Name: _____

Student Workbook

Workbook v3.0

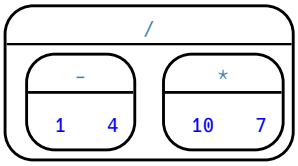
Brought to you by the Bootstrap team:

- Emmanuel Schanzer
- Kathi Fisler
- Shriram Krishnamurthi
- Dorai Sitaram
- Joe Politz
- Jennifer Poole
- Ed Campos
- Ben Lerner
- Flannery Denny

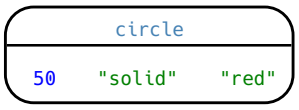
Visual Designer: Colleen Murphy

Starting to Program: Order of Operations & Contracts

- The **Editor** is a software program we use to write Code. Our Editor allows us to experiment with Code on the right-hand side, in the **Interactions Area**. For Code that we want to *keep*, we can put it on the left-hand side in the **Definitions Area**. Clicking the "Run" button causes the computer to read and load everything in the Definitions Area and erase anything that was typed into the Interactions Area.
- Our programming language has many types of **values**:
  - **Numbers** can be integers like `42`, decimals like `0.5`, or even fractions like `1/3`. Clicking on a fraction or a decimal will cause it to switch from one to the other.
  - **Strings** are anything in quotes, such as `"Programming is fun!".` A Number written in quotes is *still a String!*
- Our language also has **functions** you've seen before, such as addition (`+`), subtraction (`-`), multiplication (`*`) and division (`/`).
  - **Order of Operations** is incredibly important when programming. To help us organize our math into something we can trust, we can *diagram* a math expression using the **Circles of Evaluation**. For example, the expression $(1 - 4) \div (10 \times 7)$ can be diagrammed as shown below.



  - To convert a **Circle of Evaluation** into code, we walk through the circle from outside-in, moving left-to-right. We type an open parenthesis when we *start* a circle, and a close parenthesis when we *end* one. Once we're in a circle, we write whatever is on the left of the circle, then the **function** at the top, and then whatever is on the right. The circle above, for example, would be programmed as `(1 - 4) / (10 * 7)`.
- **Images** are pictures that are produced by functions. The `circle` function, for example, takes a Number as the radius, a String to determine if the circle should be `"solid"` or `"outline"`, and a String to specify the color. You can see the Circle of Evaluation and the Code below:




```
circle(50, "solid", "red")
```

- There are a *lot* of functions in this language! We can make many different shapes, manipulate Strings and Numbers, and a whole lot more. Keeping track of what every function takes in and what it gives back is impossible! To help us remember how to use each function, programmers write down something called a **Contract**. Contracts include the **Name** of the function, what it takes in (called the **Domain**) and what it gives back (called the **Range**). You have space at the very back of this packet to write all the Contracts for functions that you discover!

Notice and Wonder

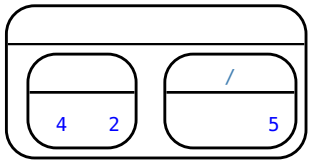
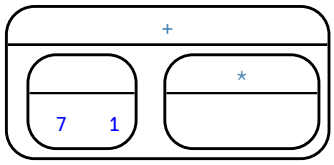
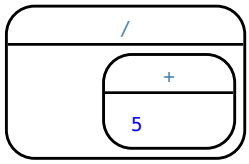
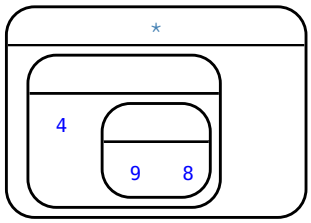
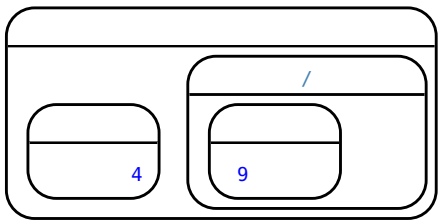
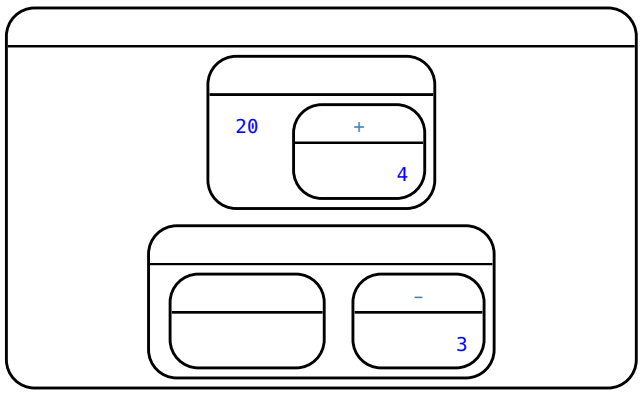
Try typing numbers into the Interactions Area, hitting "Enter", and see what you get back! Some ideas:

1. What is the largest number you can enter? The smallest?
2. Can you write decimals? Fractions?
3. After you get back a decimal, try clicking on it. What happens?
4. Can you write negative numbers? Negative fractions?
5. What else can you try?

What do you Notice?	What do you Wonder?

Completing Circles of Evaluation from Arithmetic Expressions (2)

For each expression on the left, finish the Circle of Evaluation on the right by filling in the blanks.

	Arithmetic Expression	Circle of Evaluation
1	$4 + 2 - \frac{10}{5}$	
2	$7 - 1 + 5 \times 8$	
3	$\frac{-15}{5 + -8}$	
4	$(4 + 9 - 8) \times 5$	
5	$6 \times 4 + \frac{9 - -6}{5}$	
Challenge	$\frac{20}{6 + 4} - \frac{5 \times 9}{-12 - 3}$	

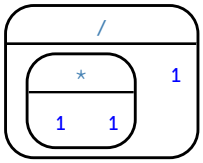
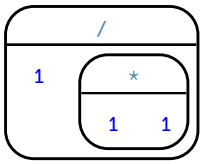
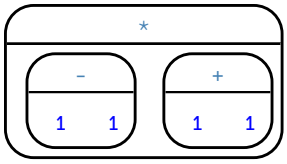
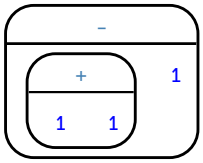
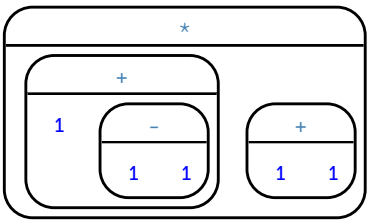
Creating Circles of Evaluation from Arithmetic Expressions (3)

For each math expression on the left, draw its Circle of Evaluation on the right.

	Math Expression	Circle of Evaluation
1	$4 - 6 - 17$	
2	$25 + 14 - 12$	
3	$1 + 15 \times 5$	
4	$\frac{15}{10 + 4 \times -2}$	

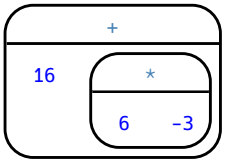
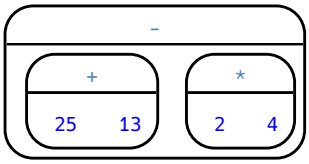
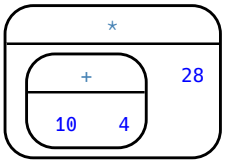
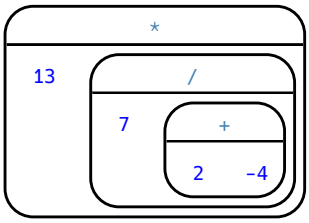
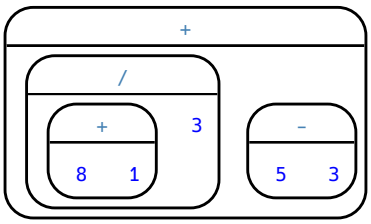
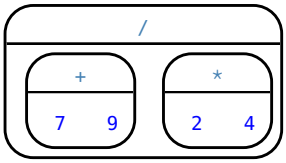
Matching Circles of Evaluation and Arithmetic Expressions

Draw a line from each Circle of Evaluation on the left to the corresponding arithmetic expression on the right.

Circle of Evaluation			Arithmetic Expression
	1	A	$\frac{1}{1 \times 1}$
	2	B	$1 + 1 - 1$
	3	C	$\frac{1 \times 1}{1}$
	4	D	$(1 + 1 - 1) \times (1 + 1)$
	5	E	$(1 - 1) \times (1 + 1)$

Completing Partial Code from Circles of Evaluation

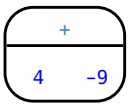
For each Circle of Evaluation on the left, finish the Code on the right by filling in the blanks.

	Circle of Evaluation	Code
1		_____ + (6 * _____)
2		(_____ + 13) _____ (_____ _____ 4)
3		(_____ + 4) _____ _____
4		13 _____ (7 _____ (2 _____ -4))
5		((8 _____ 1) _____ 3) _____ (5 _____ 3)
6		(_____ + _____) / (_____ * _____)

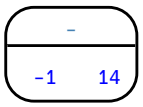
Translating Circles of Evaluation to Code

Translate the Circles of Evaluation into Code.

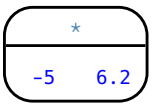
1)



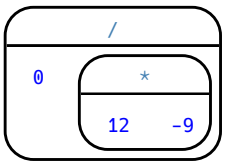
2)



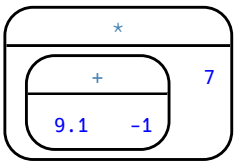
3)



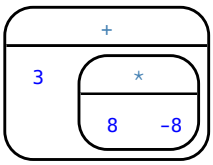
4)



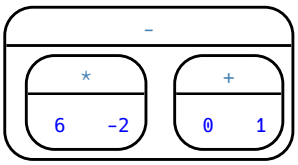
5)



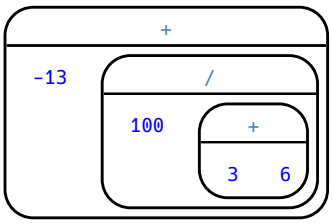
6)



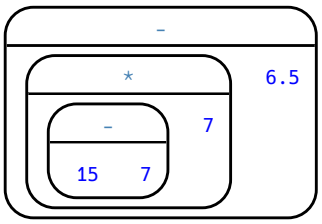
7)



8)

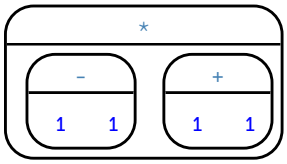
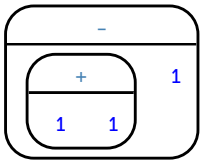
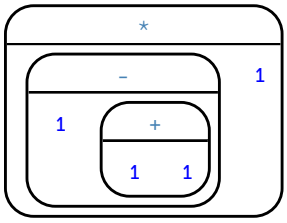
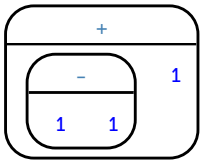
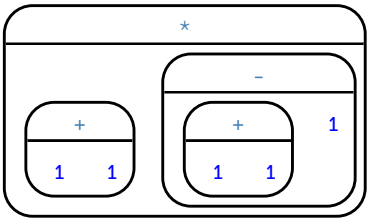


9)



Matching Circles of Evaluation & Code

Draw a line from each Circle of Evaluation on the left to the corresponding Code on the right.

Circle of Evaluation			Code
	1	A	`(1 - (1 + 1)) * 1`
	2	B	`(1 - 1) * (1 + 1)`
	3	C	`(1 + 1) * ((1 + 1) - 1)`
	4	D	`(1 + 1) - 1`
	5	E	`(1 - 1) + 1`

Arithmetic Expressions to Circles of Evaluation & Code

Translate each of the arithmetic expressions below into Circles of Evaluation, then translate them to Code.

	Arithmetic	Circle of Evaluation	Code
1	$3 \times 7 - (1 + 2)$		
2	$3 - 1 + 2$		
3	$3 - (1 + 5 \times 6)$		
4	$1 + 5 \times 6 - 3$		

Translating Circles of Evaluation to Code - w/Square Roots

Translate each of the arithmetic expressions below into Circles of Evaluation, then translate them to Code.

HINT: The function name is `num-sqrt` .

	Arithmetic	Circle of Evaluation	Code
1	$\sqrt{9}$		
2	$\sqrt{5+1}$		
3	$\sqrt{4}+1$		
4	$3\sqrt{3}+\sqrt{7}$		

Exploring Image Functions

By now you know how to make stars in this programming language. Can you figure out how to make triangles, based on what you know about making stars? Rectangles? What other shapes might we be able to make? When you've discovered code to make a new shape, draw the Circle of Evaluation in the table below, along with a sketch of the shape. Then add the function to your contracts page.

1) Use the space below to draw the Circles of Evaluation for the new functions, and draw a picture of what the function produces.

Circle of Evaluation		Image
star 50 "solid" "black"	produces →	
	produces →	
	produces →	
	produces →	

Mystery Functions!

2) There is a function called `regular-polygon` with 4 inputs. What do they mean?

3) There is a function called `radial-star` with 5 inputs. What do they mean?

4) There is a function called `text` . Try to figure out how to use it! What do the inputs mean?

Reading for Domain and Range

As you think about the functions below, remember that you can always type them into your interactions window in the Editor!

1) What is the **name** of the function being used in: `string-length("broccoli") + 8`	
2) What is the **domain** of the outermost function being used in: `scale(2, circle(40, "solid", "blue"))`	
3) What is the **domain** of the innermost function being used in: `scale(2, circle(40, "solid", "blue"))`	
4) How many **arguments** does the `+` operator take in: `string-length("broccoli") + 8`	
5) What is the **range** of the function `string-length` ?	
6) Is `text` a *String* , a *function* , or an *Image* ?	
7) Is the **range** of `text` a *String* or an *Image* ?	
8) What is the first **argument** to the `circle` function in: `scale(2, circle(40, "solid", "blue"))`	

Composing Image Functions

You'll be investigating these functions with your partner:

```
# text :: String, Number, String -> Image
# scale :: Number, Image -> Image
# rotate :: Number, Image -> Image
# flip-horizontal :: Image -> Image
# flip-vertical :: Image -> Image
```

1) Make an image of your name, in big purple letters. Draw the Circle of Evaluation and write the Code that will create this image.

2) Try using the `scale` function to make your name bigger or smaller. Draw the Circle of Evaluation (hint: use what you wrote above!), then write the Code.

3) In your own words, what does `scale` do?

---

4) Try out `rotate`, `flip-horizontal`, and `flip-vertical`. Use the space below to write your Code, then test out your Code in Pyret when you're ready.

Function Composition — Practice

1) Draw a Circle of Evaluation and write the Code for a **solid, green star, size 50** .

Circle of Evaluation:

Code: _____

Using the star described above as the **original** , draw the Circles of Evaluation and write the Code for each exercise below.

2) A solid, green star, that is triple the size of the original (using `scale`)

Circle of Evaluation:

Code: _____

3) A solid, green star, that is half the size of the original (using `scale`)

Circle of Evaluation:

Code: _____

4) A solid, green star of size 50 that has been rotated 45 degrees counter-clockwise

Circle of Evaluation:

Code: _____

5) A solid, green star that is 3 times the size of the original **and** has been rotated 45 degrees

Circle of Evaluation:

Code: _____

Defining Values and Functions

- We can define values in our program, giving them names that we can refer to later instead of re-typing the same thing over and over. This works the same way it does in math: $x = 5 + 1$
  defines the symbol x
  to be the number 6
  .
- In our language, we can define value by writing `var x = 5 + 1` . Here are a few value definitions:

```
x = 5 + 1
y = x * 7
food = "Pizza!"
dot = circle(y, "solid", "red")
```

- We can also define new **functions** in our language, to make it do things it didn't do before! To do this, we use a step-by-step process called the **Design Recipe**.
  - The first step is to write the **Contract** for the function you want to build. Remember, a Contract must include the Name, Domain and Range for the function!
  - Then we write a **Purpose Statement**, which is a short note that tells us what the function *should do*. Professional programmers work hard to write good purpose statements, so that other people can understand the code they wrote!
  - The second step is to write at least two **Examples**. These are lines of code that show what the function should do for a *specific* input. Once we see examples of at least two inputs, we can *find a pattern* and see which parts are changing and which parts aren't.
  - Circle the parts that are changing, and label them with a short **variable name** that explains what they do.
  - Finally, the third step is to define the function itself! This is pretty easy after you have some examples to work from: thing that didn't change, and replace the changeable stuff with the variable name!

Defining Values - Explore

```
shape1 = triangle(50, "solid", "red")
```

Type the line of Code above into the Definitions Area of a new program, and press “Run”.

1) What happens when you enter `shape1` into the Interactions Area?

---

2) Brainstorm some other values to define. Use the space below to draw any Circles of Evaluation you need and to organize your thoughts.

Ideas: `eye-color` (a String), `age` (a Number), `fav-shape` (an Image)

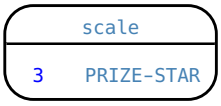
Defining Values - Practice

1) On the line below, **write the Code** to define `PRIZE-STAR` as a pink, outline star of size 65.

Using the `PRIZE-STAR` definition from above, draw the Circle of Evaluation and write the Code for each of the exercises. One Circle of Evaluation has been done for you.

2) The outline of a pink star that is 3 times the size of the original (using `scale`)

Circle of Evaluation:



Code: _____

3) The outline of a pink star that is half the size of the original (using `scale`)

Circle of Evaluation:

Code: _____

4) The outline of a pink star of size 65 that has been rotated 45 degrees

Circle of Evaluation:

Code: _____

5) The outline of a pink star that is 3 times the size of the original **and** has been rotated 45 degrees

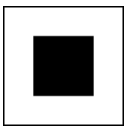
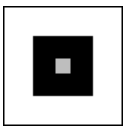
Circle of Evaluation:

Code: _____

6) How does defining values help you as a programmer?

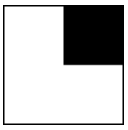
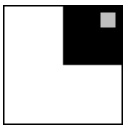
Combining Images

For each of the images below, write the code that would reproduce that image using `overlay`. The first one has been done for you. (The outermost square is of size 80)

`overlay(`
`  square(40, "solid", "black"`
`),`
`  square(80, "outline",`
`"black"))`	

For each of the images below, write the code that would reproduce that image using `put-image`. The first one has been done for you. (The outermost square is of size 80)

`put-image(`
`  square(40, "solid", "black"`
`),`
`  60, 60,`
`  square(80, "outline",`
`"black"))`	

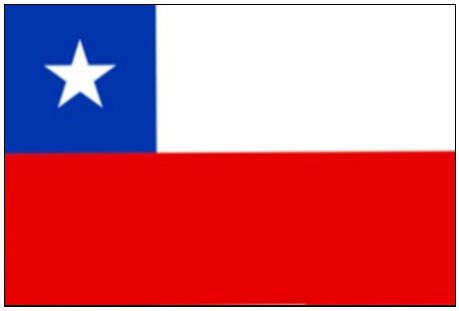
Decomposing Flags

Each of the flags below is shown with their width and height. Identify the shapes that make up each flag. Use the flag's dimensions to estimate the dimensions of the different shapes. Then estimate the x and y coordinates for the point at which the center of each shape should be located on the flag. *Hint: The bottom left corner of each flag is at (0,0) and the top right corner is given by the flags dimensions.*

Cameroon (450 x 300)

shape:	color:	width:	height:	x	y

Chile (420 x 280)

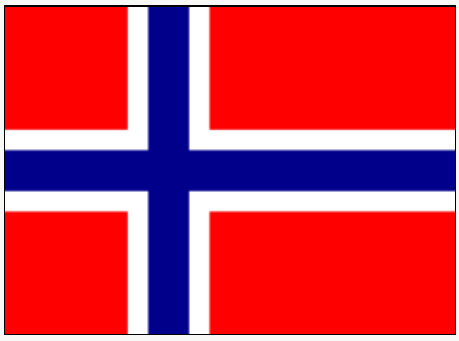


shape:	color:	width:	height:	x	y

Panama (300 x 200)

shape:	color:	width:	height:	x	y

Norway (330 x 240)

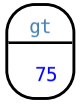
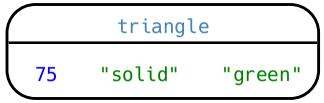


shape:	color:	width:	height:	x	y

Mapping Examples with Circles of Evaluation

Contract: _____

Purpose Statement: _____

If I type...	→	It should map to...
EXAMPLE #1: Circle of Evaluation  Code: `gt(75)`	→	Circle of Evaluation:  Code: `triangle(75, "solid", "green")`
EXAMPLE #2: Circle of Evaluation Code:	→	Circle of Evaluation: Code:

Fast Functions

There is space below to define four different functions, writing their Contracts, two examples, and the definition itself. The function `gt` - which makes solid green triangles of a given size - is provided as an example. Can you define `bc` as a function which makes solid blue circles of a given *radius*?

```
# gt:: Number -> Image
examples:
  gt ( 10 ) is triangle(10, "solid", "green")
  gt ( 20 ) is triangle(20, "solid", "green")
end
fun gt( size ):
  triangle(size, "solid", "green")
end
```

```
# ::  ->
examples:
  (  ) is
  (  ) is
end
fun (  ):

  
end
```

```
# ::  ->
examples:
  (  ) is
  (  ) is
end
fun (  ):

  
end
```

```
# ::  ->
examples:
  (  ) is
  (  ) is
end
fun (  ):

  
end
```

Word Problem: rocket-height

Directions : A rocket blasts off, traveling at 7 meters per second. Use the Design Recipe to write a function `rocket-height` , which takes in a number of seconds and calculates the height.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Writing Quality Purpose Statements

3 Reads

1st Read: What is this problem about?	2nd Read: What are the Quantities?
3rd Read: What is a good Purpose Statement?	

Stronger & Clearer

Purpose Statement 1st Revision:
Purpose Statement 2nd Revision:

Mapping Examples with Circles of Evaluation

Contract: _____

Purpose Statement: _____

If I type…	→	It should map to…
EXAMPLE #1: Circle of Evaluation Code:	→	Circle of Evaluation: Code:
EXAMPLE #2: Circle of Evaluation Code:	→	Circle of Evaluation: Code:

The Design Recipe

Directions: Write a function `marquee` that takes in a message and returns that message in large gold letters.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions: Write a function `circle-area` that takes in a radius and uses the fraction approximation of pi ($\frac{22}{7}$) to return the area of the circle.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

The Design Recipe

Directions: Write a function `minimum-wage`, that takes in a number of hours worked and returns the amount a worker will get paid at $10.25/hr.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions: Write a function `tip-calculator` that takes in the cost of a meal and returns the 15% tip for that meal.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

The Design Recipe

Directions : Getting a gym membership costs $150, and then there's a $45/month fee after that. Write a function `globo-gym` that takes in a number of months and produces the cost of a membership for that many months.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions : The cost of a ride is a starting price of $2.50, plus $1.50/mile. Write a function `rideshare` , that takes in a number of miles and produces the cost of that right.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

The Design Recipe

Directions: Write a function `moving` that takes in the days and number of miles driven and returns the cost of renting a truck. The truck is $55 per day and each driven mile is 15¢.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
```

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

```
end
```

Definition

Write the definition, giving variable names to all your input values…

```
fun
```
_____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

```
end
```

Directions: Write a function `lawn-area` that takes in the length and width of a rectangular lawn and returns its area.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
```

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

```
end
```

Definition

Write the definition, giving variable names to all your input values…

```
fun
```
_____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

```
end
```

The Design Recipe

Directions : Write a function `rect-perimeter` that takes in the length and width of a rectangle and returns the perimeter of that rectangle.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions : Write a function `rectprism-vol` that takes in the length, width, and height of a rectangular prism and returns the Volume of a rectangular prism.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

The Design Recipe

Directions: Write a function `split-tab` that takes in a cost and the number of people sharing the bill and splits the cost equally.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions: Write a function `num-cube` that takes in a number and returns the cube of that number.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Problem Decomposition

- Sometimes a problem is too complicated to solve all at once. Maybe there are too many variables, or there is just so much information that we can't get a handle on it!
- We can use **Problem Decomposition** to break those problems down into simpler pieces, and then work with the pieces to solve the whole. There are two strategies we can use for decomposition:
  - **Top-Down** - Start with the "big picture", writing functions or equations that describe the connections between parts of the problem. Then, work on defining those parts.
  - **Bottom-Up** - Start with the smaller parts, writing functions or equations that describe the parts we understand. Then, connect those parts together to solve the whole problem.
- You may find that one strategy works better for some types of problems than another, so make sure you're comfortable using either one!

Word Problem: revenue

Directions : Use the Design Recipe to write a function `revenue` , which takes in the number of glasses sold at $1.75 apiece and calculates the total revenue.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Word Problem: cost

Directions: Use the Design Recipe to write a function `cost`, which takes in the number of glasses sold and calculates the total cost of materials if each glass costs $.30 to make.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Word Problem: profit

Directions : Use the Design Recipe to write a function `profit` that calculates total profit from glasses sold, which is computed by subtracting the total cost from the total revenue.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____

function name *domain* *range*

_____

what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____

function name *input(s)* *what the function produces*

_____ (_____) **is** _____

function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):

function name *variable(s)*

_____

what the function does with those variable(s)

end

Permutation and Combination

- What are the odds of guessing someone's 8-digit password? - How many bouquets can we make choosing 4 different flowers from a collection of 10? - If 10 runners enter a road race, how many different ways can they be ranked? - If you pick two cards from a deck and they're both queens, what are the odds that the next card will be a queen?

Each of these questions deals with ***permutation*** or ***combination***. Both concepts play a big role in probability and statistics. If you know how many possible outcomes there *could* be, you can predict what your chances are. This is useful for competitive gaming, conducting surveys, and cybersecurity!

Permutation involves computing the number of different ways the same set of things can be re-arranged. If you have a dozen different doughnuts to choose from, how many different ways are there of *arranging* six of them?

Combination involves computing the number of different *subsets* you can make from the same set of things. If you have a dozen doughnuts to choose from, how many different half-dozen choices could you make?

Permutation

For each of the problems below, (1) figure out whether this involves permutation with or without replacement, then (2) compute the solution.

	Word problem	Replacement?	Solution
1	Mrs. Burke's cell phone has a 6-character password. Her son is trying to unlock it to play a game. How many possible passwords does he have to guess?	Yes No	
2	The dentist has 8 different stickers to give away to the next patients A through H. How many different ways could she give them out?	Yes No	
3	Eric Allatta is the head chef at the top restaurant in Santa Fe. His speciality is four-color enchilada platter, with each enchilada covered in a different sauce. How many ways can he order them on the plate?	Yes No	
4	A magician opens a fresh deck of 52 cards, and asks an audience member to pick six of them. He says he'll guess all six - in order. What are the chances he'll guess them correctly?	Yes No	
5	Emma is knitting a hat, and each row of stitching can be a different color. She has three different colors of yarn to choose from, and the hat has 30 rows. How many different designs could she make?	Yes No	

Combinations

For each of the problems below, (1) figure out whether this involves combination with or without replacement, then (2) compute the solution.

	Word problem	Replacement?	Solution
1	A soccer team has 20 players, but only 11 are allowed on the field at once. How many different groups of players can be on the field at one time?	Yes No	
2	A set of pool balls is numbered 1-15. How many different ways are there to choose six balls?	Yes No	
3	Six friends get together to play video games. All the games can only have two players, so they decided to pair off to make sure everyone gets to play everyone else. How many games will they have to play?	Yes No	
4	A set of pool balls is numbered 1-15. Seven of them are striped and eight are solid colors. How many different ways are there to choose 4 balls where 2 are striped and 2 are solid?	Yes No	
5	A pizzaria has a 3-topping special on any pizza, for only $12.99. If they have 10 toppings to choose from, how many different pizzas can they make?	Yes No	

Combination or Permutation?

Look at the word problems below. **Without solving them** , circle whether they are asking for a permutation or a combination?

1	How many ways can the letters in "Kathi" be re-arranged?	Permutation Combination
2	Shriram's favorite football team is lining up to run onto the field. How many different ways can they be ordered?	Permutation Combination
3	Flannery is planning to perform 8 songs at a Cajun music festival, and there are 30 different songs she could play. How many different set lists could she put together?	Permutation Combination
4	How many possible 3-color blends can be made from the seven colors of the rainbow?	Permutation Combination
5	How many 8-letter passwords are there, if no character can be used twice?	Permutation Combination
6	How many different ways are there to set a combination lock?	Permutation Combination
7	If Servane is holding a dozen different cupcakes and wants to give two to her friend, what are the chances that she chooses red velvet and chocolate froster?	Permutation Combination
8	Joy is arranging flowers for a bouqet. The store has 18 different kinds of flowers for her to choose from. If the bouquets each need 10 flowers, how many different bouqets could she make?	Permutation Combination
10	Matthias is making a candy coated in different colors, so that biting into it will "expose the rainbow" (the catchphrase he's chosen). His machine can make any of 8 different colors, but each candy can only be coated four times. How many unique color combinations can you find in these candies?	Permutation Combination

Introduction 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 *an amount*, such as a person's height, a score on a test, distance, etc. A list of quantitative data can be ordered from smallest to largest.
- **Categorical data** is data that specifies *qualities*, such as sex, 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.

Answering questions with 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 of 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 average weight of animals from the shelter?")
- **Relate Questions** require looking for trends across multiple columns. (e.g., "Do cats tend to be adopted sooner than dogs?")

The Animals Dataset

name	species	sex	age	fixed	legs	pounds	weeks
Sasha	cat	female	1	false	4	6.5	3
Snuffles	rabbit	female	3	true	4	3.5	8
Mittens	cat	female	2	true	4	7.4	1
Sunflower	cat	female	5	true	4	8.1	6
Felix	cat	male	16	true	4	9.2	5
Sheba	cat	female	7	true	4	8.4	6
Billie	snail	hermaphrodite	0.5	false	0	0.1	3
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
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
Bo	dog	male	8	true	4	76.1	10
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
Maple	dog	female	3	true	4	51.6	4

Categorical or Quantitative?

For each piece of data below, circle whether it is **Categorical** or **Quantitative** data.

1	Hair color	categorical	quantitative
2	Age	categorical	quantitative
3	ZIP Code	categorical	quantitative
4	Year	categorical	quantitative
5	Height	categorical	quantitative
6	Sex	categorical	quantitative
7	Street Name	categorical	quantitative

For each question, circle whether it will be answered by **Categorical** or **Quantitative** data.

8	We'd like to find out the average price of cars in a lot.	categorical	quantitative
9	We'd like to find out the most popular color for cars.	categorical	quantitative
10	We'd like to find out which puppy is the youngest.	categorical	quantitative
11	We'd like to find out which cats have been fixed.	categorical	quantitative
12	We want to know which people have a ZIP code of 02907.	categorical	quantitative
13	We'd like to sort a list of phone numbers by area code.	categorical	quantitative

Questions and Column Descriptions

What questions can you ask about the animals dataset? Come up with at least one **Lookup**, **Compute**, **Relate** or **Can't Answer** question, and write them as wonders below. (Note: These question types are defined on Page 1.)

What do you NOTICE about this dataset?	What do you WONDER about this dataset?	*Question Type*
		Lookup *Compute* *Relate* *Can't answer*
		Lookup *Compute* *Relate* *Can't answer*
		Lookup *Compute* *Relate* *Can't answer*
		Lookup *Compute* *Relate* *Can't answer*
		Lookup *Compute* *Relate* *Can't answer*
		Lookup *Compute* *Relate* *Can't answer*

1. This dataset is Animals that came from an animal shelter, which contains 32 data rows.

2. Some of the columns are:

   a. species, which contains categorical data. Some example values are: "cat", "dog", and "rabbit".

   b. _____, which contains _____ data. Some example values are: _____

What's on your mind?

Introduction to Programming in Pyret

Programming languages involve different *datatypes*, such as Numbers, Strings, and Booleans.

- Numbers are values like `1`, `0.4`, `1/3`, and `-8261.003`.
  - Numbers are *usually* used for quantitative data and other values are *usually* used as categorical data.
  - In Pyret, any decimal *must* start with a 0. `0.22` is valid, but `.22` is not.
- Strings are values like `"Emma"`, `"Rosanna"`, `"Jen and Ed"`, or even `"08/28/1980"`.
  - In Pyret, all strings *must* be surrounded in quotation marks.
- Booleans are either `true` or `false`.

Operators (like `+`, `-`, `*`, `<`, etc.) work the same way in Pyret that they do in math.

- Operators are written between values, for example: `4 + 2`.
- In Pyret, operators must always have a space around them. `4 + 2` is valid, but `4+2` is not.
- If an expression has different operators, parentheses must be used to show order of operations. `4 + 2 + 6` and `4 + (2 * 6)` are valid, but `4 + 2 * 6` is not.

Applying Functions also works the way it does in math. The function name is first, followed by a list of **arguments** in parentheses.

- In math this could look like `f(5)` or `f(g(10, 4))`.
- In Pyret this could look like `star(50, "solid", "red")`.
- There are many other Pyret functions, for example `num-sqr`, `num-sqrt`, `triangle`, `star`, `string-repeat`, etc.

Functions have **contracts**, which help explain how a function should be used. Every contract has three parts:

- The *Name* of the function - literally, what it's called.
- The *Domain* of the function - what *types of values* the function consumes, and in what order.
- The *Range* of the function - what *type of value* the function produces.

Value Definitions (like `x = 4`, or `y = 9 + 6`) also work the way they do in math. Every value definition starts with a *name*, followed by an equals sign, and then an expression. Once a value is defined, it can be referred to by name.

Numbers and Strings

Make sure you've loaded the code.pyret.org editor, 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:

Operators

6. Just like 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:

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

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

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.

1) `3 <= 4`	_____	7) `"a" > "b"`	_____
2) `3 == 2`	_____	8) `"a" < "b"`	_____
3) `2 < 4`	_____	9) `"a" == "b"`	_____
4) `3 <> 3`	_____	10) `"a" <> "b"`	_____
5) `5 >= 5`	_____	11) `"a" <> "a"`	_____
6) `4 >= 6`	_____	12) `"a" == "a"`	_____

13) In your own words, describe what **<** does. _____

14) In your own words, describe what **>=** does. _____

15) In your own words, describe what **<>** does. _____

16) How many **Numbers** are there in the entire universe? _____

17) How many **Strings** are there in the entire universe? _____

18) How many **Images** are there in the entire universe? _____

19) How many **Booleans** are there in the entire universe? _____

Defining Functions

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.

The Design Recipe

Directions : Define a function called `gt` , which makes solid green triangles of whatever size we want.

Contract and Purpose Statement

Every contract has three parts…

```
# gt:: (size :: Number) -> Image
```

function name | *domain* | *range*

```
# Consumes a size, and produces a solid green triangle of that size.
```

what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
  ____ (____) is ____
  ____ (____) is ____
end
```

function name | *input(s)* | *what the function produces*

Definition

Write the definition, giving variable names to all your input values…

```
fun gt(size):
  triangle(size, "solid", "green")
end
```

function name | *variable(s)* | *what the function does with those variable(s)*

Directions : Define a function called `bc` , which makes solid blue circles of whatever radius we want.

Contract and Purpose Statement

Every contract has three parts…

```
# ____ :: ____ -> ____
```

function name | *domain* | *range*

```
# ____
```

what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
  ____ (____) is ____
  ____ (____) is ____
end
```

function name | *input(s)* | *what the function produces*

Definition

Write the definition, giving variable names to all your input values…

```
fun ____(____):
  ____
end
```

function name | *variable(s)* | *what the function does with those variable(s)*

The Design Recipe

Directions : Define a function called `sticker` , which draws 50px stars in whatever color is input.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions : Define a function called `nametag` , which consumes a `Row` of the animals table and draws their name in purple, 10px letters. (Assume you have rows `animalA` and `animalB` defined.)

Contract and Purpose Statement

Every contract has three parts…

`nametag` :: `(r :: Row)` -> `Image`
function name *domain* *range*

Consumes an animal, and produces that animal's name in purple, 10px letters.
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

`nametag` (`animalA`) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun `nametag` (`r`):
function name *variable(s)*

```
text(r["name"], 10, "purple")
```
what the function does with those variable(s)

end

What's on your mind?

Applying Functions

Type this line of code into the interactions area and hit "Enter": `triangle(50, "solid", "red")`

1)	What is the name of this function?	_____
2)	What did the expression evaluate to?	_____
3)	How many arguments does `triangle` expect?	_____
4)	What does the `triangle` function produce? (Numbers? Strings? Booleans?)	_____

Catching Bugs

The following lines of code are all BUGGY! Can you spot the mistake? If you have time, type in the buggy code and see if Pyret agrees with you!

5) `triangle(20, "solid" "red")`

Can you spot the mistake? _____

What error message does Pyret return? _____

6) `triangle(20, "solid")`

Can you spot the mistake? _____

What error message does Pyret return? _____

7) `triangle(20, 10, "solid", "red")`

Can you spot the mistake? _____

What error message does Pyret return? _____

8) `triangle (20, "solid", "red")`

Can you spot the mistake? _____

What error message does Pyret return? _____

9) `triangle 20, "solid", "red")`

Can you spot the mistake? _____

What error message does Pyret return? _____

Practicing Contracts

Consider the following contract:

```
rotate :: (degree :: Number, img :: Image) -> Image
```

What is the **Name** of this function?

_____

How many things are in this function's **Domain**?

_____

What is the **type** of this function's **first argument**?

_____

What is the **name** of this function's **second argument**?

_____

What is the **Range** of this function?

_____

Circle the expression below that shows the correct application of this function, based on its contract.

1. `rotate(45, 90)`
2. `rotate(circle(99, "solid", "green"))`
3. `rotate(25, rectangle(7, 10, "outline", "black"))`
4. `rotate(rectangle(7, 10, "outline", "black"), 25)`

Matching Expressions and Contracts

Match the contract (left) with the expression described by the function being used (right).

Contract			Expression
make-id :: (name :: String, age :: Number) -> Image	1	A	`make-id("Hannah", "Smith")`
phone-bill :: (minutes :: Number, texts :: Number) -> Number	2	B	`make-id("George", 17)`
phone-bill :: (minutes :: Number) -> Number	3	C	`phone-bill(31, 287)`
make-id :: (first :: String, last :: String) -> Image	4	D	`make-id("Jessica", "Jones", 32)`
make-id :: (first :: String, last :: String, age :: Number) -> Image	5	E	`phone-bill(55)`

What's on your mind?

Data Displays and Lookups

Data scientists use data visualizations to gain better insights into their data, and to communicate their findings with others. Making a display requires answering three questions:

1. **What data** is being displayed? This could be "a random sample of 2000 people", "every animal from the shelter", or "students' aged 14-17".
2. **What variables** are being explored? Are we looking at the `species` column? The number of `kilograms` that an animal weighs? Searching for a relationship between a person's `income` and their `height` ?
3. **What display** is being used, given the variables being explored? If it's a quantitative variable, we might use a histogram or box plot. If it's categorical, we could use a pie or bar chart. If it's two quantitative variables, we probably want a scatter plot.

When **looking up a data Row** from a Table, programmers use the `row-n` method. This method takes a single number as its input, which tells the computer which Row we want. *Note: Rows are numbered starting at zero!*
For example:

```
animals-table.row-n(0)  # access the 1st data row
animals-table.row-n(16) # access the 17th data row
```

When **looking up a column** from a Row, programmers use square brackets and the name of the column they want.
For example:

```
animals-table.row-n(11)["age"]      # look up the age of the animal in the 12st data
row
animals-table.row-n(14)["species"]  # look up the species of the animal in the 15th
data row
```

Throughout the rest of the workbook, we will sometimes refer to animalA and animalB.

```
animalA = animals-table.row-n(4)
animalB = animals-table.row-n(13)
```

What Display Goes with Which Data?

Match the Display with the description of the data being plotted. Some descriptions may go with more than one display!

Pie Charts	**1**	**A**	1 column of Quantitative Data
Bar Charts	**2**		
Histograms	**3**	**B**	2 columns of Quantitative Data
Box Plots	**4**		
Scatter Plots	**5**	**C**	1 column of Categorical Data

Data Displays

Fill in the tables below, then write the Pyret code that will make that display. The first column has been filled in for you.

1) A `pie-chart` showing the `species` of animals from the shelter.

Which Rows?	Which Column(s)?	What Display?
All the animals		

code:

---

2) A `bar-chart` showing the `sex` of animals from the shelter.

Which Rows?	Which Column(s)?	What Display?
All the animals		

code:

---

3) A `histogram` of the number of `pounds` that animals weigh.

Which Rows?	Which Column(s)?	What Display?
All the animals		

code:

---

4) A `box-plot` of the number of `pounds` that animals weigh.

Which Rows?	Which Column(s)?	What Display?
All the animals		

code:

---

5) A `scatter-plot`, using the animals' `species` as the labels, `age` as the x-axis, and `pounds` as the y-axis.

Which Rows?	Which Column(s)?	What Display?
All the animals		

code:

---

6) A `scatterplot`, using the animals' `name` as the labels, `pounds` as the x-axis, and `weeks` as the y-axis.

Which Rows?	Which Column(s)?	What Display?
All the animals		

code:

Lookup Questions

The table below represents four pets:

`pets-table`

name	sex	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).

"How much does Maple weigh?"	**1**	**A**	`pets-table.row-n(3)`
"Which is the last row in the table?	**2**	**B**	`pets-table.row-n(2)["name"]`
"What is Fritz's sex?"	**3**	**C**	`pets-table.row-n(1)["sex"]`
"What's the third animal's name?"	**4**	**D**	`pets-table.row-n(3)["age"]`
"How much does Nori weigh?"	**5**	**E**	`pets-table.row-n(3)["pounds"]`
"How old is Maple?"	**6**	**F**	`pets-table.row-n(0)`
"What is Toggle's sex?"	**7**	**G**	`pets-table.row-n(2)["pounds"]`
"What is the first row in the table?"	**8**	**H**	`pets-table.row-n(0)["sex"]`

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

a.	pets-table.row-n(3)["name"]	`"Maple"`
b.	_____	`"male"`
c.	_____	`4`
d.	_____	`48`
e.	_____	`"Nori"`

What's on your mind?

Defining Row Functions & Using Table Methods

Methods are special functions that are attached to pieces of data. We use them to manipulate Tables.

- **In this course, the methods we'll be using are**
  - `row-n` **- consumes an index (starting with zero!) and produces a row from a table**
  - `order-by` **- consumes the name of a column and a Boolean value to determine if that table should be sorted by that column in ascending order**
  - `filter` **- consumes a *Boolean-producing function*, and produces a table containing only rows for which the function returns** `true`
  - `build-column` **- consumes the name of a new column, and a function that produces the values in that column for each Row**
- **Unlike functions, methods can't be used alone. They have a "secret" argument, which is the data they are attached to. They are written as part of that data, separated by a dot. For example:**

```
shapes.row-n(2)
```

- **Contracts for methods are different from other functions. They include the type of the data as part of their names. For example:**

```
<table>.row-n :: (index :: Number) -> Row
```

Reading Function Definitions

Make sure you have the "Table Methods Starter File" open on your computer, and click "Run".

1	How many functions are defined here?	
2	What are their names?	
3	What is the domain of `is-dog` ?	
4	What is the range of `is-old` ?	
5	What is the range of `lookup-name` ?	
6	What does `is-fixed(animalA)` evaluate to?	
7	What does `lookup-name(animalB)` evaluate to?	
8	What does `is-old(animalA)` evaluate to?	
9	What does `is-dog(animalA)` evaluate to?	
10	What does `is-fixed` do?	
11	What does `lookup-name` do?	
12	What does `is-old` do?	

The Design Recipe

For the word problems below, assume `animalA` and `animalB` are defined as the data rows for Felix and Midnight, respectively.

Directions: Define a function called `lookup-fixed`, which looks up whether or not an animal is fixed.

Contract and Purpose Statement

Every contract has three parts…

```
# lookup-fixed:: (r :: Row) -> Boolean
```

function name | *domain* | *range*

```
# Consumes an animal, and looks up the value in the fixed column.
```

what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
  ____________ ( ____________ ) is ____________
  ____________ ( ____________ ) is ____________
end
```

function name | *input(s)* | *what the function produces*

Definition

Write the definition, giving variable names to all your input values…

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

function name | *variable(s)* | *what the function does with those variable(s)*

Directions: Define a function called `lookup-sex`, which consumes a Row of the animals table and looks up the sex of that animal.

Contract and Purpose Statement

Every contract has three parts…

```
# ____________ :: ____________ -> ____________
```

function name | *domain* | *range*

```
# ____________
```

what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
  ____________ ( ____________ ) is ____________
  ____________ ( ____________ ) is ____________
end
```

function name | *input(s)* | *what the function produces*

Definition

Write the definition, giving variable names to all your input values…

```
fun ____________ ( ____________ ):

  ____________
end
```

function name | *variable(s)* | *what the function does with those variable(s)*

The Design Recipe

For the word problems below, assume `animalA` and `animalB` are defined as the data rows for Felix and Midnight, respectively.

Directions: Define a function called `is-cat`, which consumes a `Row` of the animals table and *computes* whether the animal is a cat.

Contract and Purpose Statement

Every contract has three parts…

`is-cat` :: `(r :: Row)` -> `Boolean`

function name | *domain* | *range*

Consumes an animal, and computes whether the species equals "cat"

what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

`is-cat` (`animalA`) **is** _____

function name | *input(s)* | *what the function produces*

_____ (_____) **is** _____

function name | *input(s)* | *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun `is-cat`(`r`):

function name | *variable(s)*

`r["species"] == "cat"`

what the function does with those variable(s)

end

Directions: Define a function called `is-young`, which consumes a Row of the animals table and *computes* whether it is less than four years old.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____

function name | *domain* | *range*

_____

what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____

function name | *input(s)* | *what the function produces*

_____ (_____) **is** _____

function name | *input(s)* | *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):

function name | *variable(s)*

_____

what the function does with those variable(s)

What's on your mind?

Method Chaining

Method chaining allows us to apply multiple methods with less code.

For example, instead of using multiple definitions, like this:

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

We can use method-chaining to write it all on one line, like this:

```
animals-table.build-column("labels", nametag).filter(is-cat).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.

The Design Recipe

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

Directions: Define a function called `is-dog`, which consumes a `Row` of the animals table and *computes* whether the animal is a dog.

Contract and Purpose Statement

Every contract has three parts…

```
# is-dog:: (r :: Row) -> Boolean
```

function name | *domain* | *range*

```
# Consumes an animal, and computes whether the species == "dog"
```

what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
  is-dog ( "animalA" ) is animalA["species"] == "dog"
  is-dog ( "animalB" ) is
end
```

function name | *input(s)* | *what the function produces*

Definition

Write the definition, giving variable names to all your input values…

```
fun is-dog( r ):
  r["species"] == "dog"
end
```

function name | *variable(s)* | *what the function does with those variable(s)*

Directions: Define a function called `is-female`, which consumes a Row of the animals table and returns true if the animal is female.

Contract and Purpose Statement

Every contract has three parts…

```
#  ::  ->
#
```

function name | *domain* | *range*

what does the function do?

Examples

Write some examples, then circle and label what changes…

```
examples:
  ( ) is
  ( ) is
end
```

function name | *input(s)* | *what the function produces*

Definition

Write the definition, giving variable names to all your input values…

```
fun ( ):

end
```

function name | *variable(s)* | *what the function does with those variable(s)*

The Design Recipe

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

Directions: Define a function called `is-old`, which consumes a Row of the animals table and *computes* whether it is more than 12 years old.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

end

Directions: Define a function called `name-has-s`, which returns true if an animal's name contains the letter "s"

Contract and Purpose Statement

Every contract has three parts…

`name-has-s` :: _____ -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

examples:

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

_____ (_____) **is** _____
function name *input(s)* *what the function produces*

end

Definition

Write the definition, giving variable names to all your input values…

fun `name-has-s(r)`:
function name *variable(s)*

```
string-contains(r["name"], "s")
```
what the function does with those variable(s)

end

Chaining Methods

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

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

The table `t` below represents four animals from the shelter:

name	sex	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).

`t.order-by("age", true)`	**1**	**A**	Produces a table containing only Toggle and Maple
`t.filter(is-fixed)`	**2**	**B**	Produces a table of only young, fixed animals
`t.build-column("sticker", nametag)`	**3**	**C**	Produces a table, sorted youngest-to-oldest
`t.filter(is-young)`	**4**	**D**	Produces a table with an extra column, named "sticker"
`t.filter(is-young)` `  .filter(is-fixed)`	**5**	**E**	Produces a table containing Maple and Toggle, in that order
`t.filter(is-young)` `  .order-by("pounds", false)`	**6**	**F**	Produces a table containing the same four animals
`t.build-column("label", nametag)` `  .order-by("age", true)`	**7**	**G**	Won't run: will produce an error
`t.order-by("agee", false)`	**8**	**H**	Produces a table with an extra "label" column, sorted youngest-to-oldest

Chaining Methods 2: Order Matters!

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

```
fun is-female(r): r["sex"] == "female"  end
fun kilograms(r): r["pounds"] / 2.2     end
fun is-heavy(r):  r["kilos"] > 25       end
```

The table `t` below represents four animals from the shelter:

name	sex	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!**

```
t.order-by("kilos", true)
```

1

A Produces a table containing Toggle, Nori and Maple, with an extra column showing their weight in kilograms

```
t.filter(is-female)
  .build-column("kilos", kilograms)
```

2

B Produces a table containing Maple, Nori and Toggle (in that order)

```
t.build-column("kilos", kilograms)
  .filter(is-heavy)
```

3

C Produces a table containing only Fritz, with a single extra column called `kilos`

```
t.filter(is-heavy)
  .build-column("kilos", kilograms)
```

4

D Won't run: will produce an error

```
t.build-column("kilos", kilograms)
  .filter(is-heavy)
  .order-by("sex", true)
```

5

E Produces a table containing only Fritz, with two extra columns

```
t.build-column("female", is-female)
  .build-column("kilos", kilograms)
  .filter(is-heavy)
```

6

F Produces a table containing Maple and Fritz

What's on your mind?

Randomness and Sample Size

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!

Random Samples are a subset of a population in which each member of the subset has an equal chance of being chosen. A random sample is intended to be a representative subset of the population. The larger the random sample, the more closely it will represent the population and the better our inferences about the population will tend to be.

Grouped Samples are a subset of a population in which each member of the subset was chosen for a specific reason. For example, we might want to look at the difference in trends between two groups ("Is the age of a dog a bigger factor in adoption time v. the age of a cat?"). This would require making grouped samples of *just the dogs* and *just the cats*.

Sampling and Inference

1) Evaluate the `big-animals-table` in the Interactions Area. This is the *complete* population of animals from the shelter! Below is a true statement about that population:

The population is 47.7% fixed and 52.3% unfixed.

2) How close to these percentages do we get with random samples?
Type each of the following lines into the Interactions Area and hit "Enter".

```
random-rows(big-animals-table, 10)
random-rows(big-animals-table, 40)
```

3) What do you get?

4) What is the contract for `random-rows` ?

5) What does the `random-rows` function do?

6) In the Definitions Area, define `small-sample` and `large-sample` to be these two random samples.

7) Make a `pie-chart` for the animals in each sample, showing percentages of fixed and unfixed.

- The percentage of fixed animals in the entire populations is **47.7%**.
- The percentage of fixed animals in `large-sample` is _____.
- The percentage of fixed animals in `large-sample` is _____.

8) Make a `pie-chart` for the animals in each sample, showing percentages for each species.

- The percentage of tarantulas in the entire population is **roughly 5%**.
- The percentage of tarantulas in `small-sample` is _____.
- The percentage of tarantulas in `large-sample` is _____.

9) Click "Run" to direct the computer to generate a different set of random samples of these sizes. Make a new `pie-chart` for each sample, showing percentages for each species.

- The percentage of tarantulas in the entire population is **roughly 5%**.
- The percentage of tarantulas in `small-sample` is _____.
- The percentage of tarantulas in `large-sample` is _____.

10) Which repeated sample gave us a more accurate inference about the whole population? Why?

Grouped Samples from the Animals Dataset

Use method chaining to define the **grouped samples** below, using the helper functions that you've already defined: `is-old`, `is-young`, `is-cat`, `is-dog`, `is-female`, `lookup-fixed`, and `has-s-name`. We've given you the solution for the first sample, to get you started.

Subset	The code to define that subset
Kittens	`kittens = animals-table.filter(is-cat).filter(is-young)`
Puppies	`young-dogs = animals-table.` _____
Fixed Cats	`fixed-cats = animals-table.` _____
Cats with "s" in their name	`s-cats = animals-table.` _____
Old Dogs	`old = animals-table.` _____
Fixed Animals	`fixed = animals-table.` _____
Old Female Cats	`old-cats = animals-table.` _____
Fixed Kittens	`young-fixed-cats = animals-table.` _____
Fixed Female Dogs	`fixed-female-dogs = animals-table.` _____
Old Fixed Female Cats	`old-fixed-female-cats = animals-table.` _____

Displaying Data

Fill in the tables below, then use Pyret to make the following displays. Record the code you used.
The first table has been filled in for you.

1) A `bar-chart` showing how many puppies are fixed or not.

What Rows?	Which Column(s)?	What Display?
puppies	*fixed*	*bar-chart*

code:

```
bar-chart(puppies, "fixed")
```

2) A `pie-chart` showing how many heavy dogs are fixed or not.

What Rows?	Which Column(s)?	What Display?

code:

3) A `histogram` of the number of `weeks` it takes for a random sample of animals to be adopted.

What Rows?	Which Column(s)?	What Display?

code:

4) A `box-plot` of the number of `pounds` that kittens weigh.

What Rows?	Which Column(s)?	What Display?

code:

5) A `scatter-plot` of a random sample using `name` as the labels, `age` as the x-axis, and `weeks` as the y-axis.

What Rows?	Which Column(s)?	What Display?

code:

6) A `scatter-plot` of fixed cats, using `species` as the labels, `pounds` as the x-axis, and `weeks` as the y-axis.

What Rows?	Which Column(s)?	What Display?

code:

What's on your mind?

Histograms

To best understand histograms, it's helpful to contrast them first with bar charts.

Bar charts show the number of rows belonging to a given category. The more rows in each category, the taller 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 sales of 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 fall within a particular "bin", the taller the bar.

- *Histograms provide a visual representation of the frequencies (or relative 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. Choosing a good bin size can take some trial and error!

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 the mean as below the mean.
- A data set that is **skewed left** and/or has low outliers has a few values that are unusually low. The histogram for a skewed left dataset has a few data points that are stretched out to the left (lower) end of the x-axis.
- A data set that is **skewed right** and/or high outliers means there are a few values that are unusually high. The histogram for a skewed right dataset has a few data points that are stretched out to the right (higher) end of the x-axis.
- One way to visualize the difference between a histogram of data that is **skewed left** or **skewed right** is to think about the lengths of our toes on our left and right feet. Much like a histogram that is "skewed left", our left feet have smaller toes on the left and a bigger toe on the right. Our right feet have the big toe on the left and smaller toes on the right, more closely resembling the shape of a histogram of "skewed right" data.

The Design Recipe

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

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

Contract and Purpose Statement

Every contract has three parts…

_____ :: `(r :: Row)` -> _____
function name *domain* *range*

_____
what does the function do?

Examples

Write some examples, then circle and label what changes…

`examples:`

_____ (_____) **`is`** _____
function name *input(s)* *what the function produces*

_____ (_____) **`is`** _____
function name *input(s)* *what the function produces*

`end`

Definition

Write the definition, giving variable names to all your input values…

`fun` _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

`end`

Directions: Define a function called `smart-dot`, which consumes a Row of the animals table and *computes* the image of a solid red circle using the animal's `pounds` as the radius.

Contract and Purpose Statement

Every contract has three parts…

_____ :: _____ -> `Image`
function name *domain* *range*

Consumes an animal, and computes a solid red circle using the weight in pounds as the radius
what does the function do?

Examples

Write some examples, then circle and label what changes…

`examples:`

`smart-dot` (`"animalA"`) **`is`** _____
function name *input(s)* *what the function produces*

_____ (_____) **`is`** _____
function name *input(s)* *what the function produces*

`end`

Definition

Write the definition, giving variable names to all your input values…

`fun` _____ (_____):
function name *variable(s)*

_____
what the function does with those variable(s)

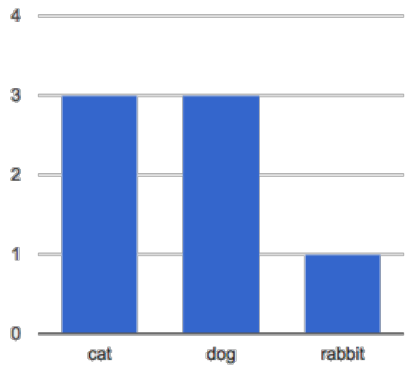
`end`

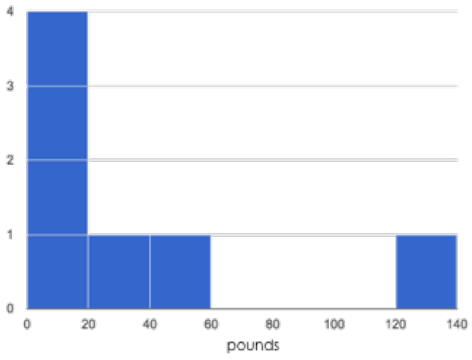
Summarizing Columns

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?	
2	How many dogs are there?	
3	How many animals weigh between 0-20 pounds?	
4	How many animals weigh between 20-40 pounds?	
5	Are there more animals weighing 40-60 than 60-140 pounds?	

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





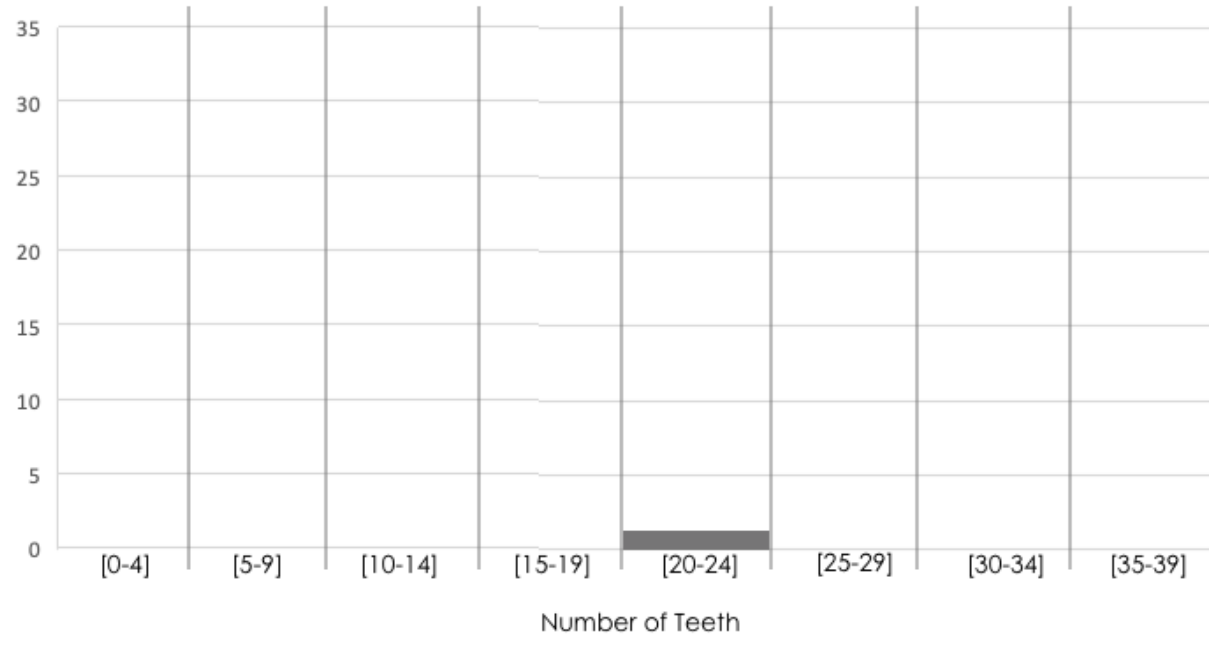
Similarities	Differences

Making Histograms

Suppose we have a data set for a group of 50 adults, showing the number of teeth each person has:

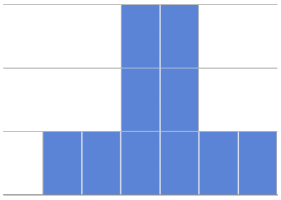
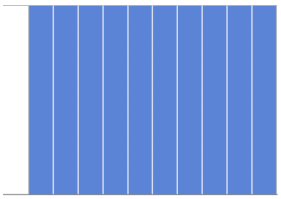
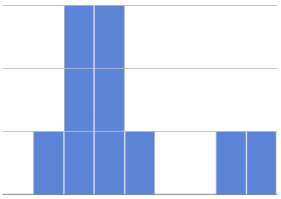
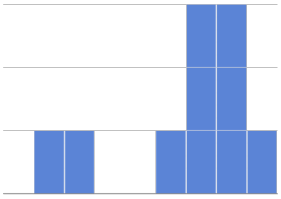
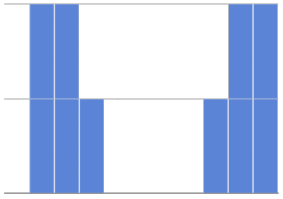
Number of teeth	Count
0	5
22	1
26	1
27	1
28	4
29	3
30	5
31	3
32	27

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.



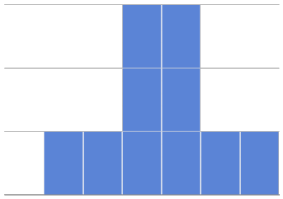
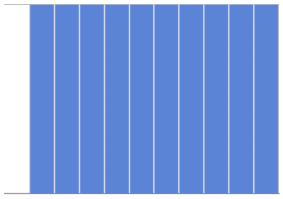
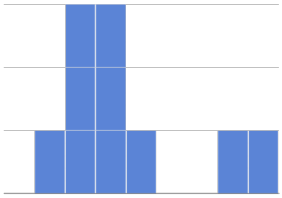
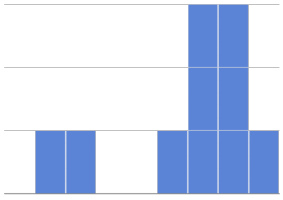
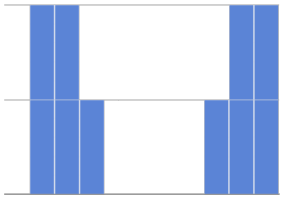
Reading Histograms

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 *shape* of 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** . These axes are intentionally unlabeled - focusing on the *shape* is what matters here!

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

Identifying Shape

Describe the shape of histograms on the left in complete sentences, using vocabulary like "Skewed Left", "Skewed Right", or "Symmetric".

1		
2		
3		
4		
5		

The Shape of the Animals Dataset

Describe two histograms made from columns of the animals dataset.

1) Make a histogram, showing the distribution of pounds (column in your dataset) for animals from the shelter (your subset, e.g., "fixed dogs from the shelter").

2) Make another histogram, showing the distribution of _____ (column in your dataset) for _____ (your subset, e.g., "fixed dogs from the shelter").

3) What do you Notice and Wonder about these two histograms? What shape do they have?

What do you NOTICE?	What do you WONDER?

The Spread of My Dataset

Describe two of the histograms you made from your dataset.

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

_____.
your subset, e.g., "fixed dogs from the shelter"

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

_____.
your subset, e.g., "fixed dogs from the shelter"

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

Measures of Center and Spread

There are three ways to measure the **center** of a dataset, to summarize a whole column of quantitative 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. In an ordered list the median will either be the middle number or the average of the two middle numbers.
- The **mode(s)** of a data set is the value (or values) occurring most often. When all of the values occur equally often, a dataset has no mode.

In a **symmetric** dataset, values are just as likely to occur a certain distance above the mean as below the mean, and the median and mean are usually close together.

When a dataset is asymmetric, the median is a more decriptive measure of center than the median.

- A dataset with **left skew**, and/or low outliers, has a few values that are unusually low, pulling the mean *below* the median.
- A dataset with **right skew**, and/or high outliers, means there are a few values that are unusually high, pulling the mean *above* the median.

When a dataset contains a small number of values, the mode may be the most descriptive measure of center.

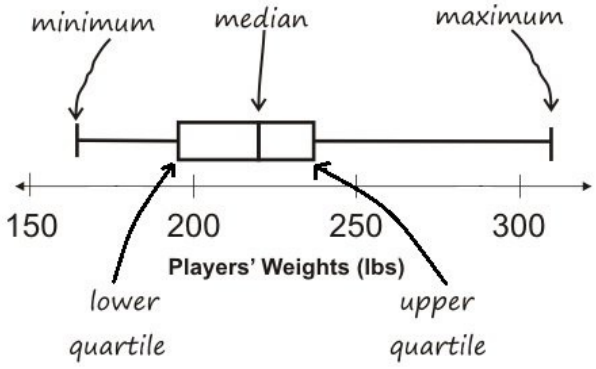
Data Scientists can also measure the **spread** of a dataset using a **five-number summary** :

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

Measures of Center and Spread (continued)

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

- Each of the four sections of the box plot contains 25% of the data. *If the values are distributed evenly across the range, the four sections of the box plot will be equal in width.* Uneven distributions will show up as differently-sized sections of a box plot.
- The left **whisker** extends from the minimum to Q1.
- The **box**, or **interquartile range**, extends from Q1 to Q3. It is divided into 2 parts by the **median**. Each of those parts contains 25% of the data, so the whole box contains the central 50% of the data.
- The right **whisker** extends from Q3 to the maximum.



The box plot above, for example, tells us that:

- The minimum weight is about 165 pounds. The median weight is about 220 pounds. The maximum weight is about 310 pounds.
  - 1/4 of the players weigh roughly between 165 and 195 pounds
  - 1/4 of the players weigh roughly between 195 and 220 pounds
  - 1/4 of the players weigh roughly between 220 and 235 pounds
  - 1/4 of the players weigh roughly between 235 and 310 pounds
  - 50% of the players weigh roughly between 165 and 220 pounds
  - 50% of the players weigh roughly between 195 and 235 pounds
  - 50% of the players weigh roughly between 220 and 310 pounds
- The densest concentration of players' weights is between 220 and 235 pounds.
- Because the widest section of the box plot is between 235 and 310 pounds, we understand that the weights of the heaviest 25% fall across a wider span than the others. 310 may be an outlier, the weights of the players weighing between 235 pounds and 310 pound could be evenly distributed across the range, or all of the players weighing over 235 pounds may weigh around 310 pounds.

Summarizing Columns in the Animals Dataset

Find the measures of center and spread to summarize the _____pounds_____ column of the Animals Table.

Be sure to add examples to your Contracts page as you work.

Measures of Center

The three measures of center for this column are:

Mean (Average)	Median	Mode(s)

Since the mean is _____ compared to the median, this suggests the shape is

[higher/lower/about equal]

_____.

[skewed right (or high outliers) / skewed left (or low outliers) / symmetric]

Measures of Spread

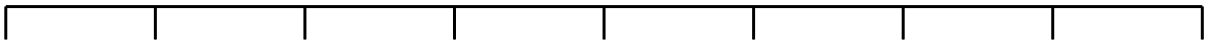
My five-number summary is:

Minimum	Q1	Median	Q3	Maximum

Displaying Center and Spread with a Box Plot

Draw a box plot from this summary on the number line below.

Be sure to label the number line with consistent intervals.



From this summary and box plot, I conclude:

Interpreting Spread

Consider the following dataset, representing the annual income of ten people.

All numbers represent *thousands of dollars* (so `14` means "$14,000"):

```
60, 10, 21, 180, 14, 20, 45, 35, 45, 170
```

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

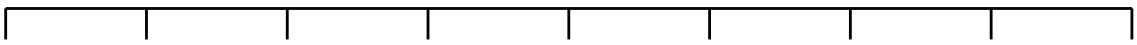
2) In the table below, compute the **measures of center** for this dataset.

Mean (Average)	Median	Mode(s)

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

Minimum	Q1	Q2 (Median)	Q3	Maximum

4) On the number line below, draw a **box plot** for this dataset.

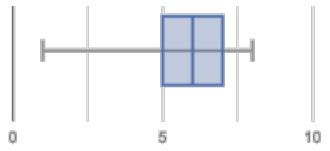
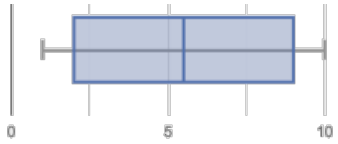
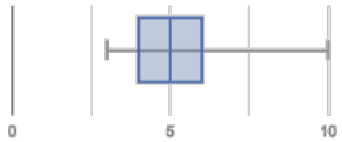
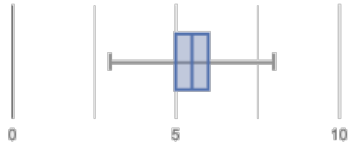
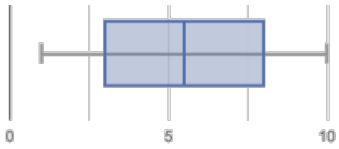


5) The following statements are *correct* … but misleading. Write down the reason why.

Statement	Why it's misleading
"They're rich! The average person makes more than $70k dollars!"	
"It's a middle-income list: the most common salary is $45k/yr!"	
"This group is very low-income, the most common salary range is from $10k-$25k!"	

Identifying Shape

Describe the shape of the box plots below in complete sentences, using vocabulary like "Skewed Left", "Skewed Right", or "Symmetric".

1		
2		
3		
4		
5		

Shape of My Dataset

Find the measures of center and spread to summarize a column of your dataset.

The column I chose to summarize is _____.

Measures of Center

The three measures of center for this column are:

Mean (Average)	Median	Mode(s)

Since the mean is _____ compared to the median, this suggests the shape is
[higher/lower/about equal]

_____.
[skewed right (or high outliers) / skewed left (or low outliers) / symmetric]

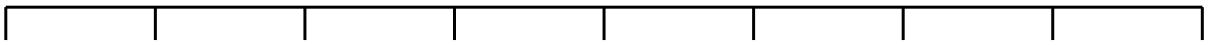
Measures of Spread

My five-number summary is:

Minimum	Q1	Q2 (Median)	Q3	Maximum

Displaying Center and Spread with a Box Plot

Draw a box plot from this summary on the number line below.
Be sure to label the number line with consistent intervals.



From this summary and box plot, I conclude:

_____

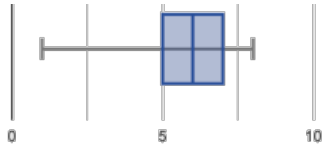
_____

_____

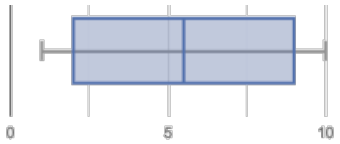
_____

Matching Box-Plots to Histograms

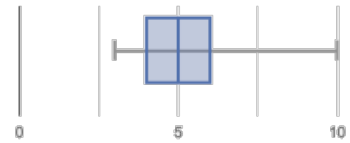
Students watched 5 videos, and rated them on a scale of 1 to 10. For each video, their ratings were used to generate box-plots and histograms. **Match the box-plot to the histogram that displays the same data.**



1



2



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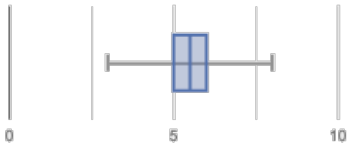
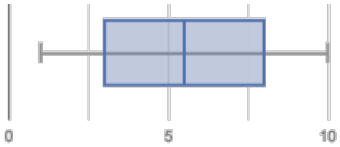
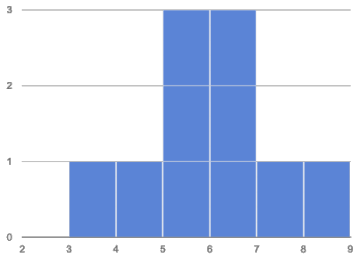


4

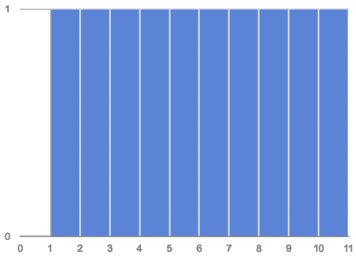


5

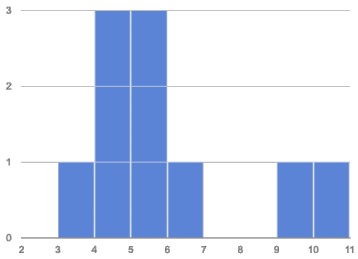
A



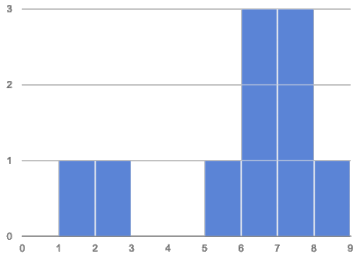
B



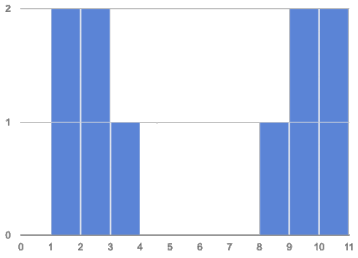
C



D



E



What's on your mind?

Scatter Plots

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 suggests that a linear relationship exists between those two columns. A number called a **correlation** can be used to summarize this relationship.
- r is the name of the **correlation statistic**. The r-value will always fall between −1 and +1. The sign tells us whether the correlation is positive or negative. Distance from 0 tells us the strength of the correlation.
  - −1 or +1 are the strongest possible negative and possible correlations.
  - 0 means no correlation.
- The correlation is **positive** if the point cloud slopes up as it goes farther to the right. This means larger y-values tend to go with larger x-values. 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. That means knowing the x-value gives us a pretty good idea of the y-value. If they are loosely scattered it is a **weak** correlation, and the y-value doesn't depend much on the x-value.
- 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 all the points taken together is as small as possible. This line is called the **line of best fit** and allows

lues based on x-values.

(Dis)Proving a Claim

"Smaller animals get adopted faster because they're cuter."

Do you agree? If so, why?

I hypothesize …

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

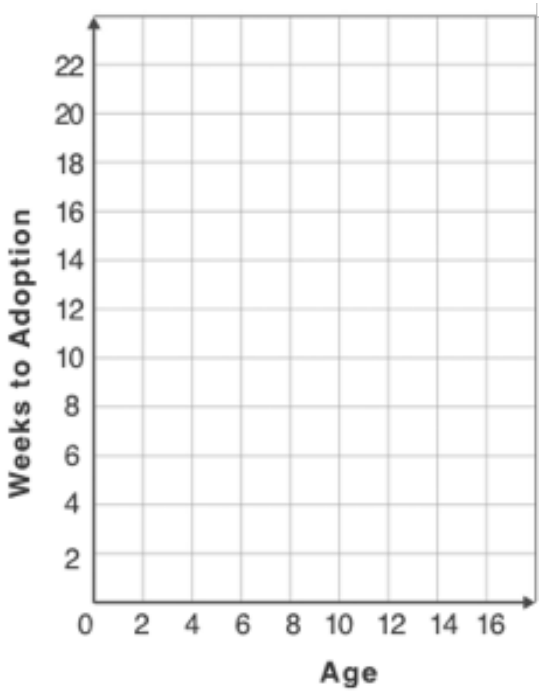
Creating a Scatter Plot

1. **For each row in the Sample Table on the left, add a point to the scatter plot on the right**. 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 go up or down as age increases to the right?
   - **Draw a cloud around all the points, and a line around which the cloud appears to be centered**
3. Does the line slope upwards or downwards?

   _____
4. Are the points tightly clustered around the line or loosely scattered?

   _____

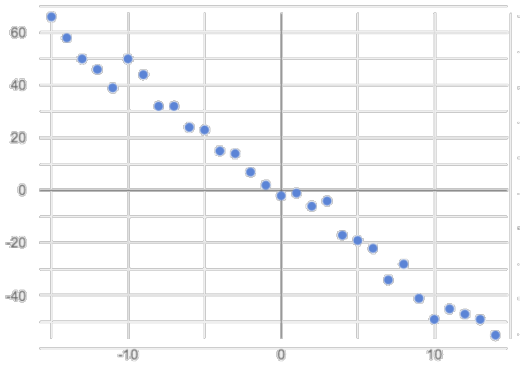
name	species	age	weeks
"Sasha"	"cat"	1	3
"Boo-boo"	"dog"	11	5
"Felix"	"cat"	16	4
"Buddy"	"lizard"	2	24
"Nori"	"dog"	6	9
"Wade"	"cat"	1	2
"Nibblet"	"rabbit"	6	12
"Maple"	"dog"	3	2



Identifying Form, Direction and Strength

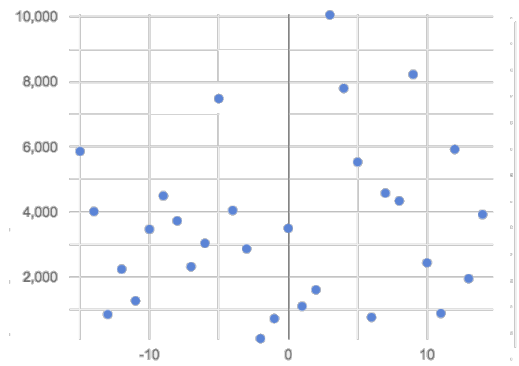
Can you identify the Form, Direction, & Strength of these displays? **Note:** If the form is non-linear, we shouldn't report direction - a curve may rise and then fall

A



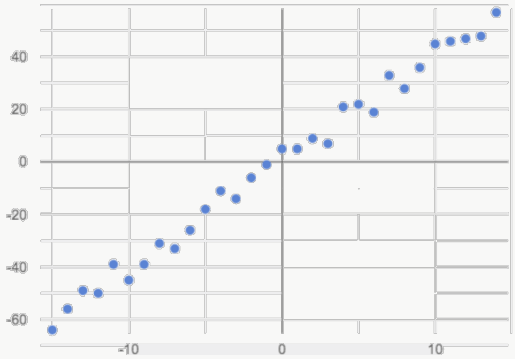
Form :	Linear	Non-Linear	None
Direction :	Positive	Negative	None
Strength :	Strong	Weak	None

B



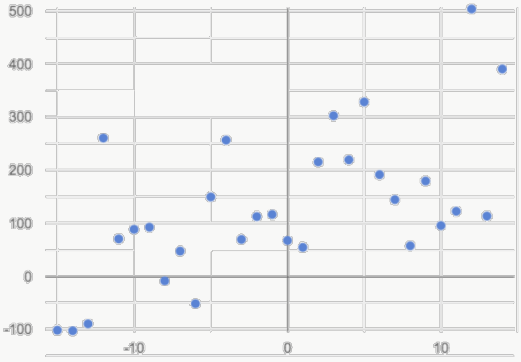
Form :	Linear	Non-Linear	None
Direction :	Positive	Negative	None
Strength :	Strong	Weak	None

C



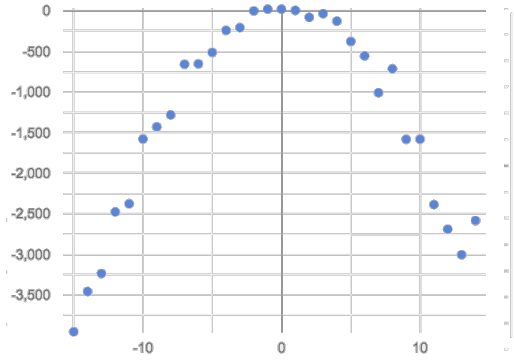
Form :	Linear	Non-Linear	None
Direction :	Positive	Negative	None
Strength :	Strong	Weak	None

D



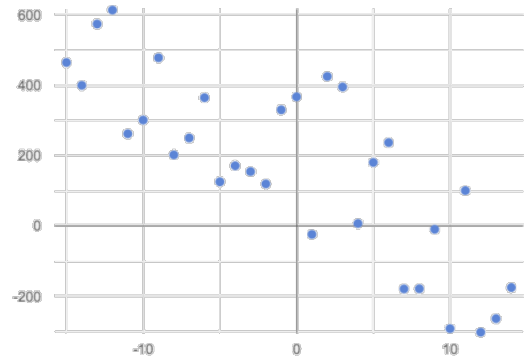
Form :	Linear	Non-Linear	None
Direction :	Positive	Negative	None
Strength :	Strong	Weak	None

E



Form :	Linear	Non-Linear	None
Direction :	Positive	Negative	None
Strength :	Strong	Weak	None

F



Form :	Linear	Non-Linear	None
Direction :	Positive	Negative	None
Strength :	Strong	Weak	None

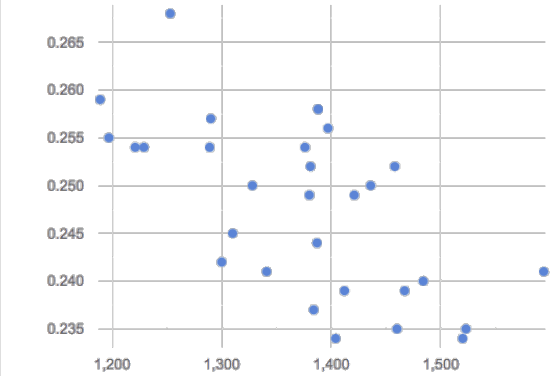
Identifying Form and r-Values

Can you identify the Form, Direction, and Strength of these displays?

If the form is linear, approximate the r-value to express Direction and Strength.

Reminder: An r-value close to -1 is a strong negative relationship, an r-value close to 0 is weak, and an r-value close to +1 is a strong positive! If the relationship's strength is moderate, the r-value will be closer to -0.5 or +0.5.

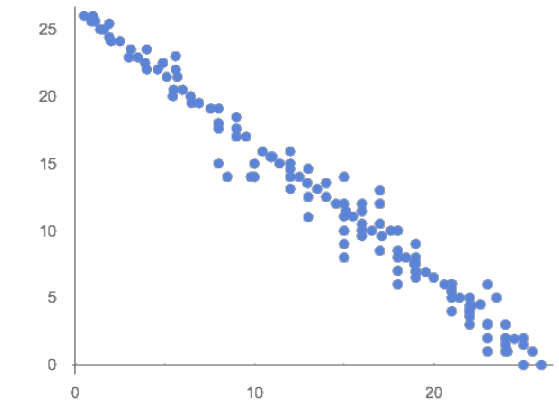
A



Form :

r close to :

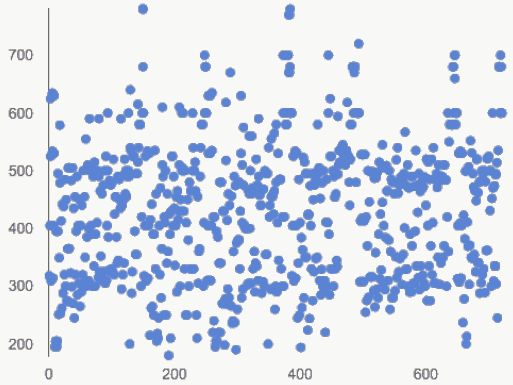
B



Form :

r close to :

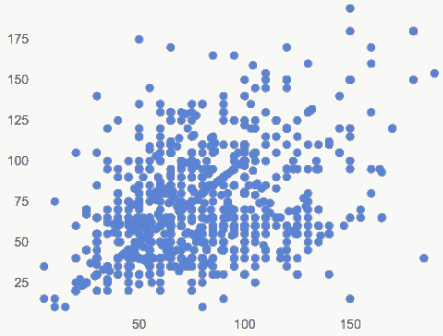
C



Form :

r close to :

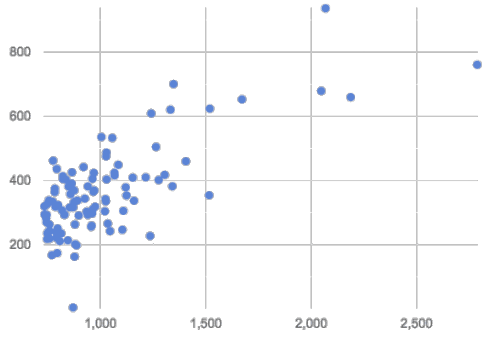
D



Form :

r close to :

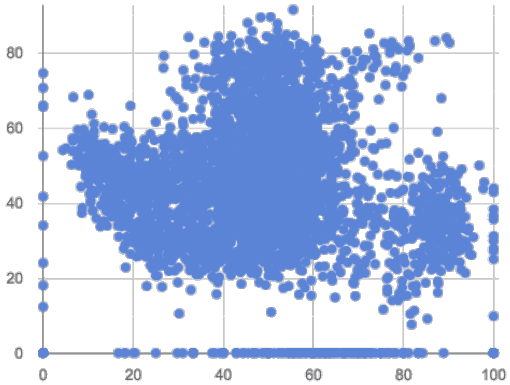
E



Form :

r close to :

F



Form :

r close to :

Correlations in My Dataset

1) There may be a correlation between _____ (column) and _____ (column).

I think it is a _____ (strong/weak), _____ (positive/negative) correlation,

because

_____.

It might be stronger if I looked at

_____ (a sample or extension of my data).

---

2) There may be a correlation between _____ (column) and _____ (column).

I think it is a _____ (strong/weak), _____ (positive/negative) correlation,

because

_____.

It might be stronger if I looked at

_____ (a sample or extension of my data).

---

3) There may be a correlation between _____ (column) and _____ (column).

I think it is a _____ (strong/weak), _____ (positive/negative) correlation,

because

_____.

It might be stronger if I looked at

_____ (a sample or extension of my data).

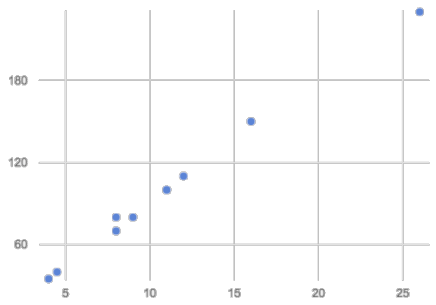
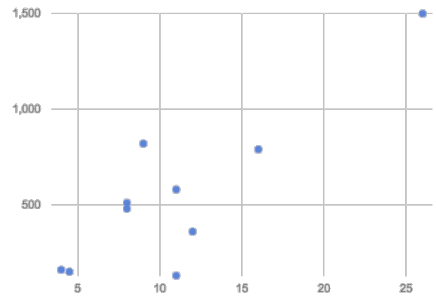
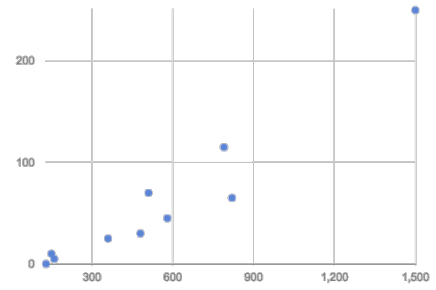
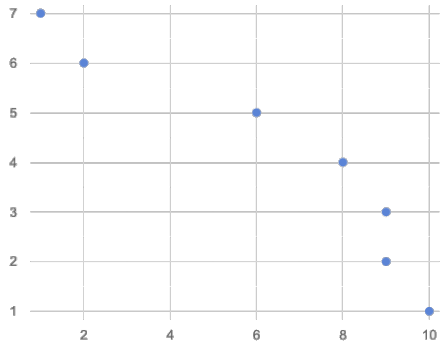
Computing Relationships

Linear Regression is a way of computing the **line of best fit** , which minimizes the *sum of the squares* of the vertical distances from the points to 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) will increase or decrease for each unit that the x-variable (explanatory variable) increases.
- **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, but 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.

Drawing Predictors

For each of the scatter plots below, draw a **predictor line** that seems like the best fit. Describe the correlation in terms of Direction and Strength, then estimate the r-value as being close to -1, -0.5, 0, +0.5, or +1.

A		**Direction** : Positive Negative None **Strength** : Strong Weak **r** : _____
B		**Direction** : Positive Negative None **Strength** : Strong Weak **r** : _____
C		**Direction** : Positive Negative None **Strength** : Strong Weak **r** : _____
D		**Direction** : Positive Negative None **Strength** : Strong Weak **r** : _____

Interpreting Regression Lines & r-Values

Each description on the left is written about the linear regression findings on the right. Fill in the blanks using the information in the line of best fit and the r-value.

1	For every additional Marvel Universe movie released each year, the average person is predicted to consume _____ [amount] _____ [more / fewer] pounds of sugar! This correlation is _____ [strong, moderate, weak, practically non-existent].	`y = −3.19x + 12` `r = −0.05`
2	Shoe size and height are _____ [strongly, moderately, weakly, not], _____ [positively / negatively] correlated. If person A is one size bigger than person B, we predict that they will be roughly _____ [amount] inches taller than person B as well.	`y = 1.65x + 52` `r = 0.89`
3	There is _____ [a strong, a moderate, a weak, no] relationship found between the number of Uber drivers in a city and the number of babies born each year.	`y = −15.3x + 1150` `r = 0.01`
4	The correlation between weeks-of-school-missed and SAT score is _____ [strong, moderate, weak, practically non-existent] and _____ [positive / negative]. For every week a student misses, we predict a more than a _____ [amount] point _____ [gain / drop] in their SAT score.	`y = −5.35x − 16` `r = −0.65`
5	There is a _____ [strong, moderate, weak, practically non-existent], _____ [positive / negative] correlation between the number of streaming video services someone has, and how much they weigh. For each service, we expect them to be roughly _____ [amount] pounds heavier.	`y = 1.6x + 140` `r = 0.12`

Regression Analysis in the Animals Dataset

1) I performed a linear regression on a sample of cats from 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 years) ([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]).

---

2) I performed a linear regression on a sample of _____ (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]).

---

3) I performed a linear regression on a sample of _____ (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 Your Dataset

My Dataset is _____.

1) I performed a linear regression on _____ and found
dataset or subset

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

_____ and _____.
[x-axis] [y-axis]

I would predict that a 1 _____ increase in _____ is associated with a
[x-axis units] [x-axis]

_____ _____ in _____.
[slope, y-units] [increase/decrease] [y-axis]

---

2) I performed a linear regression on _____ and found
dataset or subset

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

_____ and _____.
[x-axis] [y-axis]

I would predict that a 1 _____ increase in _____ is associated with a
[x-axis units] [x-axis]

_____ _____ in _____.
[slope, y-units] [increase/decrease] [y-axis]

---

3) I performed a linear regression on _____ and found
dataset or subset

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

_____ and _____.
[x-axis] [y-axis]

I would predict that a 1 _____ increase in _____ is associated with a
[x-axis units] [x-axis]

_____ _____ in _____.
[slope, y-units] [increase/decrease] [y-axis]

What's on your mind?