

Scatter Plots

(Also available in [CODAP](#))

Students investigate scatter plots as a method of visualizing the relationship between two quantitative variables. In the programming environment, points on the scatter plot can be labelled with a third variable!

Lesson Goals	<p>Students will be able to...</p> <ul style="list-style-type: none">• consider explanatory and response roles of variables• make scatter plots by hand, given a list of (x,y) pairs• make scatter plots using Pyret.• identify a possible linear relationship by looking at a point cloud.• Consider unusual observations in a scatter plot.
Student-facing Lesson Goals	<ul style="list-style-type: none">• Let's use Pyret to create scatter plots of data.
Prerequisites	<ul style="list-style-type: none">• Simple Data Types• Contracts: Making Tables and Displays
Materials	<ul style="list-style-type: none">• PDF of all Handouts and Page• Animals Starter File• Data Exploration Project Slide Template• Lesson Slides• Printable Lesson Plan (a PDF of this web page)
Supplemental Materials	<ul style="list-style-type: none">• Autodesk website (Autodesk)
Preparation	<ul style="list-style-type: none">• All students should log into code.pyret.org (CPO) and open their saved "Animals Starter File". If they don't have the file, they can open a new one from Animals Starter File.

Key Points For The Facilitator

- Make sure students understand what a scatter plot with *no* relationship looks like.
- Point out that randomly sampling a few points from a population with a pattern may not expose that pattern! *Sample size matters!*
- Emphasize the importance of students using their eyes - it's not just about the numbers.

Glossary

dependent variable :: When modeling a relationship between an input and an output (e.g. - distance over time), we are curious about how a change in the input (typically graphed on the x-axis) impacts the output (y). When the output is entirely dependent on the input, we refer to the output as the "dependent variable".

explanatory variable :: When modeling a possible relationship between an input and an output (e.g. - height and age), we are curious about how a change in the input (typically graphed on the x-axis of a scatter plot) might "explain" the output (y). When the behavior of the output may be explained by the input, we refer to the input as the "explanatory variable".

independent variable :: When modeling a relationship between an input and an output (e.g. - distance over time), we are curious about how a change in the input (typically graphed on the x-axis) impacts the output (y). When the output is entirely dependent on the input, we refer to the input as the "independent variable".

quantitative data :: number values for which arithmetic makes sense

response variable :: the variable in a relationship, generally plotted on the y-axis of a scatter plot, that is presumed to be affected by the explanatory variable; in some contexts the response variable is referred to as the "dependent variable" or the "output"

scatter plot :: a display of the relationship between two quantitative variables, graphing each explanatory value on the x axis and the accompanying response on the y axis

Overview

Students create **scatter plots**, which are visualizations that show the relationship between two **quantitative** variables. They learn how to construct scatter plots by hand, and in Pyret.

Launch



- Do you think that younger animals get adopted faster? Why or why not?
 - *The goal here is to have an open discussion and draw students in. Allow students to share their opinions freely. (For example: Yes, baby animals get adopted quickly because they're so cute! No, animals require too much work when they are young.)*
- What kind of data is age? What kind of data is weeks?
 - *Both age and weeks are quantitative.*
- What kind of display would help us analyze the relationship between age and adoption time?
 - *Again, solicit students ideas and discuss why each display type would or would not work.*

Pie and Bar charts help us see the *frequency* of values in a *categorical* column. There are other displays, like histograms and box plots, that help us explore the *distribution* of values in a *quantitative* column.

What we really want is a display that will help us search for a **relationship between two quantitative columns**, and that's exactly what scatter plots do.

Scatter plots reveal the relationship between two columns by plotting one on the x-axis and the other on the y-axis.

Before we can draw a **scatter plot**, we have to make an important decision: which variable is **explanatory** and which is the **response**?

In this case, are we suspecting that an animal's weight can explain how long it takes to be adopted, or that how long it takes to be adopted can explain how much an animal weighs?

The first one makes sense, and reflects our suspicion that age plays a role in adoption time.

It's customary to use the horizontal axis for our explanatory variable and the vertical axis for the response variable. Each row in the dataset will be a point on the scatter plot with age for x and weeks for y.

Why not Independent/Dependent?

When modeling with functions, we typically use terms like *dependent variable* and *independent variable*. But even in the presence of a strong correlation, the y-values in a scatter plot are *never* fully dependent on the x-values. Plenty of scatter plots have no correlation: the y-coordinates do not depend on the x-coordinates at all!

Statisticians commonly use the words *explanatory variable* and *response variable*, to more accurately describe the role one column of data plays in *explaining* another when searching for a relationship.

Investigate

We will produce our scatter plot by graphing each animal as a point, using age for x and weeks for y.



Complete [Creating a Scatter Plot](#) to get a feel for making scatter plots by hand.

Teaching Tip

As an alternative to plotting the small table, assign a handful of rows from the *full table* to each student and have them plot those animals on the board. This can be done collaboratively, resulting in a whole-class scatter plot!

When you created the scatter plot by hand, you started with a Table. Then you plotted a series of dots, using one column for your x's, one column for your y's, and the name column to provide a label for each dot.

The `scatter-plot` function works exactly the same way: it starts with a table, and then needs to know which columns to use for labels, x-coordinates (xs), and y-coordinates (ys). Here's the Contract:

```
# scatter-plot :: ( Table, String, String, String ) -> Image  
                  table-name labels xs ys
```



- Open your saved Animals Starter File, or [make a new copy](#).

- Make a scatter plot that displays the relationship between age and adoption time (weeks).

To do this, students will need to type in:

```
scatter-plot(animals-table, "name", "age", "weeks")
```



- Are there any patterns or trends that you see here?
 - *It appears that younger animals get adopted more quickly.*

What about Line Graphs?

Line graphs and scatter plots have a lot in common! They both visualize the relationship between two columns, and both columns must be quantitative.

There is an important difference, however, in that **line graphs are typically used when the x-axis measures *time***. Only in this situation can it be appropriate to "connect the dots", because they represent the *rise* and *fall* of a measure over time. Without time, there's no notion of "slope"!

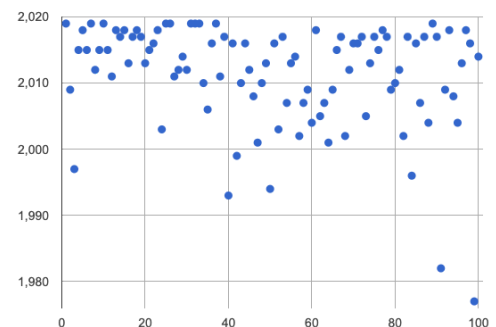
For students who want to use line graphs, the Contract is:

```
# line-graph :: Table, String, String -> Image
```

Synthesize

Have students report back on their findings from the starter file and on [Creating a Scatter Plot](#).

Scatter plots show us a collection of points, arranged along two axes. If there's a relationship between these axes, we'll see clumps and clouds of points in the graph.



- What pattern do you see in *your* scatter plot?
- Are there any points that seem unusual? Why?

- *Suppose we plotted the age and adoption time of four random animals, and found that they all fell in a line.*
- Is this enough to determine that there's a relationship between the variables?
 - *No! Just as four flips of a fair coin might come up tails, four points chosen from a scatter plot with no pattern might still fall on a line! As our sample size increases, the chance of us seeing a pattern by random chance gets smaller and smaller.*

Overview

Students apply what they've learned about scatter plots to the Data Cycle, using it to answer questions about relationships in the animals dataset.

Launch



Is age the only factor that determines how long it takes for an animal to get adopted?

Have students discuss.

Many apartment buildings do not allow large breeds of dogs, and have a limit on how heavy a tenant's dog can be. Bigger dogs are not welcome in many apartments.

*Perhaps the **weight** of an animal influences the adoption time!*



Take a look at the Tte Animals Dataset on [the spreadsheet](#) or on [this page](#) (for those using a printed workbook, you'll find it at the front). Do you think there's a relationship between pounds and weeks in this table? Why or why not?

Do you think there's a relationship between pounds and weeks in this table? Why or why not?

Investigate



Complete the first Data Cycle on [Data Cycle: Relationships in the Animals Dataset](#).

Discuss as a class:

- What did you find when you looked at the scatter-plot?
- Does there appear to be a pattern or trend?
- What might be problematic about including every species in the same scatter plot of weight?
- What follow-up questions do you have?



Write your follow-up question in the second Data Cycle on [Data Cycle: Relationships in the Animals Dataset](#), and complete the Data Cycle for your new question.

Synthesize

There are many ways to visualize or reason about single columns of data, but scatter plots are special because they let us see relationships between two columns at the same time!

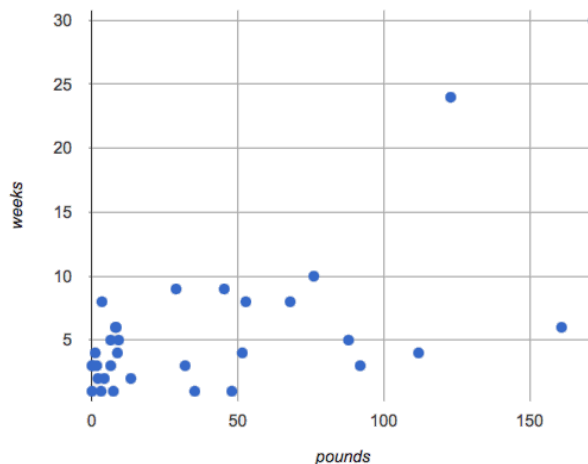
- What new questions did the Data Cycle lead you to ask? What did you find?

Overview

Students are asked to identify patterns in their scatter plots. This activity builds towards the idea of *linear associations*, but does not go into depth (as a later lesson on correlations does).

Launch

Shown below is a scatter plot of the relationships between the animals' pounds and the number of weeks it takes to be adopted.



- Does the number of weeks to adoption seem to go up or down as the weight increases?
- Are there any points that “stray from the pack”? Which ones?

Teaching Tip

Project the scatter plot at the front of the room, and have students come up to the plot to point out their patterns.

A straight-line pattern in the cloud of points suggests a linear relationship between two columns. If we can find a line around which the points cluster (as we'll do in a future lesson), it would be useful for making predictions. For example, our line might predict how many weeks a new dog would wait to be adopted, if it weighs 68 pounds.

- Do any data points seem unusually far away from the main cloud of points?
- Which animals are those?



These points are called **unusual observations**. Unusual observations in a scatter plot are like outliers in a histogram, but more complicated because it's the *combination* of x and y values that makes them stand apart from the rest of the cloud.

Unusual observations are *always* worth thinking about!

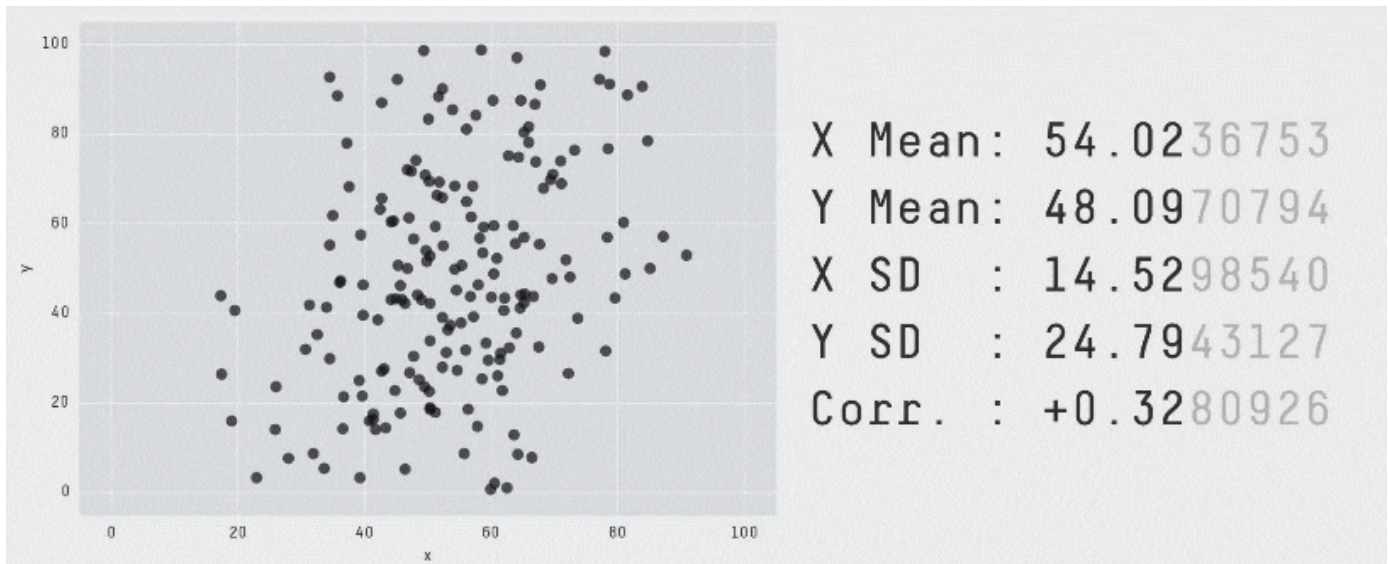
- Sometimes unusual observations are *just random*. Felix seems to have been adopted quickly, considering how much he weighs. Maybe he just met the right family early, or maybe we find out he lives nearby, got lost and his family came to get him. In that case, we might need to do some deep thinking about whether or not it's appropriate to remove him from our dataset.
- Sometimes unusual observations can give you a *deeper insight* into your data. Maybe Felix is a special, popular (and heavy!) breed of cat, and we discover that our dataset is missing an important column for breed!
- Sometimes unusual observations are *the points we are looking for*! What if we wanted to know which restaurants are a good value, and which are rip-offs? We could make a scatter plot of restaurant reviews vs. prices, and look for an observation that's high above the rest of the points. That would be a restaurant whose reviews are *unusually good* for the price. An observation way below the cloud would be a really bad deal.

Investigate

Data Scientists and Statisticians use their eyes all the time. Sometimes there's a pattern hiding in the data, which can't be seen just by focusing on numbers and measures. Until we really look at the *shape* of the data, we aren't seeing the whole picture.

Look at both numbers and displays before drawing conclusions

Each of these scatter plots and accompanying set of numbers corresponds to a dataset. The patterns in the scatter plots vary wildly, but the numbers that summarize the datasets barely change at all!



This animation is from Autodesk, which has an amazing page showing off how similar numbers can be generated from radically different scatter plots. If time allows, have students explore some of the visualizations on the [Autodesk website \(Autodesk\)](#)!



For practice, consider each of the following relationships. First think about what you *expect*, then make the scatter plot to see if it supports your hunch.

- How are the **pounds** of an animal related to its **age**?
- How are the number of **weeks** it takes for an animal to be adopted related to its number of **legs**?
- How are the number of **legs** an animal has related to its **age**?
- Do you see a linear (straight-line) relationship in any of these?
- Are there any unusual observations?

All of these are phrased as "how is the *explanatory variable* related to the *response variable*?"

Synthesize

Debrief, showing the plots on the board. Make sure students see plots for which there is no relationship!

It might be tempting to go straight into making a scatter plot to explore how weeks to adoption may be affected by age. But different animals have very different lifespans!

Why does that matter?

A 5-year-old tarantula is still really young, while a 5-year-old rabbit is fully grown. With differences like this, it doesn't make sense to put them all on the same scatter plot. By mixing them together, we may be *hiding* a real relationship, or creating the illusion of a relationship that isn't really there!

It would be nice if the dots in our scatter plot were different colors or shapes, depending on the species. That would give us a much better picture of what's really going on in the data. **But making a special image for every single row in the table would take a very long time!** If only there was a function with a Contract like:

```
species-dot :: (r :: Row) -> Image
```

This function could take in a row from the animals table, and draw a special dot depending on the species. Unfortunately, no such function exists...yet!

There are ways to [define functions of your own](#), and extend Pyret to deepen your analysis, [create more useful and engaging charts](#), and dig further into our data.

Data Exploration Project (Scatter Plots)

flexible

Overview

Students apply what they have learned about scatter plots to their chosen dataset. They will add two items to their [Data Exploration Project Slide Template](#): (1) at least two scatter plots and (2) any interesting questions that emerge. To learn more about the sequence and scope of the Exploration Project, visit [Project: Dataset Exploration](#). For teachers with time and interest, [Project: Create a Research Project](#) is an extension of the Dataset Exploration, where students select a single question to investigate via data analysis.

Launch

Let's review what we have learned about making and interpreting scatter plots.



- Does a scatter plot display categorical or quantitative data? How many columns of data does a scatter plot display?
 - *Scatter plots display two columns of quantitative data and a third column of quantitative or categorical data is used to label the points.*
- What do scatter plots show us about a dataset?
 - *Scatter plots allow us to look for relationships between two columns of dataset.*

Investigate

Let's connect what we know about scatter plots to your chosen dataset.



- Open your chosen dataset starter file in Pyret.
 - *Students have the opportunity to choose a dataset that interests them from our [List of Datasets](#) in the [Choosing Your Dataset](#) lesson.*
- Choose two quantitative columns from your dataset whose relationship you want to explore, and another column that makes sense to use as labels for your points.
- What question does your display answer?
 - *Possible response: What is the relationship between column A and column B of my dataset?*
- Write down that question in the top section of [Data Cycle: Relationships in Your Dataset](#).
- Complete the rest of the data cycle, recording how you considered, analyzed and interpreted the question.
- Repeat this process for at least one other pair of quantitative columns.

Confirm that all students have created and understand how to interpret their scatter plots. Once you are confident that all students have made adequate progress, invite them to access their [Data Exploration Project Slide Template](#) from Google Drive.



- It's time to add to your [Data Exploration Project Slide Template](#).
- Copy/paste at least two scatter plots. Be sure to also add any interesting questions that you developed while making and thinking about your scatter plots.

You may need to help students locate the "Scatter plot" slide in the "Making Displays" section. They will need to duplicate the slide to add their second display. The "My Questions" section is at the end of the slide deck.

Synthesize

Share your findings!

Were the relationships you investigated stronger or weaker than they expected?

What questions did the scatter plots raise about your dataset?

What, if any, outliers did you discover when making scatter plots?

Were there any surprises when you compared your findings with other students? (For instance: Did everyone find outliers? Was there more or less similarity than expected?)