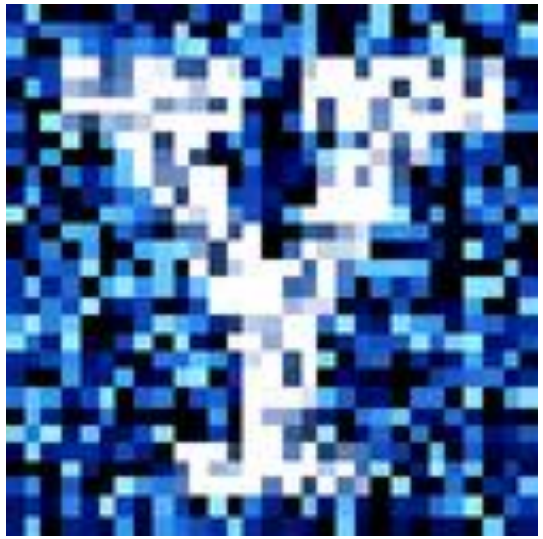
YData: Introduction to Data Science



Class 06: Array computations

Overview

Brief review of statistics and visualizations

NumPy arrays

- Creating arrays
- Array computations
- Boolean masking
- If there is time: Percentiles and boxplots

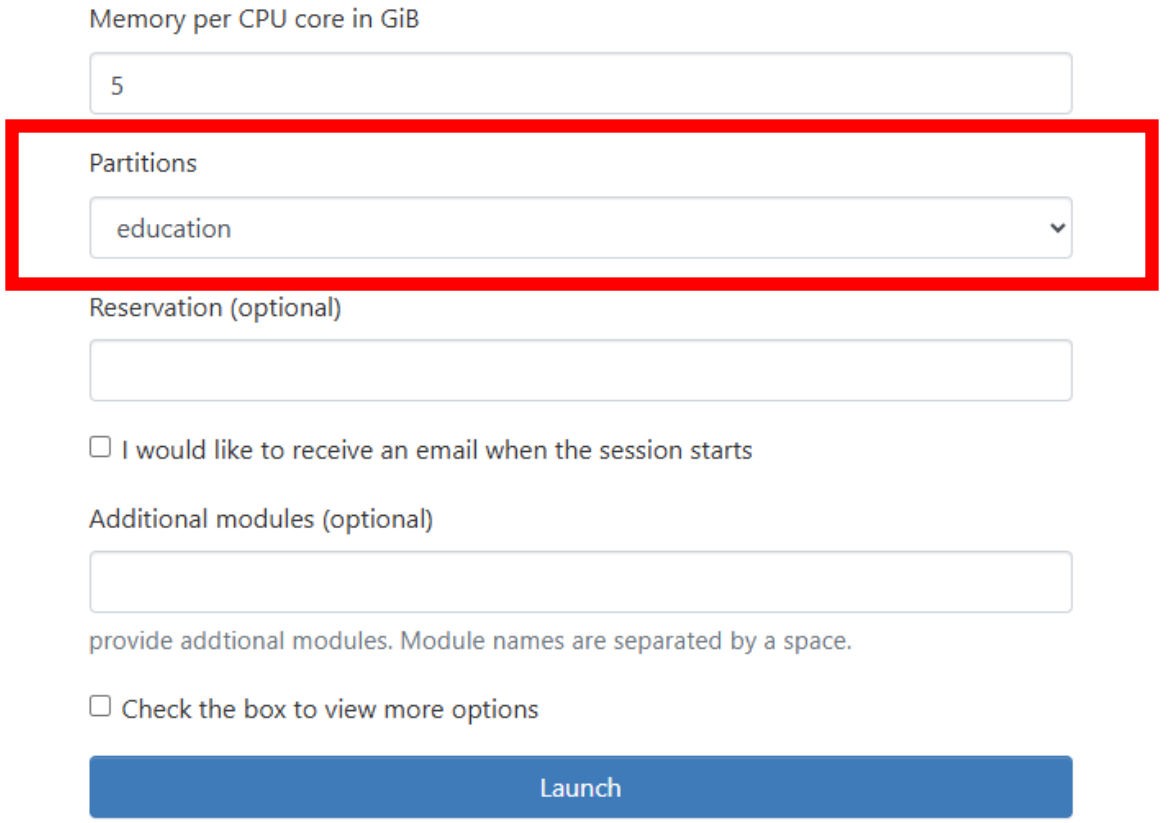
Announcement

Homework 3 has been posted!

It is due on Gradescope on Sunday September 21st at 11pm

- **Be sure to mark each question on Gradescope!**

Also, be sure to use the “education” partition on the YCRC server



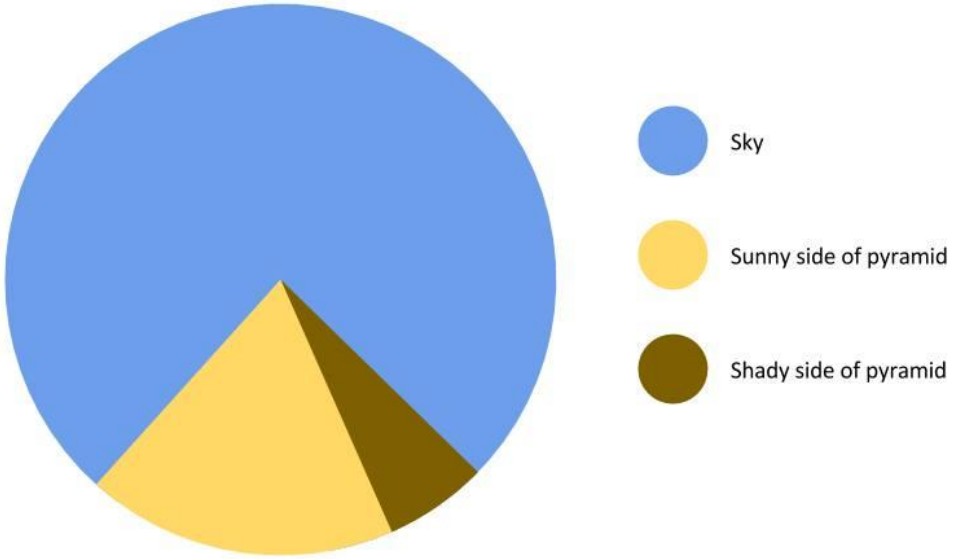
Quick review: categorical data

Categorical data

$$\text{Proportion} = \frac{\text{number in category}}{\text{total number}}$$

```
bechdel.count("PASS")/len(bechdel)
```

```
import matplotlib.pyplot as plt
    plt.bar(labels, data)
    plt.pie(data)
```



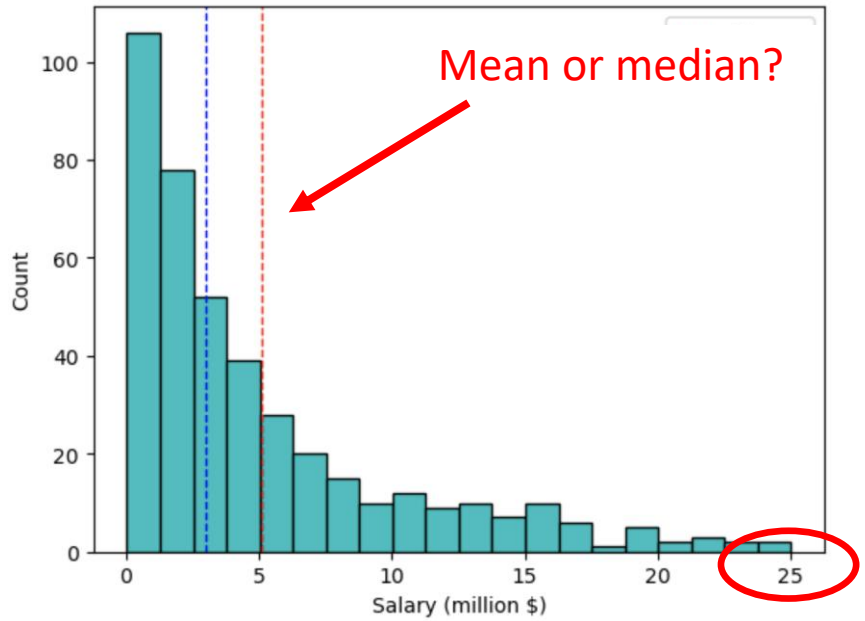
Quick review: one quantitative variable data

Basics statistics and plots:

plt.hist(data)

statistics.mean(data) $= \frac{1}{n}\sum_{i=1}^{n} x_i$

statistics.median(data)

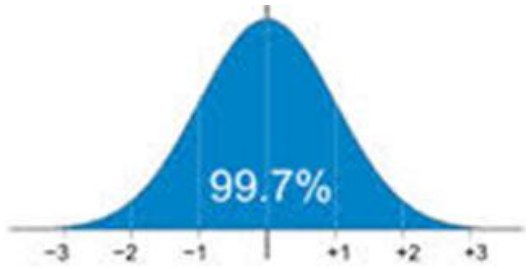


Outliers

Quantitative data spread

statistics.stdev(data) $s = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \overline{x})^2}$

$$\text{z-score}(x_i) = \frac{x_i - \bar{x}}{s}$$



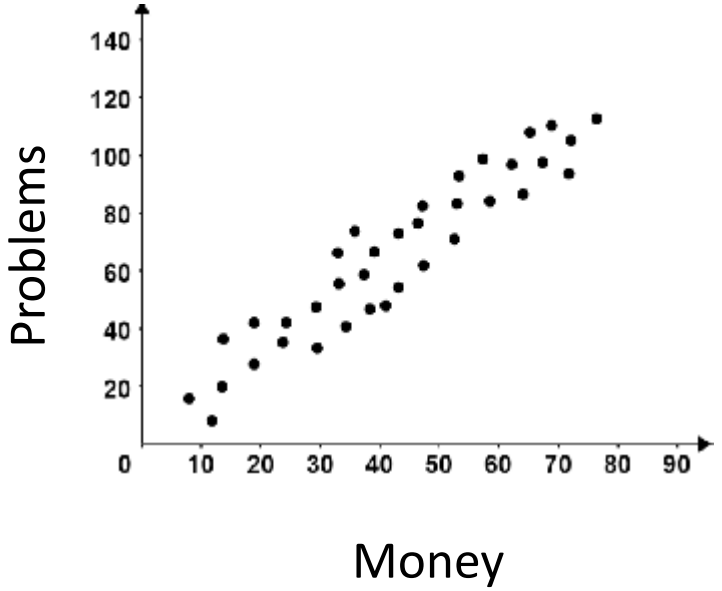
Quick review: two quantitative variables data

Basics statistics and plots:

plt.plot(x, y, '.')

statistics.correlation(x, y)

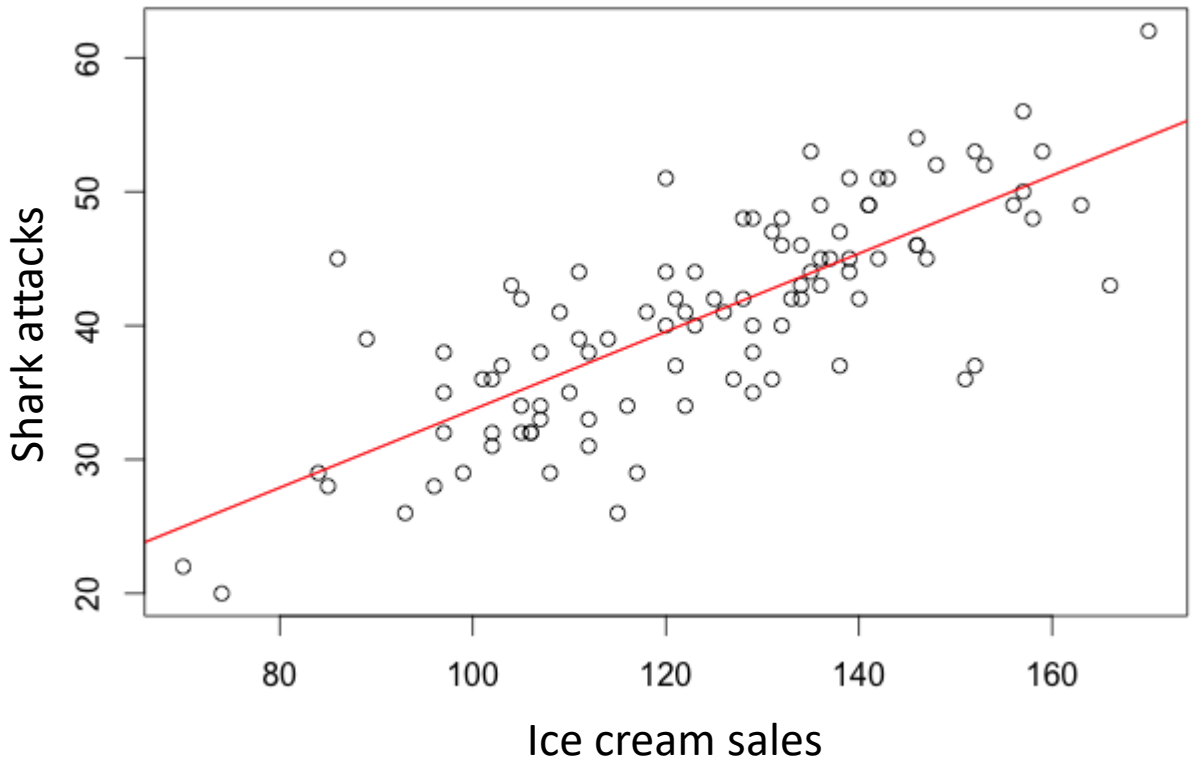
$$r = \frac{1}{(n-1)} \sum_{i=1}^{n} \left(\frac{x_i - \overline{x}}{s_x} \right) \left(\frac{y_i - \overline{y}}{s_y} \right)$$



- Correlation as always between -1 and 1: $-1 \leq r \leq 1$
- The sign of r indicates the direction of the association
- Values close to ± 1 show strong linear relationships, values close to 0 show no linear relationship
- Correlation is symmetric: r = cor(x, y) = cor(y, x)

Correlation caution #1

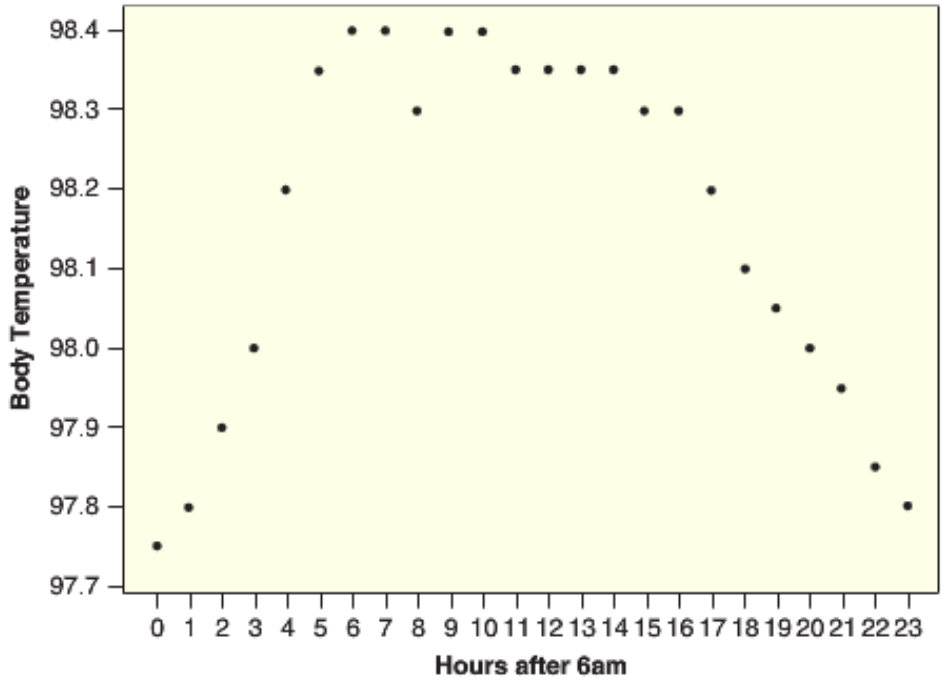
A strong positive or negative correlation does not (necessarily) imply a cause and effect relationship between two variables



Correlation caution #2

A correlation near zero does not (necessarily) mean that two variables are not associated. Correlation only measures the strength of a linear relationship.

Example: Body temperature as a function of time of the day



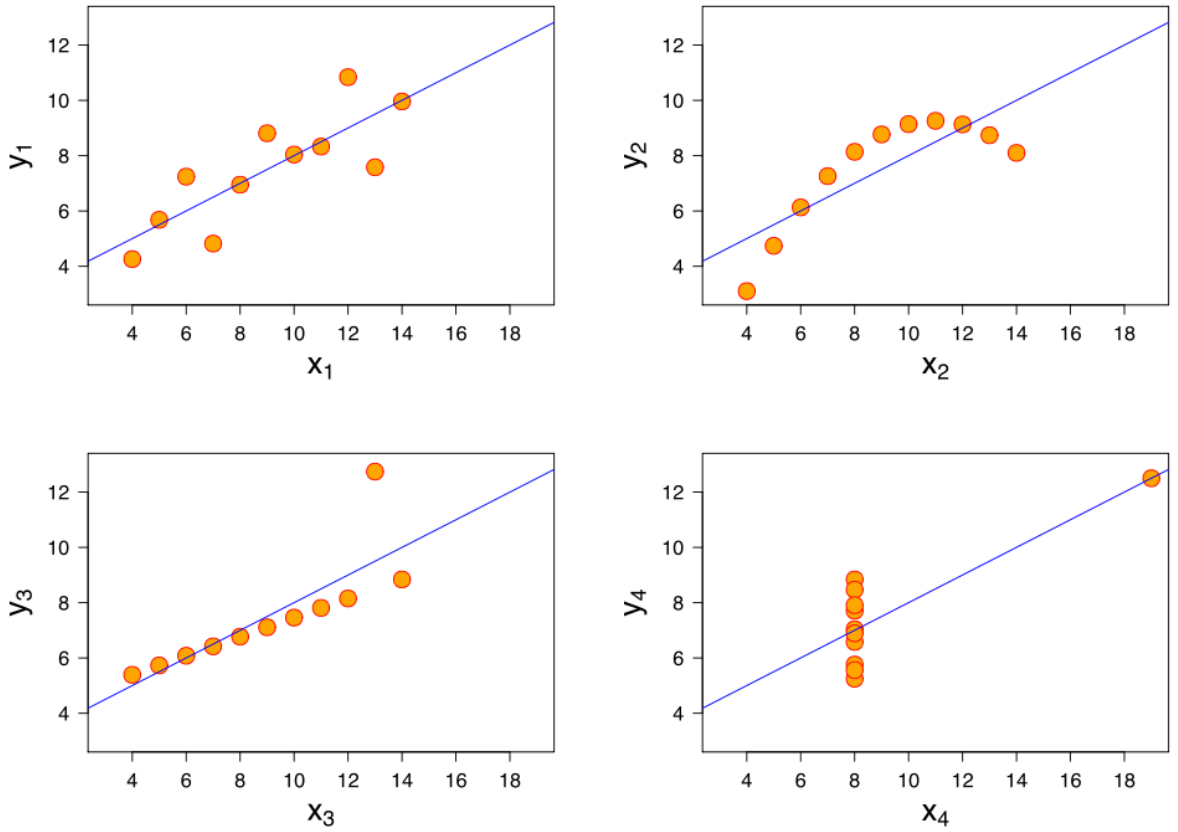
r = -0.08

Correlation caution #3

Correlation can be heavily influenced by outliers. Always plot your data!

Example:
"Anscombe's quartet"

r = 0.81 for all plots



Warm-up exercises: NBA salaries

Let’s practice analyzing data by explore salaries of NBA players

- (from the 2022-2023 season)

Player Name	Salary	Position	Team	PTS
Stephen Curry	48070014	PG	GSW	29.4
John Wall	47345760	PG	LAC	11.4
Russell Westbrook	47080179	PG	LAL/LAC	15.9
LeBron James	44474988	PF	LAL	28.9
Kevin Durant	44119845	PF	BRK/PHO	29.1
Bradley Beal	43279250	SG	WAS	23.2
Kawhi Leonard	42492492	SF	LAC	23.8
Paul George	42492492	SF	LAC	23.8
Giannis Antetokounmpo	42492492	PF	MIL	31.1
Damian Lillard	42492492	PG	POR	32.2

Array computations

Arrays

Often, we are processing data that is all of the same type

- For example, we might want to do processing on a data set of numbers
  - e.g., if we were analyzing salary data

When we have data that is all of the same type, there are more efficient ways to process data than using a list

- i.e., methods that are faster and take up less memory

In Python, the *NumPy package* offers ways to store and process data that is all of the same type using a data structure called a ***ndarray***

There are also functions that operate on ndarrays that can do computations very efficiently

ndarrays

We can import the NumPy package using: `import numpy as np`

We can then create an array by passing a list to the *np.array()* function

- `my_array = np.array([1, 2, 3])`

We can get elements of an array using similar syntax as using a list

- `my_array[1]` `# what does this return`

ndarrays have properties that tell us the type and size

- `my_array.dtype` `# get the type of elements stored in the array`
- `my_array.shape` `# get the dimension of the array`
- `my_array.astype('str')` `# convert the numbers to strings`
- `sequential_nums = np.arange(1, 10)` `# creates numbers 1 to 9`

Let's explore this in Jupyter!

NumPy functions on numerical arrays

The NumPy package has a number of functions that operate very efficiently on numerical ndarrays

- np.sum(), np.max(), np.min()
- np.mean(), np.median()
- np.diff() # takes the difference between elements
- np.cumsum() # cumulative sum
- np.prod() # calculates the product of all elements in an array $\prod_{i=1}^{n} x_i$

There are also "broadcast" functions that operate on all elements in an array

- my_array = np.array([12, 4, 6, 3, 4, 3, 7, 4])
- my_array * 2
- my_array2 = np.array([10, 9, 2, 8, 9, 3, 8, 5])
- my_array - my_array2

FRED: Federal Reserve Economic Data

Federal Reserve Economic Data (FRED) is a database maintained by the Research division of the Federal Reserve Bank of St. Louis that has more than 816,000 economic time series from various sources.

They cover:

- E.g., Consumer price indexes
- Employment and population
- Gross domestic product
- Producer price indexes
- Etc.

We can read this data into Python using pandas_datareader

```
from pandas_datareader.fred import FredReader

FredReader("GASREGW").read()
```

Let's explore numpy functions using the price of gas from FRED!

Boolean arrays

It is often to compare all values in an ndarray to a particular value

- my_array = np.array([12, 4, 6, 3, 4, 3, 7, 4])
- my_array < 5 # any guesses what this will return
  - array([False, True, False, True, True, True, False, True])

This can be useful for calculating proportions

- True == 1 and False == 0
- Taking the sum of a Boolean array gives the total number of True values
- The number of True 's divided by the length is the proportion
  - Or we can use the np.mean() function

Categorical Variable

PLAYER	POSITION	TEAM	SALARY
str	str	str	f64
"Paul Millsap"	"PF"	"Atlanta Hawks"	18.671659
"Al Horford"	"C"	"Atlanta Hawks"	12.0
"Tiago Splitter..."	"C"	"Atlanta Hawks"	9.75625
"Jeff Teague"	"PG"	"Atlanta Hawks"	8.0
"Kyle Korver"	"SG"	"Atlanta Hawks"	5.746479

$$\text{Proportion centers} = \frac{\text{number of centers}}{\text{total number}}$$

Let's explore this in Jupyter!

Boolean masking

We can also use Boolean arrays to return values in another array

- This is called "Boolean masking", "Boolean subsetting" or "Boolean indexing"

```
my_array = np.array([12, 4, 6, 3])
boolean_mask = np.array([False, True, False, True])

smaller_array = my_array[boolean_mask]
```

This can be useful for calculating statistics on data that meet particular criteria:

- `np.mean(my_array[my_array < 5])  # what does this do?`

Boolean masking

Suppose you wanted to get the average movie revenue for movies that passed the Bechdel test

- domgross_2013: Movie revenue
- bechdel: whether a movie passed the Bechdel test

Can you do it?

Let's explore this in Jupyter!

Percentiles

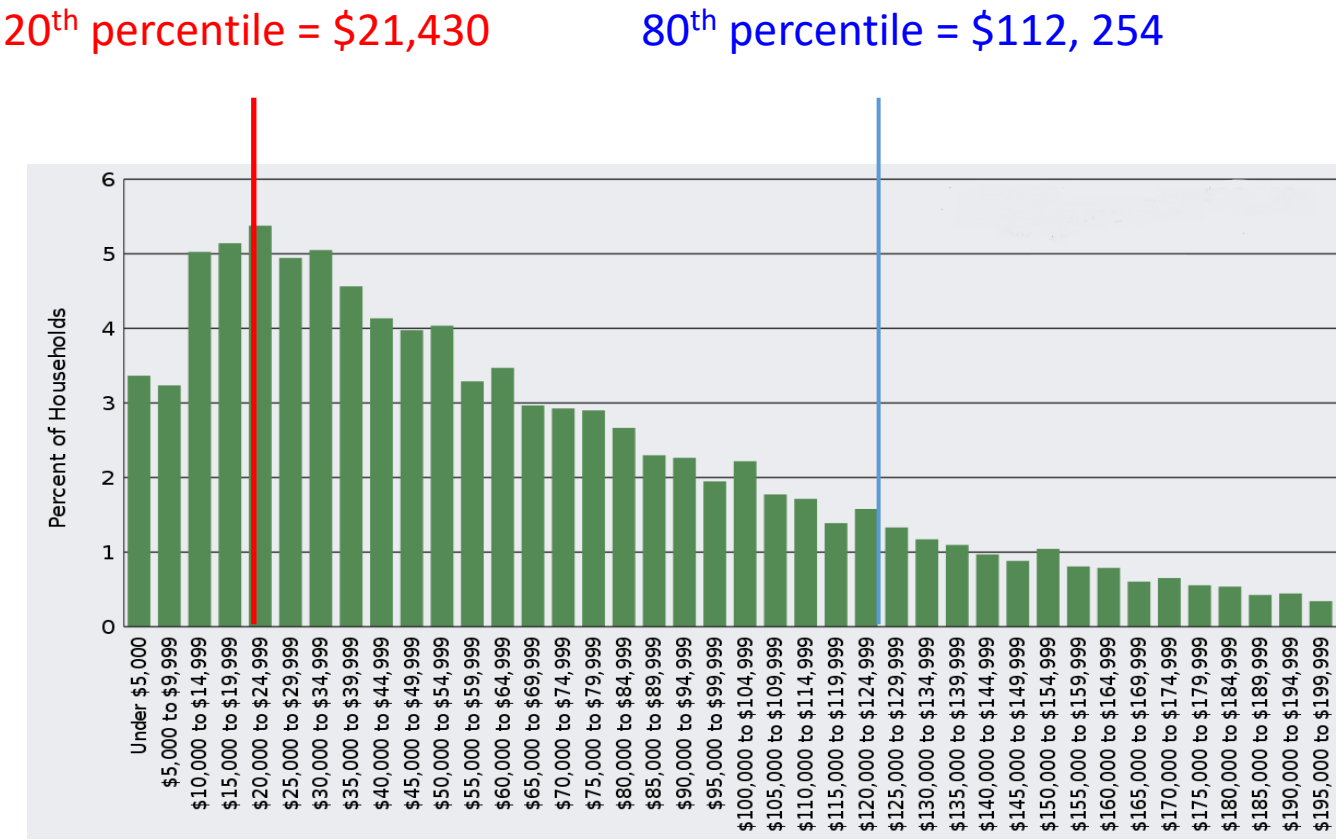
The **p^{th} percentile** is the value ***x*** which is greater than P percent of the data

- i.e., p% of your data is less than the value x

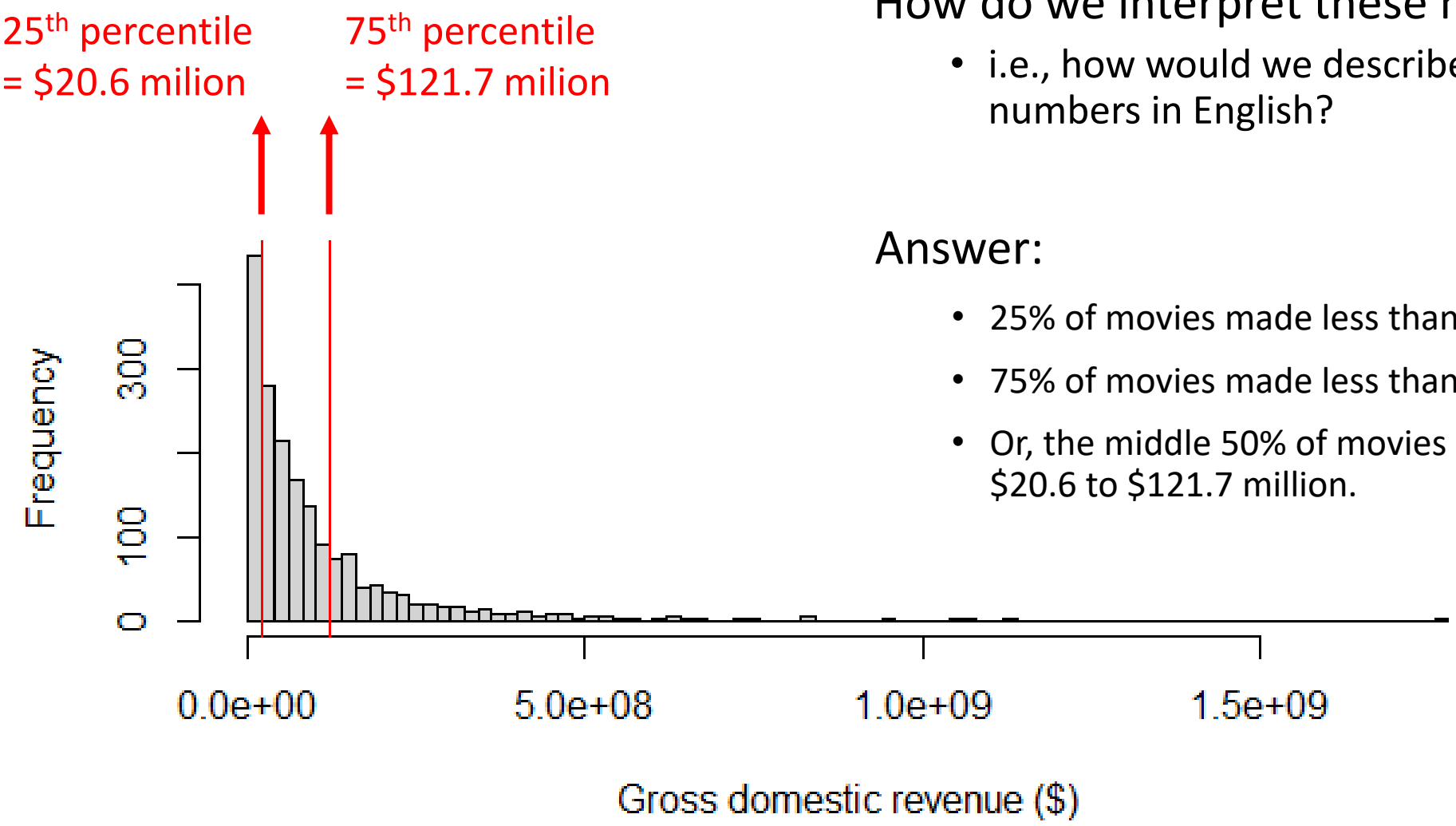
For the US income distribution what are the 20^{th} and 80^{th} percentiles?

We can calculate percentiles using np.percentile()

np.percentile(data, [20, 80])



Movie revenue percentiles



How do we interpret these numbers?

- i.e., how would we describe these numbers in English?

Answer:

- 25% of movies made less than $20.6 million
- 75% of movies made less than $121.7 million
- Or, the middle 50% of movies made between $20.6 to $121.7 million.

Five Number Summary

Five Number Summary = (minimum, Q_1, median, Q_3, maximum)

Q_1 = 25^{th} percentile (also called 1^{st} quartile)

Q_3 = 75^{th} percentile (also called 3^{rd} quartile)

Roughly divides the data into fourths

Range and Interquartile Range

Range = maximum – minimum

Interquartile range (IQR) = $Q_3 - Q_1$

Let's calculate these statistics on Bechdel movie revenue data!

Box plots and outliers

Detecting of outliers

As a rule of thumb, we call a data value an **outlier** if it is:

Smaller than: Q_1 - 1.5 * IQR

Larger than: Q_3 + 1.5 * IQR

Box plots

A **box plot** is a graphical display of the five-number summary and consists of:

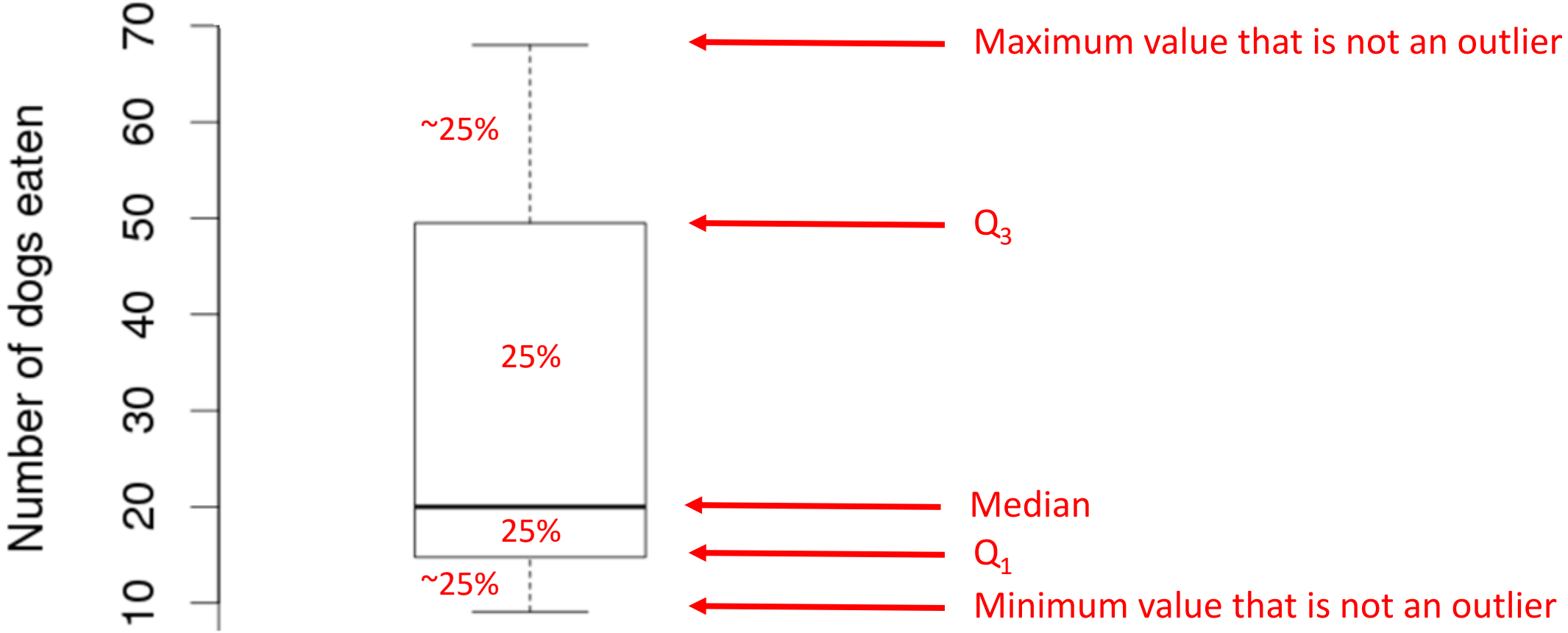
1. Drawing a box from Q_1 to Q_3

2. Dividing the box with a line (or dot) drawn at the median

3. Draw a line from each quartile to the most extreme data value that is not and outlier

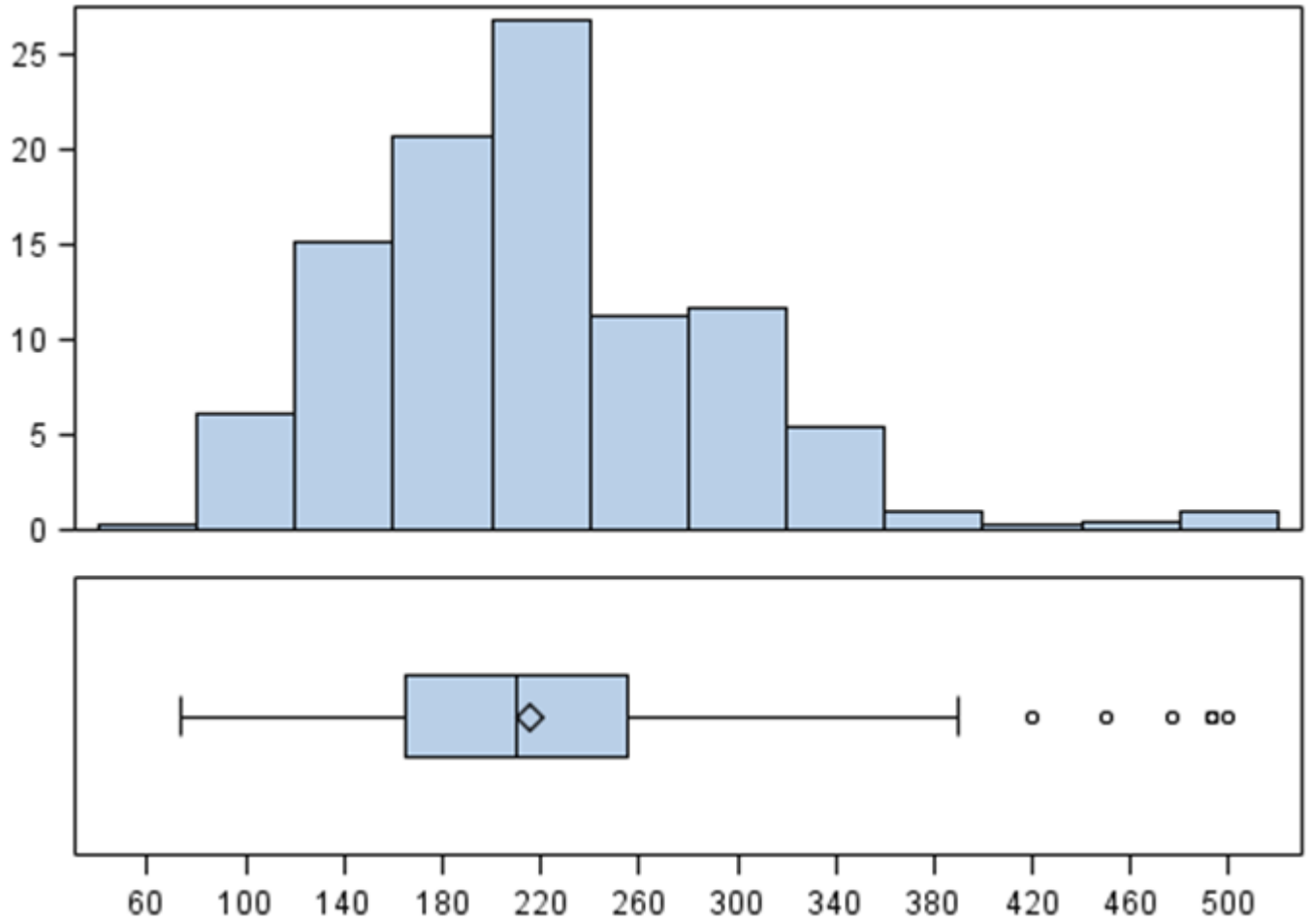
4. Draw a dot/asterisk for each outlier data point.

Box plot of the number of hot dogs eaten by the men's contest winners 1980 to 2010



Matplotlib: `plt.boxplot(data, tick_labels)`

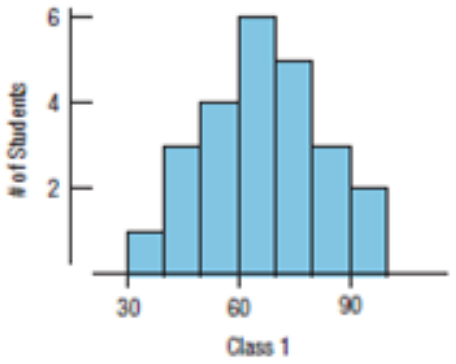
Box plots extract key statistics from histograms



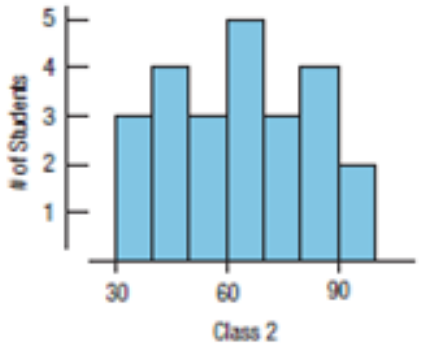
Box plots extract key statistics from histograms

Question: which Box plot goes with which histogram?

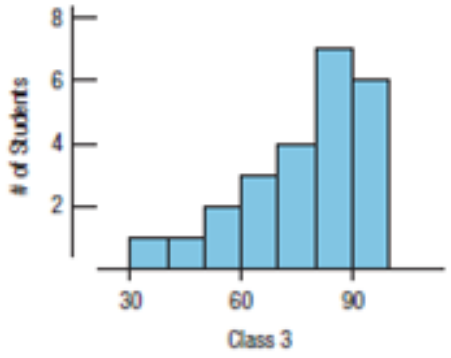
Histogram 1

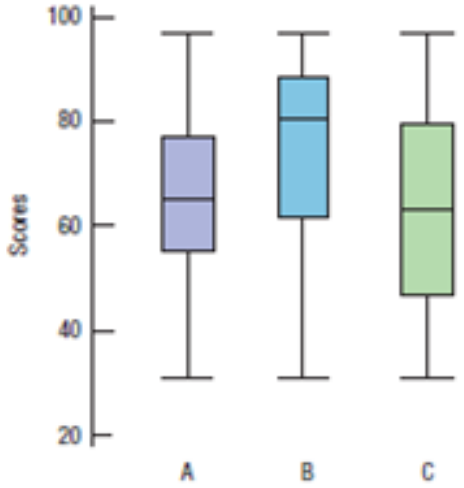


Histogram 2



Histogram 3

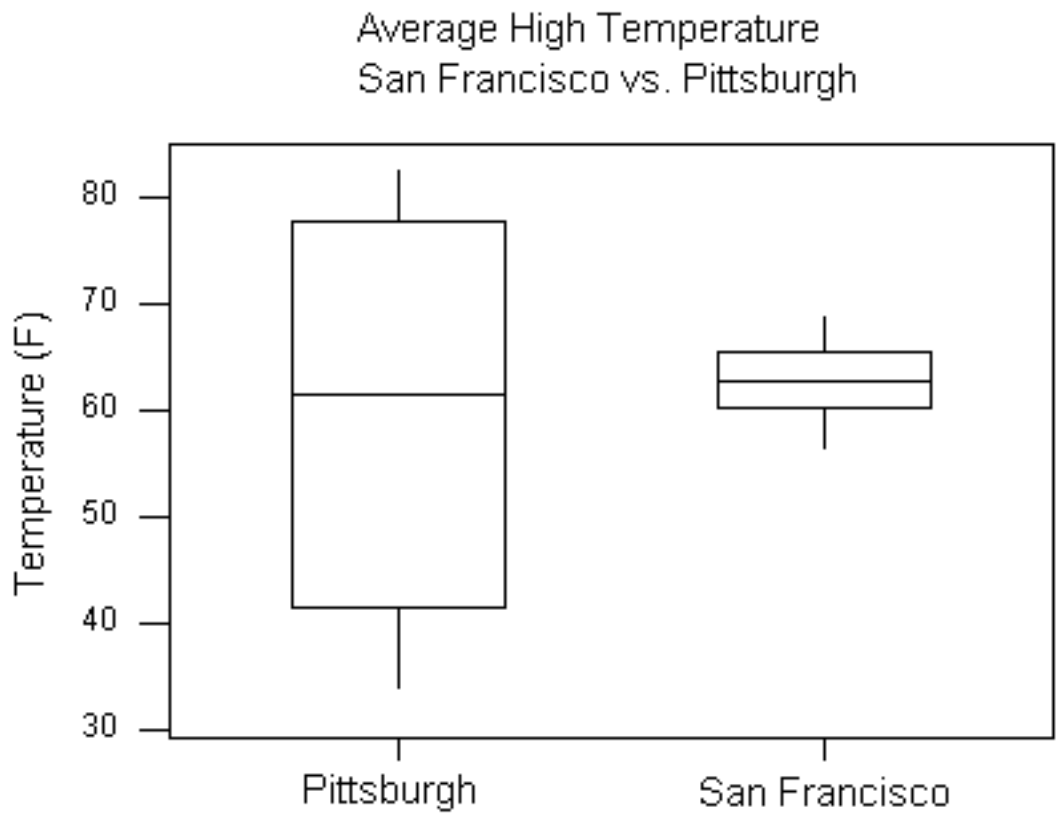




Comparing quantitative variables across categories

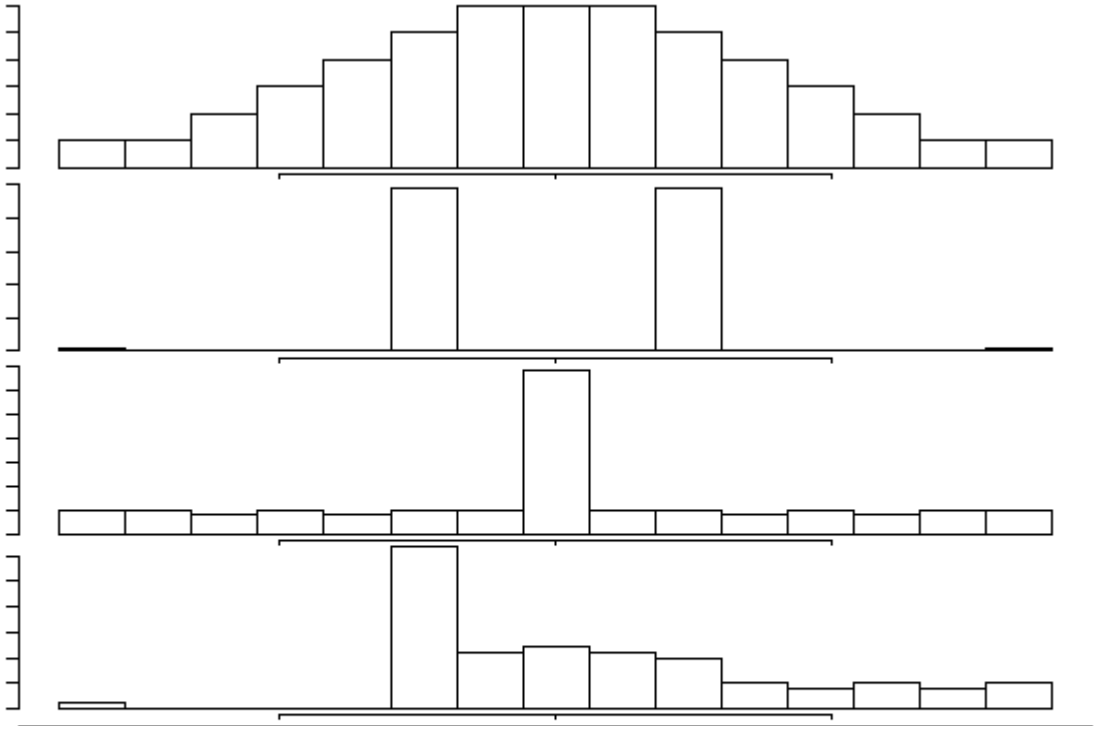
Often one wants to compare quantitative variables across categories

Side-by-Side graphs are a way to visually compare quantitative variables across different categories




```
plt.boxplot([data1, data2],  tick_ labels = ["name 1", "name 2"])
```

Box plots don’t capture everything



Do you think the box plots for these distributions look similar?

Let's explore side-by side boxplots on the Bechdel data to try to see if movies that pass the Bechdel test make a larger profit!