
your subset (for example, "fixed dogs at the shelter")

In the table below, describe the histograms. Are they symmetric? Do they show left skewness and/or low outliers? Right skewness and/or high outliers?

What do you NOTICE about these displays?	What do you WONDER about these displays?

What's on your mind?

Unit 5

Center and Spread

- There are three ways to measure the "center" of a dataset, to summarize a whole column of data using just one number:

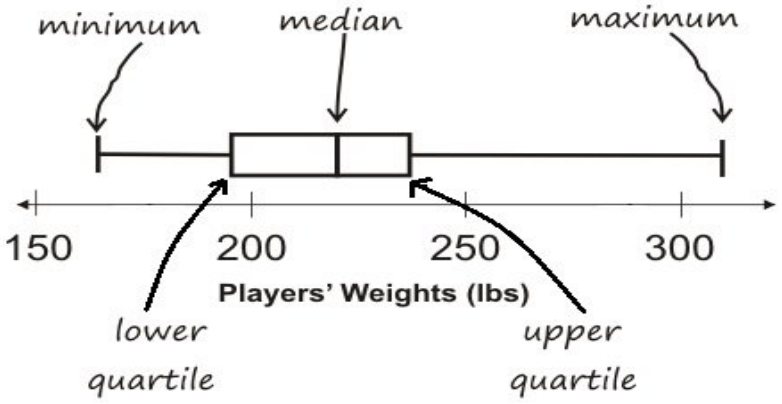
    - The **mean** of a dataset is the average of all the numbers.
    - The **median** of a dataset is a value that is smaller than half the dataset, and larger than the other half.
    - The **mode(s)** of a dataset is the value (or values) that occurs most often.

- The **shape** of a data set tells us which values are more or less common. In a *symmetric* data set, values are just as likely to occur a certain distance above or below the mean. A data set with left skewness and/or low outliers has a few values that are unusually low, pulling the mean *below* the median. Right skewness and/or high outliers means there are a few values that are unusually high, pulling the mean *above* the median.

- Data Scientists can also measure the **spread** of a dataset using a **five-number summary:**

    - The **minimum** – the smallest value in the dataset
    - The **first, or "lower" quartile (Q1)** – the middle of the smaller half of values which separates the smallest quarter from the next smallest quarter.
    - The **second quartile (Q2)** – the median value which separates the entire dataset into "top" and "bottom" halves.
    - The **third, or "upper" quartile (Q3)** – the middle of the larger half of values which separates the second largest quarter from the largest quarter.
    - The **maximum** – the largest value in the dataset.

- The **five-number summary** can be used to draw a **box-and-whisker plot.**



Summarizing Columns in `Animals`

1) The column I choose to measure is pounds

Measures of Center

The three measures for this column are:

Mean (Average)	Median	Mode(s)
40.994	13.4	6.5

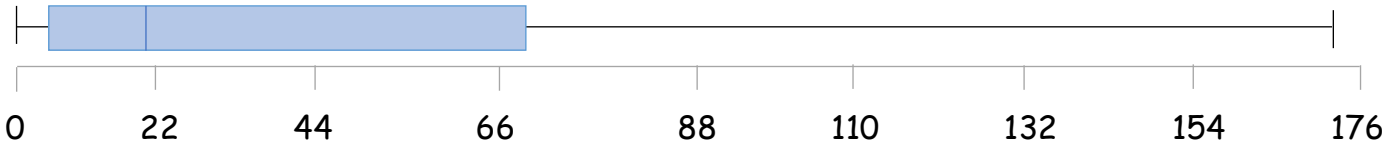
2) Since the mean is higher [higher/lower] than the median, this suggests that there may be outliers or skewness due to values that are unusually high [high / low].

Measures of Spread

My five-number summary is:

Minimum	Q1	Q2 (Median)	Q3	Maximum
0.1	4.3	13.4	68	172

Use the tick marks below to create a scale, and draw a horizontal box-plot above it.



From this summary and box-plot, I conclude:

Half the animals weigh less than 13.4 pounds, but there is wide variation amound outliers, some of whom a lot more!

Interpreting Spread

Consider the following list dataset, representing the annual income of ten people:

`$65k, $12k, $14k, $280k, $15k, $22k, $45k, $34k, $45k, $175k`

1. In the space below, rewrite this dataset in **sorted order**.

$12k, $14k, $15k, $22k, $34k, $45k, $45k, $65k, $175k, $280k

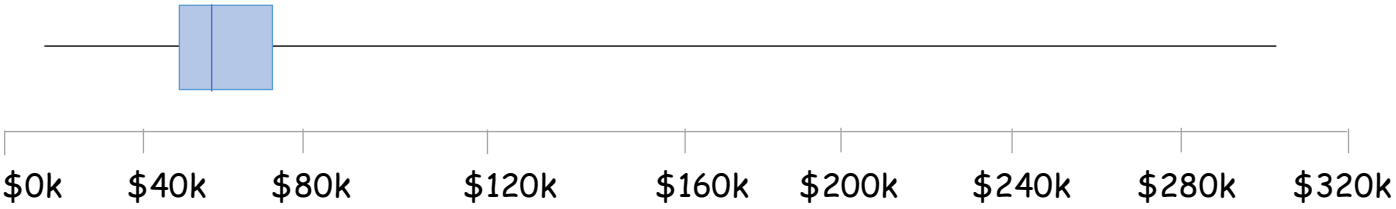
2. In the table below, compute the **measures of center** for this dataset.

Mean (Average)	Median	Mode(s)
70,700	39,500	45,000

3. In the table below, compute the **five number summary** of this dataset.

Minimum	Q1	Q2 (Median)	Q3	Maximum
12,000	15,000	39,500	65,000	280,000

4. Use the tick marks below to create a scale, and draw a horizontal box-plot above it.

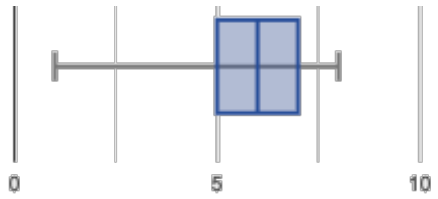


5. The following statements are *correct*…but misleading. Write down the reason why.

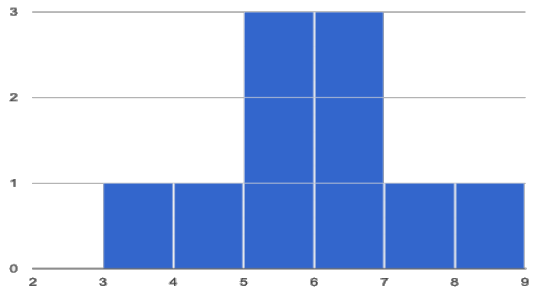
Statement	Why it's misleading
"They're rich! The average person makes more than $70k dollars!"	While the mean is close to $70k, there are some very high earning outliers pushing the average up.
"It's a middle-income list: the most common salary is $45k/yr!"	In the full dataset, more than half of the entries are people making less than $45k, making the mode misleading.
"This group is really diverse, with people making as little as 12k and as much as $280k!"	While the spread of incomes is large, the vast majority are still making less than $65k, with very high earning outliers.

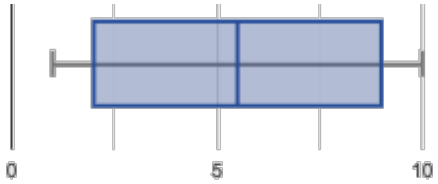
Matching Box-Plots to Histograms

Students watched 5 videos, and rated them on a scale of 1 to 10. For each video, their ratings were used to generate box-plots and histograms. **Match the box-plot to the histogram that displays the same data.**

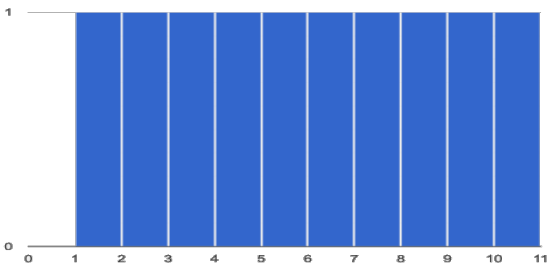


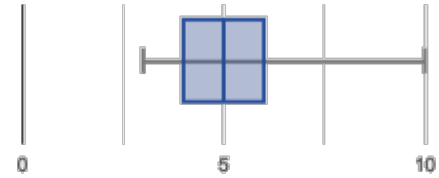
1 (D) **A**



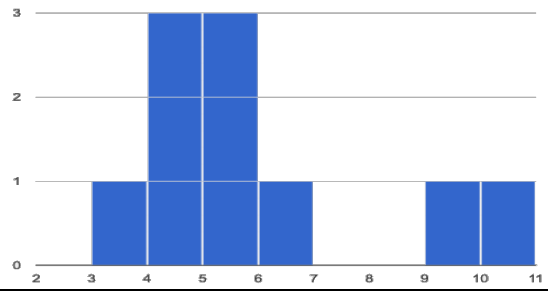


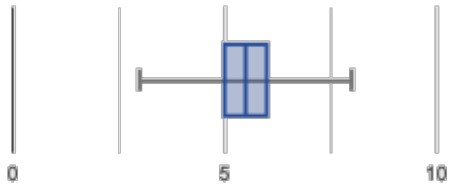
2 (E) **B**



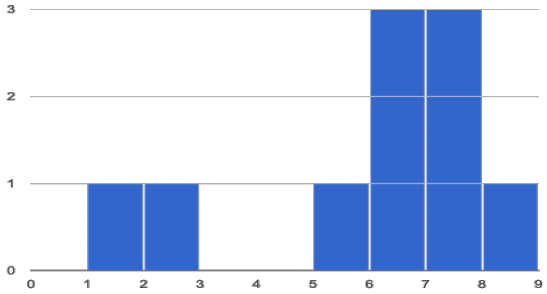


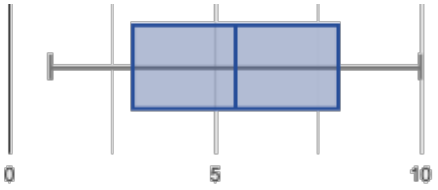
3 (C) **C**



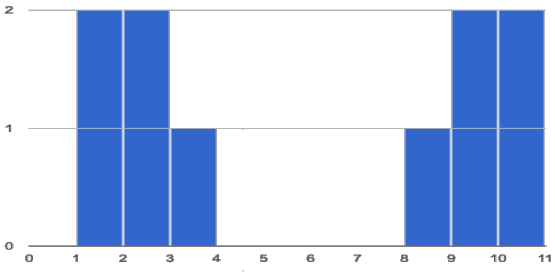


4 (A) **D**





5 (B) **E**



Shape of My Dataset

1) The column I choose to measure is _____

Measures of Center

The three measures for this column are:

Mean (Average)	Median	Mode(s)

2) Since the mean is _____ than the median, this suggests that there may
[higher/lower]

be outliers or skewness due to values that are unusually _____.
[high / low]

Measures of Spread

My five-number summary is:

Minimum	Q1	Q2 (Median)	Q3	Maximum

Use the tick marks below to create a scale, and draw a horizontal box-plot above it.

From this summary and box-plot, I conclude:

What's on your mind?

Unit 6

Advanced Analysis

Method chaining allows us to apply multiple method with less code:

For example, we can use method-chaining to write this:

```
table.build-column("labels", nametag).filter(is-dog).order-by("age", true")
```

Instead of using multiple definitions, like this:

```
with-labels = table.build-column("labels", nametag)
dogs = with-labels.filter(is-dog)
dogs.order-by("age", true)
```

Order Matters! The methods are applied in the order they appear. For example, trying to order a table by a column that hasn't been built will result in an error.

Data Scientists have to know whether or not they can trust their tools. Fortunately, then can *use* Data Science to **verify** that their tools do what they're supposed to!

Chaining Methods

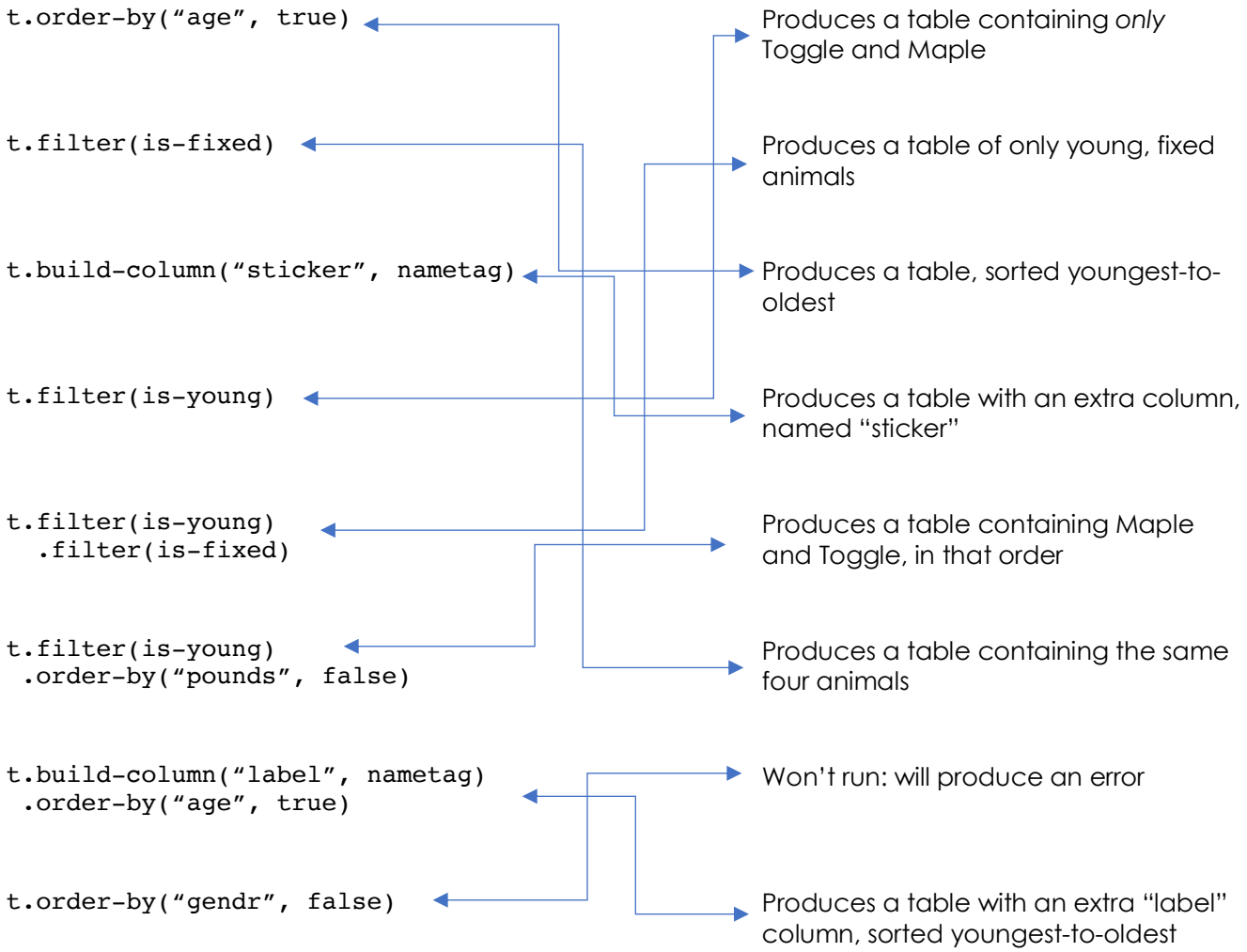
You have the following functions defined below (read them *carefully*!):

```
fun is-fixed(animal): animal["fixed"]                    end
fun is-young(animal): animal["age"] < 4                  end
fun nametag(animal):  text(animal["name"], 20, "red") end
```

The table **t** below represents four animals at the shelter:

name	gender	age	fixed	pounds
"Toggle"	"female"	3	true	48
"Fritz"	"male"	4	true	92
"Nori"	"female"	6	true	35.3
"Maple"	"female"	3	true	51.6

Match each Pyret expression (left) to the description of what it does (right).



Chaining Methods 2: Order Matters!

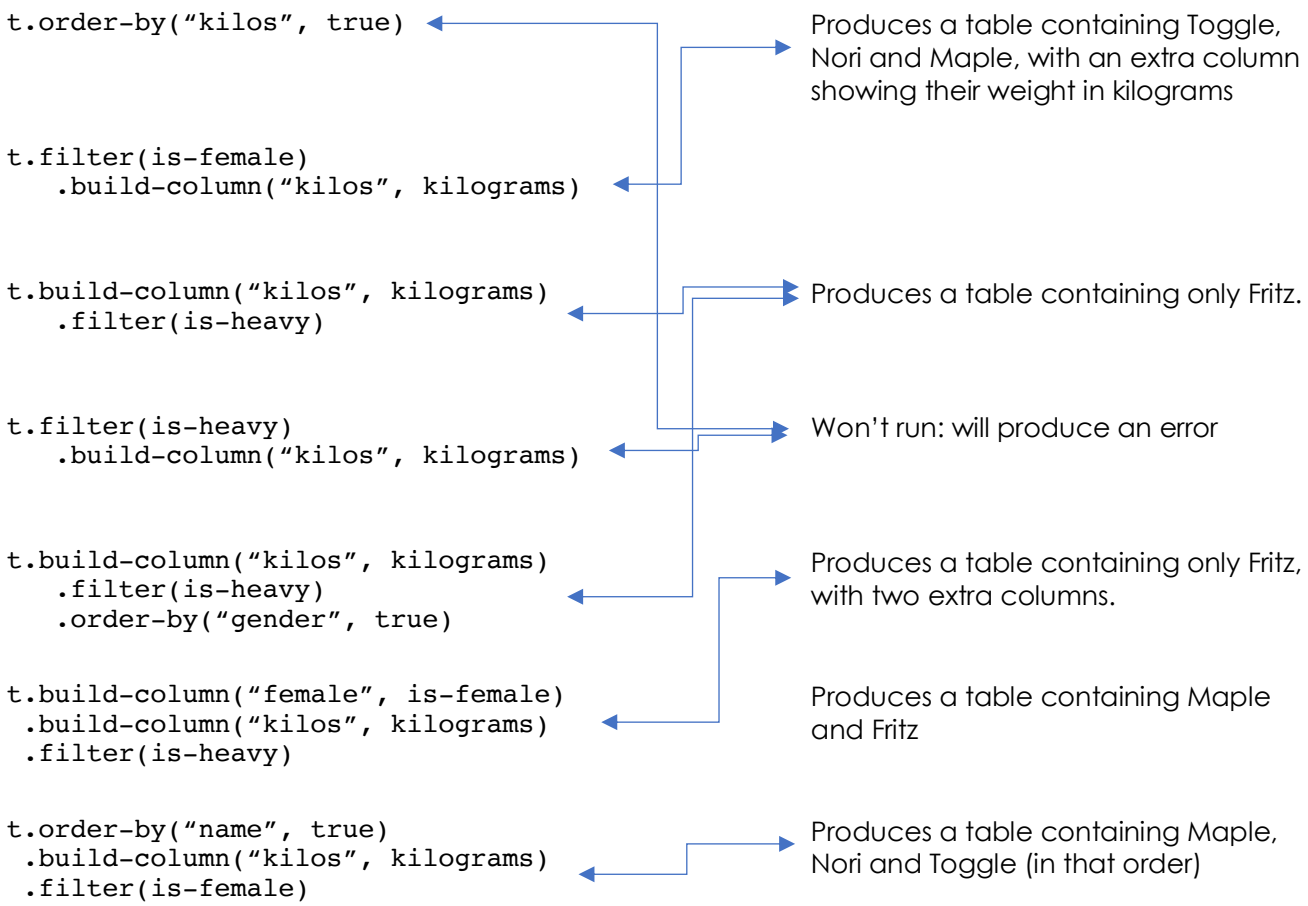
You have the following functions defined below (read them *carefully*!):

```
fun is-female(animal): animal[“gender”] == “female”    end
fun kilograms(animal): animal[“pounds”] / 2.2          end
fun is-heavy(animal):  animal["kilograms"] > 25        end
```

The table **t** below represents four animals at the shelter:

name	gender	age	fixed	pounds
“Toggle”	“female”	3	true	48
“Fritz”	“male”	4	true	92
“Nori”	“female”	6	true	35.3
“Maple”	“female”	3	true	51.6

Match each Pyret expression (left) to the description of what it does (right). **Note: one description might match multiple expressions!**



"Trust, but verify…"

A "helpful" Data Scientist gives you access to the following functions:

```
# fixed-cats :: (animals :: Table) → Table
# consumes a table of animals, and produces a table containing only
# cats that have been fixed, sorted from youngest-to-oldest
```

You can *use* the function, *but you can't see the code for it!* **How do you know if you can trust their code?**

HINT:

- You could make a verification subset that contains one of every species, and make sure that the function filters out everything but cats
- You could make sure this subset that has multiple cats *not* in order of youngest-to-oldest, and make sure the function puts them in the right order

1. What *other* qualities would this subset need to have?

Animals that are cats, and animals that are NOT cats

Cats that are fixed, and cats that are NOT fixed

2. Create your verification subset! In the space below, list the name of each animal in your subset. *(Remember: the first data row is always index zero!)*

Name

"Trust, but verify…"

A "helpful" Data Scientist gives you access to the following functions:

```
# old-dogs-nametags:: (animals :: Table) → Table
# consumes a table of animals, and produces a table containing only
# dogs 10 years or older, with an extra column showing their name in red
```

You can *use* the function, *but you can't see the code for it!* **How do you know if you can trust their code?**

1. What qualities would a verification subset need to have?

Animals that are dogs, and animals that are NOT dogs

Dogs that are 10 years or older, and dogs that are less than 10 years old

2. Create your verification subset! In the space below, list the name and index of each animal in your subset. *(Remember: the first data row is always index zero!)*

Name

What's on your mind?

Unit 7

Visualizing Relationships

- **Scatter Plots** can be used to show a relationship between two quantitative columns. Each row in the dataset is represented by a point, with one column providing the x-value and the other providing the y-value. The resulting "point cloud" makes it possible to look for a relationship between those two columns.

- If the points in a scatter plot appear to follow a straight line, it is possible that a linear relationship exists between those two columns. A number called a **correlation** can be used to summarize this relationship.

- The correlation is **positive** if the point cloud slopes up as it goes farther to the right. It is **negative** if it slopes down as it goes farther to the right. If the points are tightly clustered around a line, it is a **strong** correlation. If they are loosely scattered, it is a **weak** correlation.

- Points that are far above or below the cloud of points in a scatter plot are called **outliers**.

- We graphically summarize this relationship by drawing a straight line through the data cloud, so that the vertical distance between the line and each of the points is as small as possible. This line is called the **line of best fit** and allows us to predict y-values based on x-values.

(Dis)Proving a Claim

"Younger animals get adopted faster."

Do you agree? If so, why?

I hypothesize…

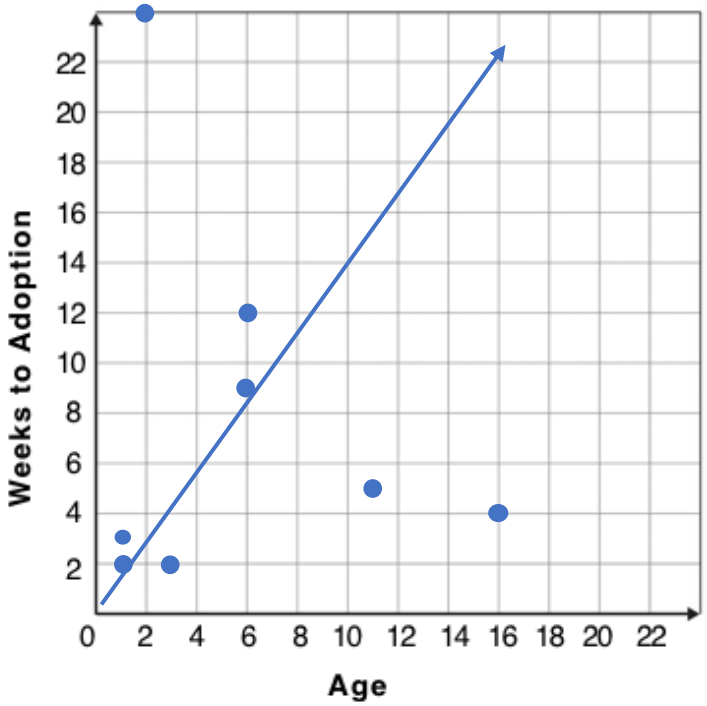
that younger animals *will* get adopted faster, possibly because they are considered cuter, but there may be other factors causing them to get adopted faster.

What would you look for in the dataset to see if you are right?

I would look at both the ages and number of weeks until adoption for each animal to see if there was a correlation. I would also want to collect more data, such as conduct a survey of adopters.

Creating a Scatter Plot

name	species	age	weeks
"Sasha"	"cat"	1	3
"Boo-boo"	"dog"	11	5
"Felix"	"cat"	16	4
"Buddy"	"lizard"	2	24
"Nori"	"dog"	6	9
"Wade"	"cat"	1	2
"Nibblet"	"rabbit"	6	12
"Maple"	"dog"	3	2



1. **For each row in the Sample Table on the left, add a point to the scatter plot on the right**. The first 3 rows have been completed for you. Use the values from the `age` column for the x-axis, and values from the `weeks` column for the y-axis.

2. Do you see a pattern? Do the points seem to shift up or down as age increases? **Draw a line on the scatter plot to show this pattern**.

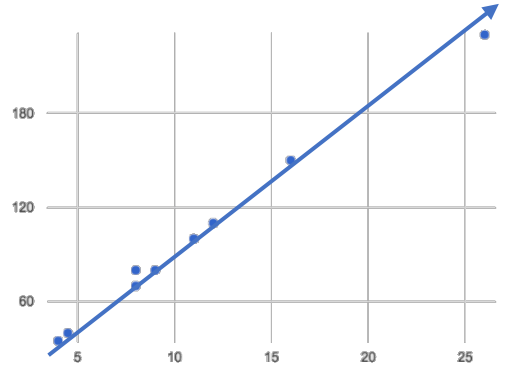
3. Does the line slope upwards or downwards? Slightly upwards

4. Are the points clustered around the line? Loosely scattered? Scattered

Drawing Predictors

For each of the scatter plots below, draw a **predictor line** that fits best.

A

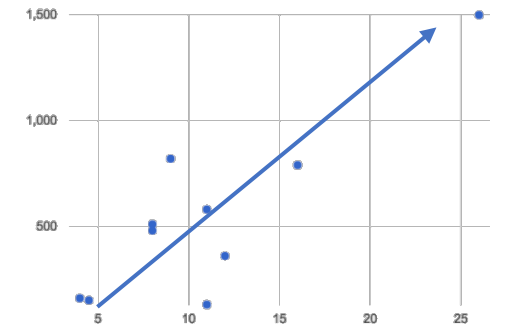


fat (g) v. calories-from-fat in common menu items

Direction: (Positive) Negative None

Strength: (Strong) Weak

B

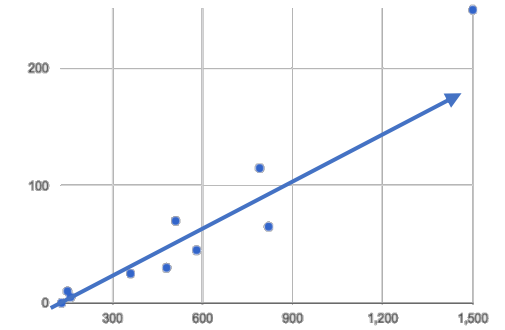


fat (g) v. sodium (g) in common menu items

Direction: (Positive) Negative None

Strength: (Strong) Weak

C

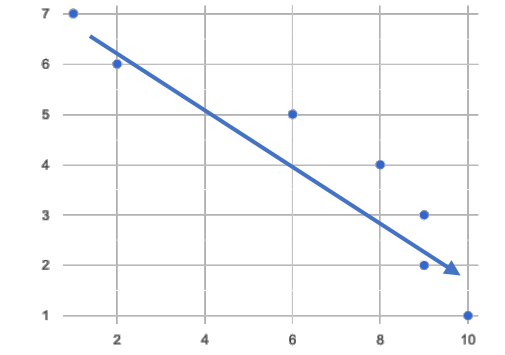


sodium (g) v. cholesterol (mg) in common menu items

Direction: (Positive) Negative None

Strength: (Strong) Weak

D



fat (g) v. sugar (g) in common menu items

Direction: Positive (Negative) None

Strength: Strong (Weak)

Correlations in My Dataset

1) There *may* be a correlation between _____ and
column

_____. I think it is a _____, _____
column strong / weak positive / negative

correlation, because _____

_____. It might be stronger if I looked

at _____.
a subset or extension of my data

---

2) There *may* be a correlation between _____ and
column

_____. I think it is a _____, _____
column strong / weak positive / negative

correlation, because _____

_____. It might be stronger if I looked

at _____.
a subset or extension of my data

---

3) There *may* be a correlation between _____ and
column

_____. I think it is a _____, _____
column strong / weak positive / negative

correlation, because _____

_____. It might be stronger if I looked

at _____.
a subset or extension of my data

What's on your mind?

Unit 8

Computing Relationships

- **Linear Regression** is a way of computing the **line of best fit**, which minimizes the sum of squared vertical distances of all scatter plot points from the line. Calculating the slope and intercept of this line is a task best left to computing or statistical software.
    - **Slope** provides us with the easiest summary to grasp: it's how much we predict the y-variable (*response variable*) to increase or decrease, for each unit that the x-variable (e*xplanatory variable*) increases
    - **r** is the name of the correlation statistic, which is also computed by linear regression. The r-value will always fall between -1 and +1. The sign tells us whether the correlation is positive or negative, and distance from 0 tells us the strength of the correlation (-1 or +1 is really strong, 0 means no correlation)

- **Correlation is not causation**! Correlation only suggests that two column variables are *related*, but does not tell us if one *causes* the other. For example, hot days are *correlated* with people running their air conditioners, air conditioners do not *cause* hot days!

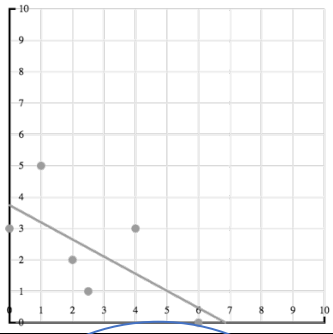
- **Sample size matters!** The number of data values is also relevant. We'd be more convinced of a positive relationship in general between cat age and time to adoption if a correlation of +0.57 were based on 50 cats instead of 5.

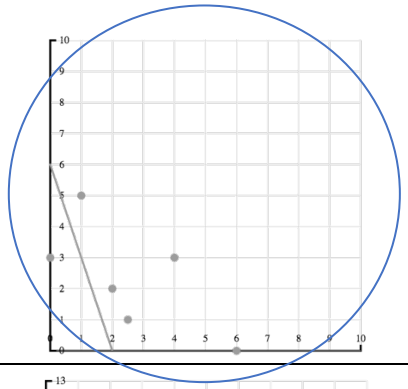
Grading Predictors

Below are the scatter plots for data sets A-D, with two different predictor lines drawn on top. For plots A-D:

1. Circle the plot with the line that fits better
2. Give the plot you circled a grade between 0 (no correlation) and 1 (perfect correlation)

A

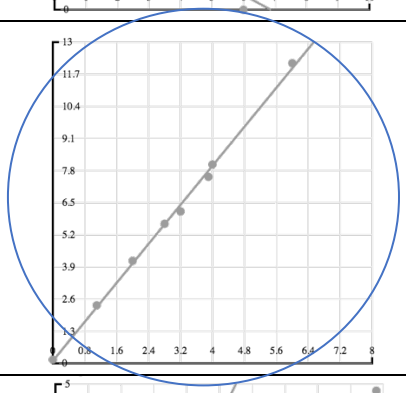


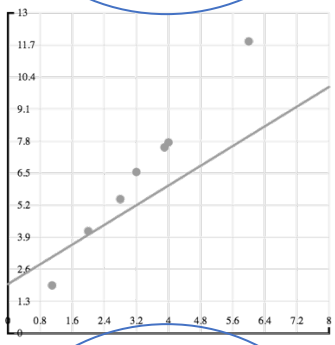


r =

-1 (-0.5) +0.5 +1

B

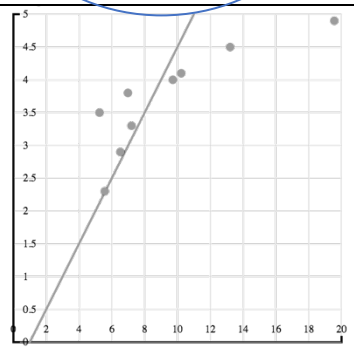


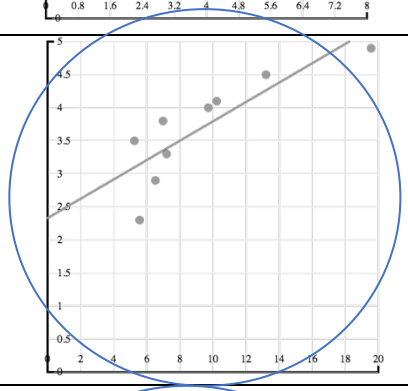


r =

-1 -0.5 +0.5 (+1)

C

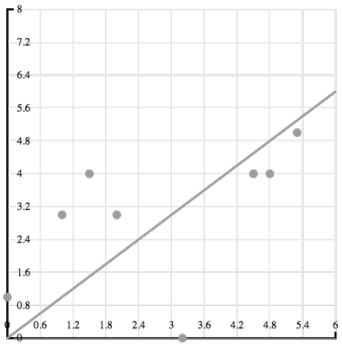


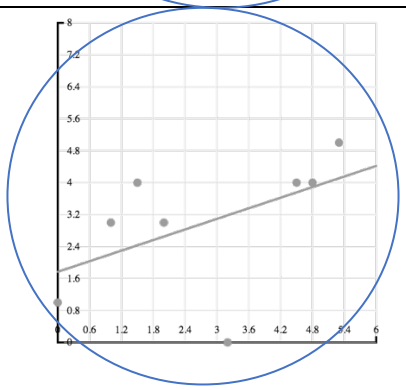


r =

-1 -0.5 (+0.5) +1

D





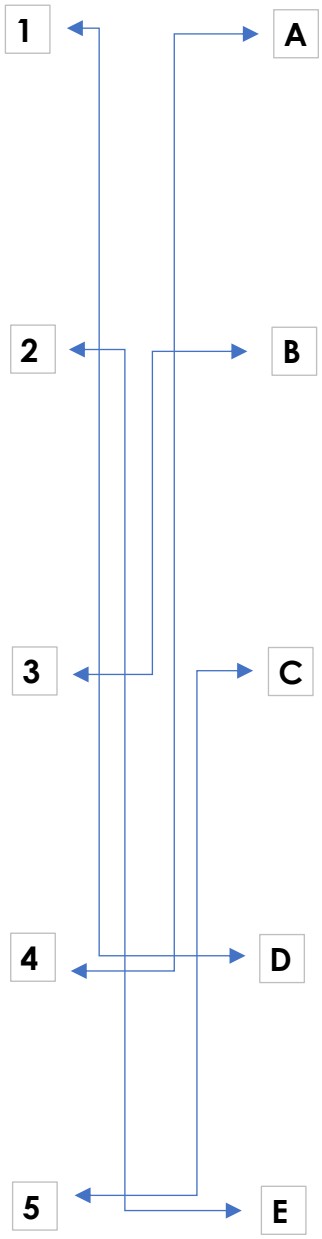
r =

-1 (-0.5) +0.5 +1

Reading Regression Lines & *r*-Values

Match the summary description (left) with the line of best fit and r-value (right).

The correlation between weeks-of-school-missed and SAT score is moderate and negative. For every week a student misses, we predict a more than a 5-point drop in their SAT score.	1	A
There is a weak, positive correlation between the number of streaming video services someone has, and how much they weigh. For each service, we expect them to be roughly 1.6 pounds heavier.	2	B
Foot size and height are strongly, positively correlated. If person A is one size bigger than person B, we predict that they will be roughly two and a half inches taller than person B as well.	3	C
For every additional Marvel Universe movie released each year, the average person is predicted to consume more than three pounds less sugar! However, this correlation is extremely weak.	4	D
There is virtually no relationship found between the number of Uber drivers in a city and the number of babies born each year.	5	E



A: $y = -3.19x + 12$, $r = -0.05$

B: $y = 2.5x - 2.8$, $r = 0.89$

C: $y = 0.012x + 7.8$, $r = 0.01$

D: $y = -5.35x - 16$, $r = -0.65$

E: $y = 1.6x + 160$, $r = 0.12$

Regression Analysis in the `animals` Dataset

I performed a linear regression on cats at the shelter (dataset or subset), and found a moderate (r=0.566), positive (a weak/strong/moderate (R=__), positive/negative) correlation between age of the cats (in weeks) [x-axis] and number of weeks to adoption [y-axis]. I would predict that a 1 year [x-axis units] increase in age [x-axis] is associated with a 0.23 week [slope, y-units] increase [increase/decrease] in adoption time [y-axis].

I performed a linear regression on _____ (dataset or subset), and found _____ (a weak/strong/moderate (R=__), positive/negative) correlation between _____ [x-axis] and _____ [y-axis]. I would predict that a 1 _____ [x-axis units] increase in _____ [x-axis] is associated with a _____ [slope, y-units] _____ [increase/decrease] in _____ [y-axis].

I performed a linear regression on _____ (dataset or subset), and found _____ (a weak/strong/moderate (R=__), positive/negative) correlation between _____ [x-axis] and _____ [y-axis]. I would predict that a 1 _____ [x-axis units] increase in _____ [x-axis] is associated with a _____ [slope, y-units] _____ [increase/decrease] in _____ [y-axis].

Regression Analysis in My Dataset

I performed a linear regression on _____, and
dataset or subset

found _____ correlation between
a weak/strong/moderate (R=__), positive/negative

_____ and _____. I would predict that
[x-axis] [y-axis]

a 1 _____ increase in _____ is associated with a _____
[x-axis units] [x-axis] [slope, y-units]

_____ in _____.
[increase/decrease] [y-axis]

I performed a linear regression on _____, and
dataset or subset

found _____ correlation between
a weak/strong/moderate (R=__), positive/negative

_____ and _____. I would predict that
[x-axis] [y-axis]

a 1 _____ increase in _____ is associated with a _____
[x-axis units] [x-axis] [slope, y-units]

_____ in _____.
[increase/decrease] [y-axis]

I performed a linear regression on _____, and
dataset or subset

found _____ correlation between
a weak/strong/moderate (R=__), positive/negative

_____ and _____. I would predict that
[x-axis] [y-axis]

a 1 _____ increase in _____ is associated with a _____
[x-axis units] [x-axis] [slope, y-units]

_____ in _____.
[increase/decrease] [y-axis]

What's on your mind?

Unit 9

Threats to Validity

Threats to Validity can undermine a conclusion, even if the analysis was done correctly. Some examples of threats are:

- **Selection bias** – identifying the favorite food of the rabbits won't tell us anything reliable about what all the animals eat.

- **Sample size** – averaging the age of only three animals won't tell us anything reliable about the age of animals at the shelter!

- **Sample error** – surveying dogs when they are puppies won't tell us anything reliable about overall dog behavior, since their behavior changes as they age.

- **Confounding variables** – shelter workers might steer people towards newer animals, because they've become attached to the animals that have been there for a while, making it *appear* that "staying at the shelter longer" means "less likely to be adopted".

Threats to Validity

Some volunteers from the animal shelter surveyed a group of pet owners at a local dog park. They found that almost all of the owners were there with their dogs, and from this survey they concluded that dogs are the most popular pet in the region.

What are some possible threats to the validity of this conclusion?

Not many people are likely to walk their cats at the park, so if the volunteers only surveyed pet owners at the park, dogs are likely to be more highly represented in their sampling.

The animal shelter noticed a large increase in pet adoptions between Christmas and Valentine's Day. They conclude that at this current rate, there will be a huge demand for pets this Spring.

What are some possible threats to the validity of this conclusion?

Lots of people may be adopting animals during the holiday season, so these past patterns are unlikely to predict future patterns in adoption rates.

Threats to Validity

The animal shelter wanted to find out what kind of food to buy for their animals. They took a random sample of two animals and the food they eat, and found that spider and rabbit food was by far the most popular cuisine!

What are some possible threats to the validity of this conclusion?

A random sample may not be representative of the whole group of pets. In this case, there are many more dogs and cats than spiders and rabbits at the shelter, so using this random sample to draw conclusions about the whole group is wrong!

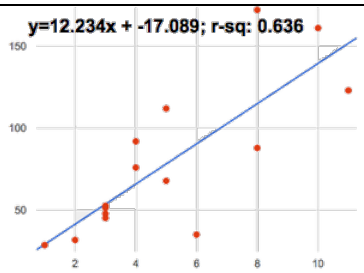
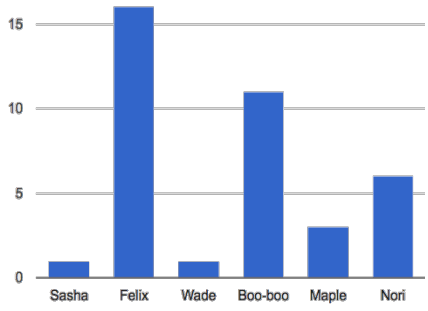
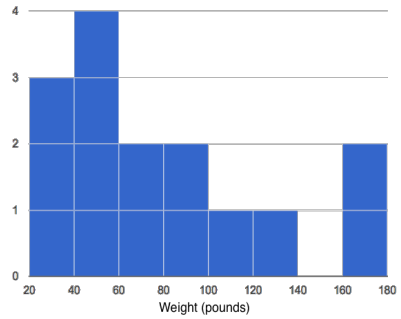
A volunteer opens the shelter in the morning and walks all the dogs. At mid-day, another volunteer feeds all the dogs and walks them again. In the evening, a third volunteer walks the dogs a final time, and closes the shelter. The volunteers report that the dogs are much friendlier and more active at mid-day, so the shelter staff assume the second volunteer must be better with animals then the others.

What are some possible threats to the validity of this conclusion?

There may be other reasons the dogs are happier at mid-day than morning and evening- for instance, mid-day is when they eat lunch, which is likely to make the dogs very excited!

Fake News!

Every claim below is *wrong*! Your job is to figure out why, by looking at the data.

	Data	Claim	Why it's *wrong*
1	The average player on a basketball team is 6'1".	*"Most of the players on the team are taller than 6'."*	The average is based on all the players, and there may be outliers pushing the average height up-average tells you nothing about the majority of the players.
2	After performing linear regression on census data, a positive correlation (r^2=0.18) was found between people's height and salary.	*"Taller people get paid more."*	Only 18% of the spread in salary is based on height, which is not a large enough r-squared value to say that taller people get paid more.
3		*"According to the predictor function indicated here, the value on the x-axis is will predict the value on the y-axis 63.6% of the time."*	The r-squared value of 0.636 does not mean how often the y-value will be predicted, rather what percent of spread in the y-value is based on the x-value.
4	 Bar Chart of Pet Ages	*"According to this bar chart, Felix makes up a little more than 15% of the total ages of all the animals in the dataset."*	Bar charts are not the most appropriate image for showing the percentage of each measurement based on the total- pie charts should be used for that info. This bar chart shows that Felix is a little more than 15 years old.
5		*"According to this histogram, most animals weigh between 40 and 60 pounds."*	More animals fit into the histogram bin between 40-60 pounds than any other bin, but that doesn't mean that most animals weigh between 40-60 pounds.
6	After performing linear regression, a negative correlation (r^2=0.91) was found between the number of hairs on a person's head and their likelihood of owning a wig.	*"Owning wigs causes people to go bald."*	Though there is a strong correlation between hair and owning a wig, correlation does NOT equal causation.

Lies, Darned Lies, and Statistics…

1. Using real data and displays from your dataset, come up with a misleading claim.
2. Trade papers with someone and figure out why their claims are wrong!

	Data	**Claim**	**Why it's *wrong***
1			
2			
3			
4			

Blank Recipes and References

Design Recipes

```
# ______________::_______________________ → ______________
      name                domain                 range
# ____________________________________________________________
examples:

    ____________(________) is ______________________________

    ____________(________) is ______________________________
end

fun ____________ (_______):  ______________________________

end
```

```
# ______________::_______________________ → ______________
      name                domain                 range
# ____________________________________________________________
examples:

    ____________(________) is ______________________________

    ____________(________) is ______________________________
end

fun ____________ (_______):  ______________________________

end
```

Design Recipes

```
# ______________::_______________________ → ______________
      name                 domain                 range
# ____________________________________________________________
examples:

    ____________(________) is ______________________________

    ____________(________) is ______________________________
end

fun ____________ (_______):  ______________________________

end
```

```
# ______________::_______________________ → ______________
      name                 domain                 range
# ____________________________________________________________
examples:

    ____________(________) is ______________________________

    ____________(________) is ______________________________
end

fun ____________ (_______):  ______________________________

end
```

Design Recipes

```
# ______________::_______________________ → ______________
      name                 domain                 range
# ____________________________________________________________
examples:

    ____________(________) is ______________________________

    ____________(________) is ______________________________
end

fun ____________ (_______):  ______________________________

end
```

```
# ______________::_______________________ → ______________
      name                 domain                 range
# ____________________________________________________________
examples:

    ____________(________) is ______________________________

    ____________(________) is ______________________________
end

fun ____________ (_______):  ______________________________

end
```

Contracts

Contracts tell us how to use a function. For example: `num-sqr :: (n :: Number) → Number` tells us that the name of the function is **`num-sqr`**, that it takes one input (a **`Number`**), and that it evaluates to a number. From the contract, we know **`num-sqr(4)`** will evaluate to a **`Number`**.

Name	Domain		Range
`triangle`	`:: (side-length :: Number, style :: String, color :: String)`	→	`Image`
`circle`	`:: (radius :: Number, style :: String, color :: String)`	→	`Image`
`star`	`:: (radius :: Number, style :: String, color :: String)`	→	`Image`
`rectangle`	`:: (width :: Num, height :: Num, style :: Str, color :: Str)`	→	`Image`
`ellipse`	`:: (width :: Num, height :: Num, style :: Str, color :: Str)`	→	`Image`
`square`	`:: (size-length :: Number, style :: String, color :: String)`	→	`Image`
`text`	`:: (str :: String, size :: Number, color :: String)`	→	`Image`
`overlay`	`:: (img1 :: Image, img2 :: Image)`	→	`Image`
`rotate`	`:: (degree :: Number, img :: Image)`	→	`Image`
`scale`	`:: (factor :: Number, img :: Image)`	→	`Image`
`string-repeat`	`:: (text :: String, repeat :: Number)`	→	`String`
`string-contains`	`:: (text :: String, search-for :: String)`	→	`Boolean`
`num-sqr`	`:: (n :: Number)`	→	`Number`
`num-sqrt`	`:: (n :: Number)`	→	`Number`
`num-min`	`:: (a :: Number, b:: Number)`	→	`Number`
`num-max`	`:: (a :: Number, b:: Number)`	→	`Number`

Contracts

Contracts tell us how to use methods. For example: `<Table>.filter :: (test :: (Row→Boolean)) → Table` tells us that the name of the function is **`.filter`** and that it is a **`Table`** method. The domain says it has one input (a function that consumes **`Rows`** and produces **`Booleans`**), and that the method evaluates to a Table.

Name	Domain		Range
count	:: (t :: *Table*, col :: *String*)	→	*Table*
random-rows	:: (t :: *Table*, num-rows :: *Number*)	→	*Table*
<Table>.row-n	:: (n :: *Number*)	→	*Row*
<Table>.order-by	:: (col :: *String*, *increasing* :: *Boolean*)	→	*Table*
<Table>.filter	:: (test :: *(Row → Boolean)*)	→	*Table*
<Table>.build-column	:: (col :: *String*, *builder* :: *(Row → Value)*)	→	*Table*
mean	:: (t :: *Table*, col :: *String*)	→	*Number*
median	:: (t :: *Table*, col :: *String*)	→	*Number*
modes	:: (t :: *Table*, col :: *String*)	→	*List<Number>*
bar-chart	:: (t :: *Table*, col :: *String*)	→	*Image*
pie-chart	:: (t :: *Table*, col :: *String*)	→	*Image*
bar-chart-raw	:: (t :: *Table*, labels :: *String*, values :: *String*)	→	*Image*
pie-chart-raw	:: (t :: *Table*, labels :: *String*, values :: *String*)	→	*Image*
box-plot	:: (t :: *Table*, col:: *String*)	→	*Image*
histogram	:: (t :: *Table*, values :: *String*, bin-width :: *Number*)	→	*Image*
scatter-plot	:: (t :: *Table*, labels :: *String*, xs :: *String*, ys :: *String*)	→	*Image*
lr-plot	:: (t :: *Table*, labels :: *String*, xs :: *String*, ys :: *String*)	→	*Image*