What is statistics?

INTRODUCTION TO STATISTICS IN PYTHON

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What is statistics?

- **The field of statistics** - the practice and study of collecting and analyzing data
- **A summary statistic** - a fact about or summary of some data

What can statistics do?

What is statistics?

- **The field of statistics** - the practice and study of collecting and analyzing data
- **A summary statistic** - a fact about or summary of some data

What can statistics do?

- How likely is someone to purchase a product? Are people more likely to purchase it if they can use a different payment system?
- How many occupants will your hotel have? How can you optimize occupancy?
- How many sizes of jeans need to be manufactured so they can fit 95% of the population? Should the same number of each size be produced?
- A/B tests: Which ad is more effective in getting people to purchase a product?

What can't statistics do?

- *Why* is *Game of Thrones* so popular?

Instead...

- Are series with more violent scenes viewed by more people?

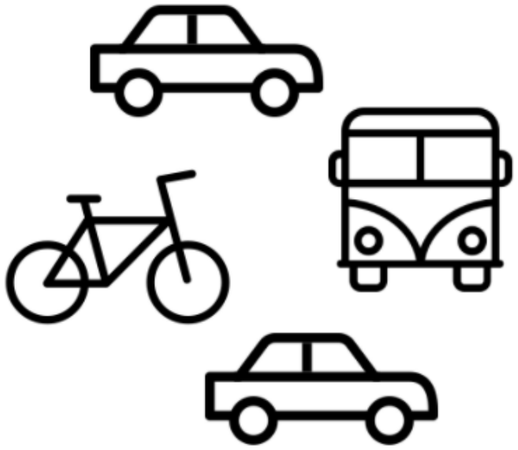
But...

- Even so, this can't tell us if more violent scenes lead to more views

Types of statistics

Descriptive statistics

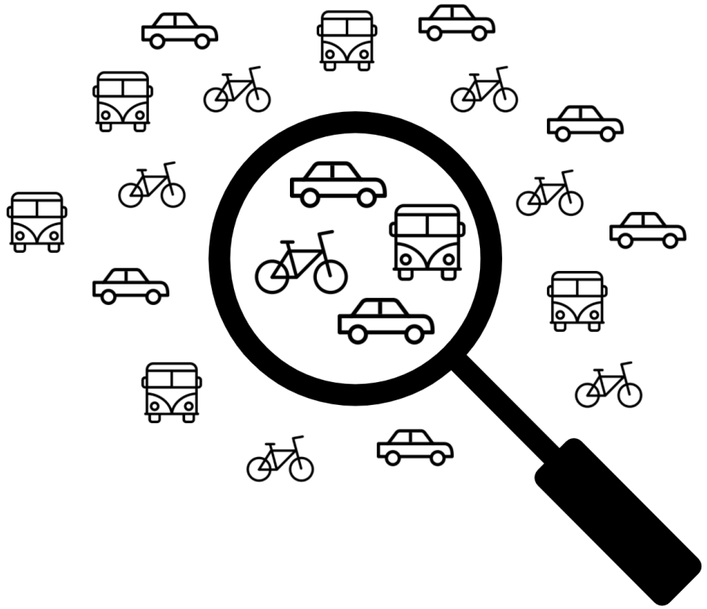
- *Describe* and summarize data



- 50% of friends drive to work
- 25% take the bus
- 25% bike

Inferential statistics

- Use a sample of data to make *inferences* about a larger population



What percent of people drive to work?

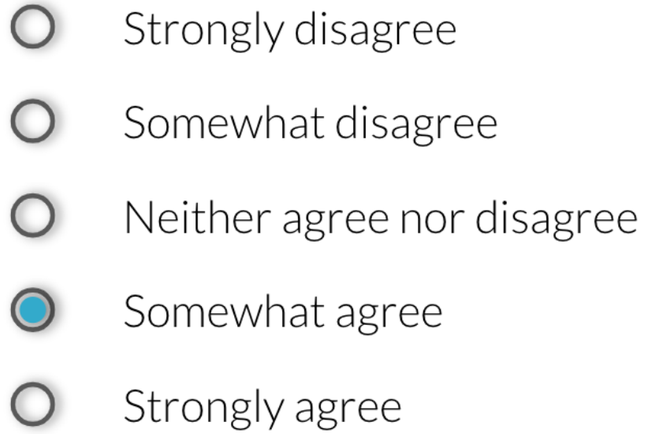
Types of data

Numeric (Quantitative)

- **Continuous (Measured)**
  - Airplane speed
  - Time spent waiting in line
- **Discrete (Counted)**
  - Number of pets
  - Number of packages shipped

Categorical (Qualitative)

- **Nominal (Unordered)**
  - Married/unmarried
  - Country of residence
- **Ordinal (Ordered)**



Categorical data can be represented as numbers

Nominal (Unordered)

- Married/unmarried (`1` / `0`)
- Country of residence (`1` , `2` , ...)

Ordinal (Ordered)

- Strongly disagree (`1`)
- Somewhat disagree (`2`)
- Neither agree nor disagree (`3`)
- Somewhat agree (`4`)
- Strongly agree (`5`)

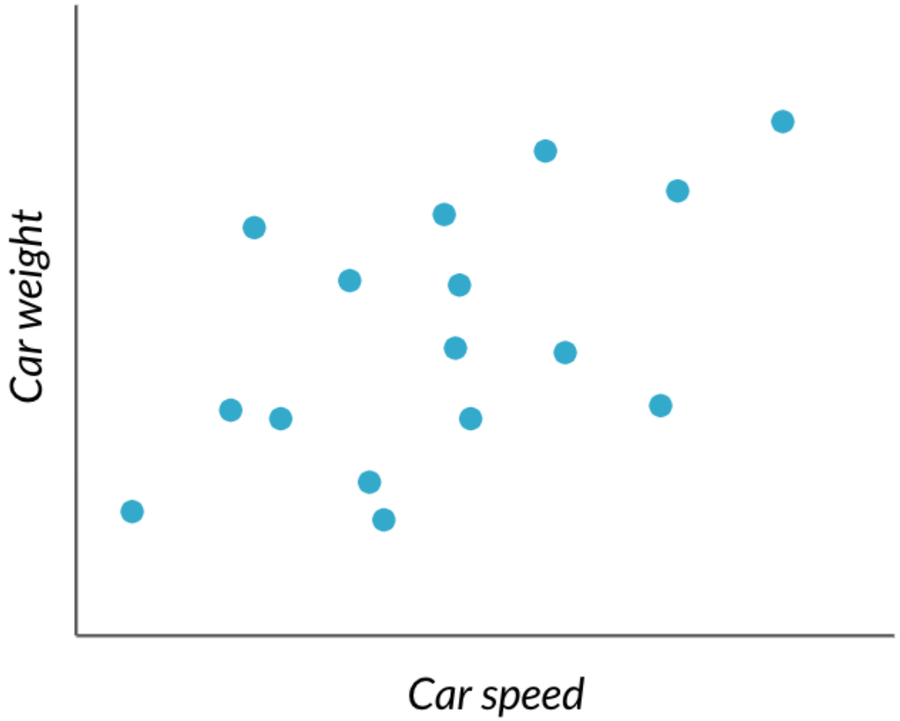
Why does data type matter?

Summary statistics

```
import numpy as np
np.mean(car_speeds['speed_mph'])
```

```
40.09062
```

Plots



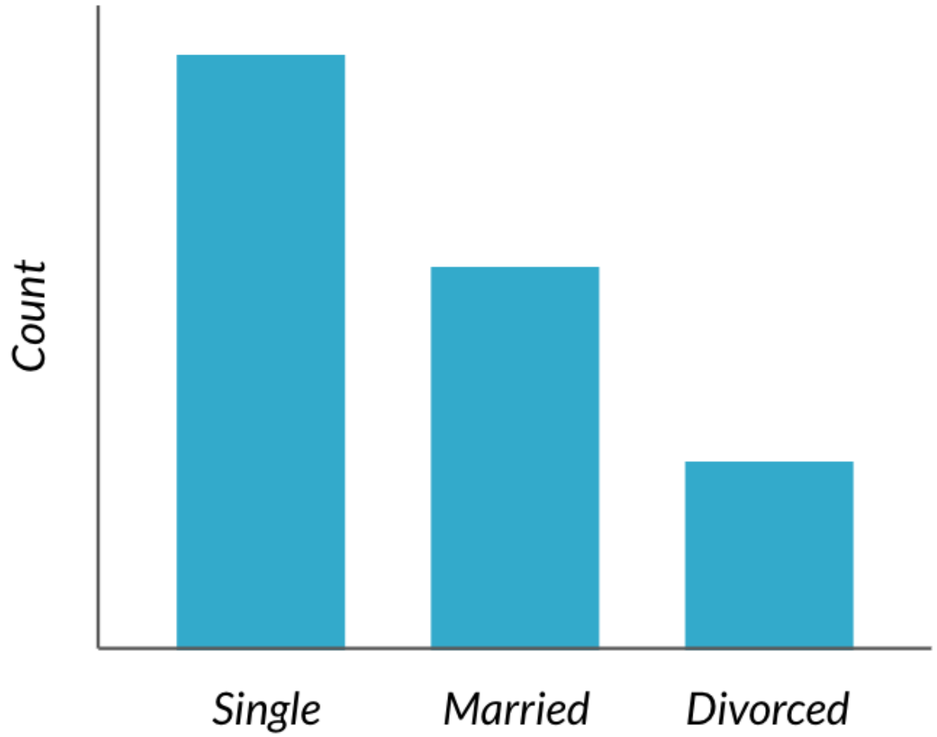
Why does data type matter?

Summary statistics

```
demographics['marriage_status'].value_counts()
```

```
single      188
married     143
divorced    124
dtype: int64
```

Plots



Let's practice!

INTRODUCTION TO STATISTICS IN PYTHON

Measures of center

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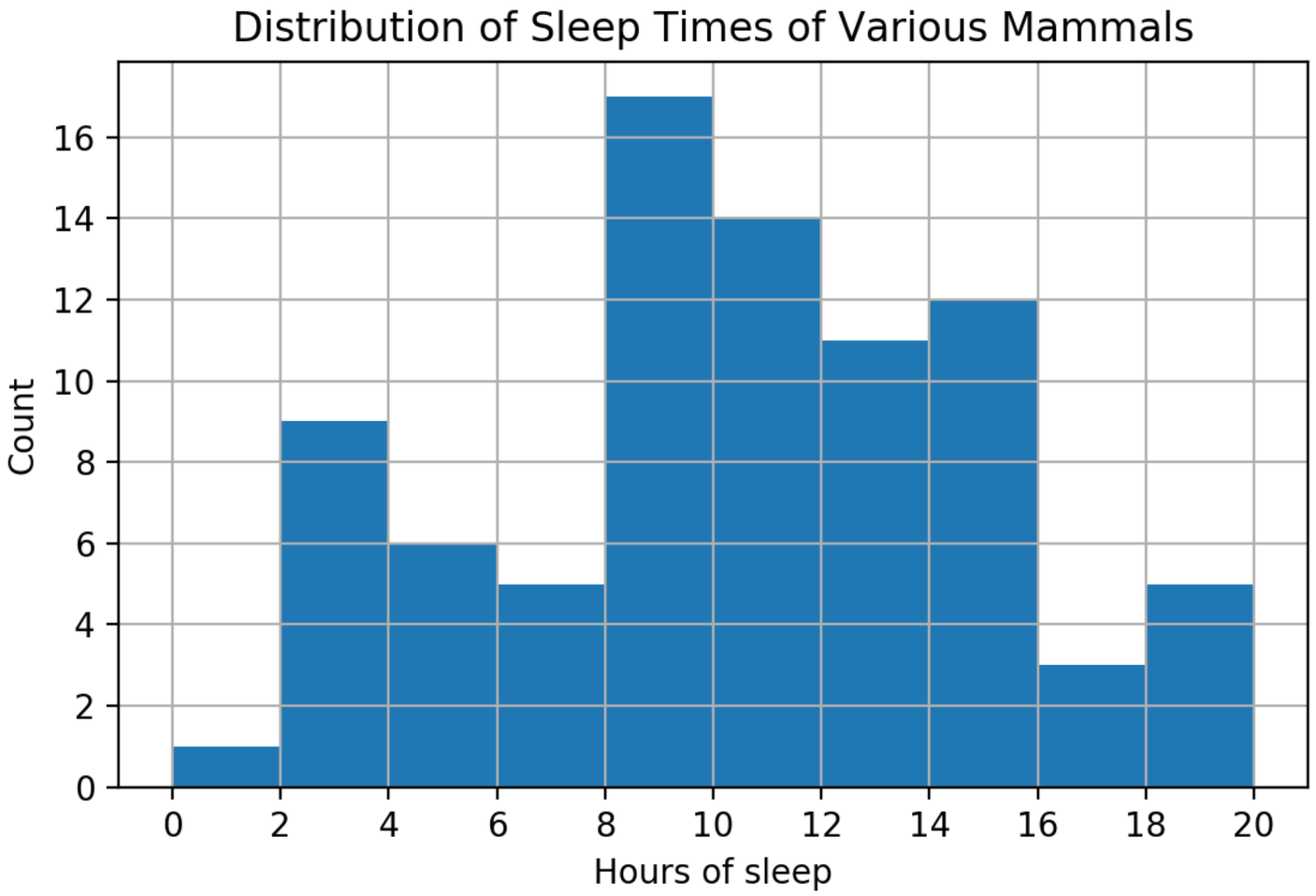
Mammal sleep data

```
print(msleep)
```

```
                 name       genus   vore         order  ... sleep_cycle  awake  brainwt   bodywt
1             Cheetah    Acinonyx  carni     Carnivora  ...         NaN   11.9      NaN   50.000
2          Owl monkey       Aotus   omni      Primates  ...         NaN    7.0  0.01550    0.480
3     Mountain beaver  Aplodontia  herbi      Rodentia  ...         NaN    9.6      NaN    1.350
4 Greater short-ta...     Blarina   omni  Soricomorpha  ...    0.133333    9.1  0.00029    0.019
5                 Cow         Bos  herbi  Artiodactyla  ...    0.666667   20.0  0.42300  600.000
..                ...         ...    ...           ...  ...         ...    ...      ...      ...
79         Tree shrew      Tupaia   omni    Scandentia  ...    0.233333   15.1  0.00250    0.104
80 Bottle-nosed do...    Tursiops  carni       Cetacea  ...         NaN   18.8      NaN  173.330
81              Genet     Genetta  carni     Carnivora  ...         NaN   17.7  0.01750    2.000
82         Arctic fox       Vulpes  carni     Carnivora  ...         NaN   11.5  0.04450    3.380
83            Red fox       Vulpes  carni     Carnivora  ...    0.350000   14.2  0.05040    4.230
```

Histograms

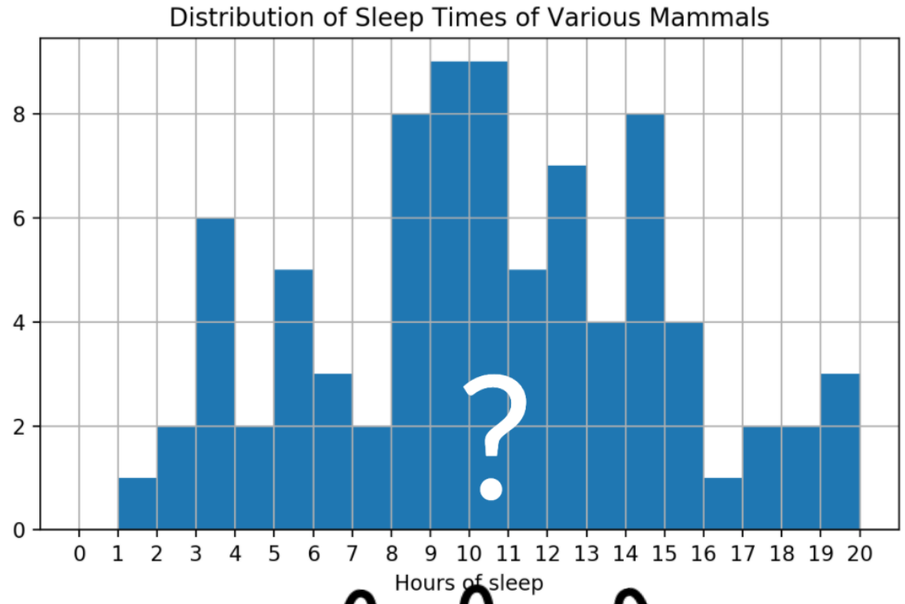

Distribution of Sleep Times of Various Mammals
Count
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
12
14
16
18
20
Hours of sleep

How long do mammals in this dataset typically sleep?

What's a typical value?

Where is the center of the data?

- Mean
- Median
- Mode



Measures of center: mean

	name	sleep_total
1	Cheetah	12.1
2	Owl monkey	17.0
3	Mountain beaver	14.4
4	Greater short-t...	14.9
5	Cow	4.0
..	...	...

```
import numpy as np
np.mean(msleep['sleep_total'])
```

```
10.43373
```

$$\text{Mean sleep time} = \frac{12.1 + 17.0 + 14.4 + 14.9 + \ldots}{83} = 10.43$$

Measures of center: median

```
msleep['sleep_total'].sort_values()
```

```
29     1.9
30     2.7
22     2.9
9      3.0
23     3.1
      ...
19    18.0
61    18.1
36    19.4
21    19.7
42    19.9
```

```
msleep['sleep_total'].sort_values().iloc[41]
```

```
10.1
```

```
np.median(msleep['sleep_total'])
```

```
10.1
```

Measures of center: mode

Most frequent value

```
msleep['sleep_total'].value_counts()
```

```
12.5    4
10.1    3
14.9    2
11.0    2
8.4     2
...
14.3    1
17.0    1
Name: sleep_total, Length: 65, dtype: int64
```

```
msleep['vore'].value_counts()
```

```
herbi      32
omni       20
carni      19
insecti     5
Name: vore, dtype: int64
```

```
import statistics
statistics.mode(msleep['vore'])
```

```
'herbi'
```

Adding an outlier

```
msleep[msleep['vore'] == 'insecti']
```

	name	genus	vore	order	sleep_total
22	Big brown bat	Eptesicus	insecti	Chiroptera	19.7
43	Little brown bat	Myotis	insecti	Chiroptera	19.9
62	Giant armadillo	Priodontes	insecti	Cingulata	18.1
67	Eastern american mole	Scalopus	insecti	Soricomorpha	8.4

Adding an outlier

```
msleep[msleep['vore'] == "insecti"]['sleep_total'].agg([np.mean, np.median])
```

```
mean      16.53
median    18.9
Name: sleep_total, dtype: float64
```

Adding an outlier

```
msleep[msleep['vore'] == 'insecti']
```

	name	genus	vore	order	sleep_total
22	Big brown bat	Eptesicus	insecti	Chiroptera	19.7
43	Little brown bat	Myotis	insecti	Chiroptera	19.9
62	Giant armadillo	Priodontes	insecti	Cingulata	18.1
67	Eastern american mole	Scalopus	insecti	Soricomorpha	8.4
84	Mystery insectivore	...	insecti	...	0.0

Adding an outlier

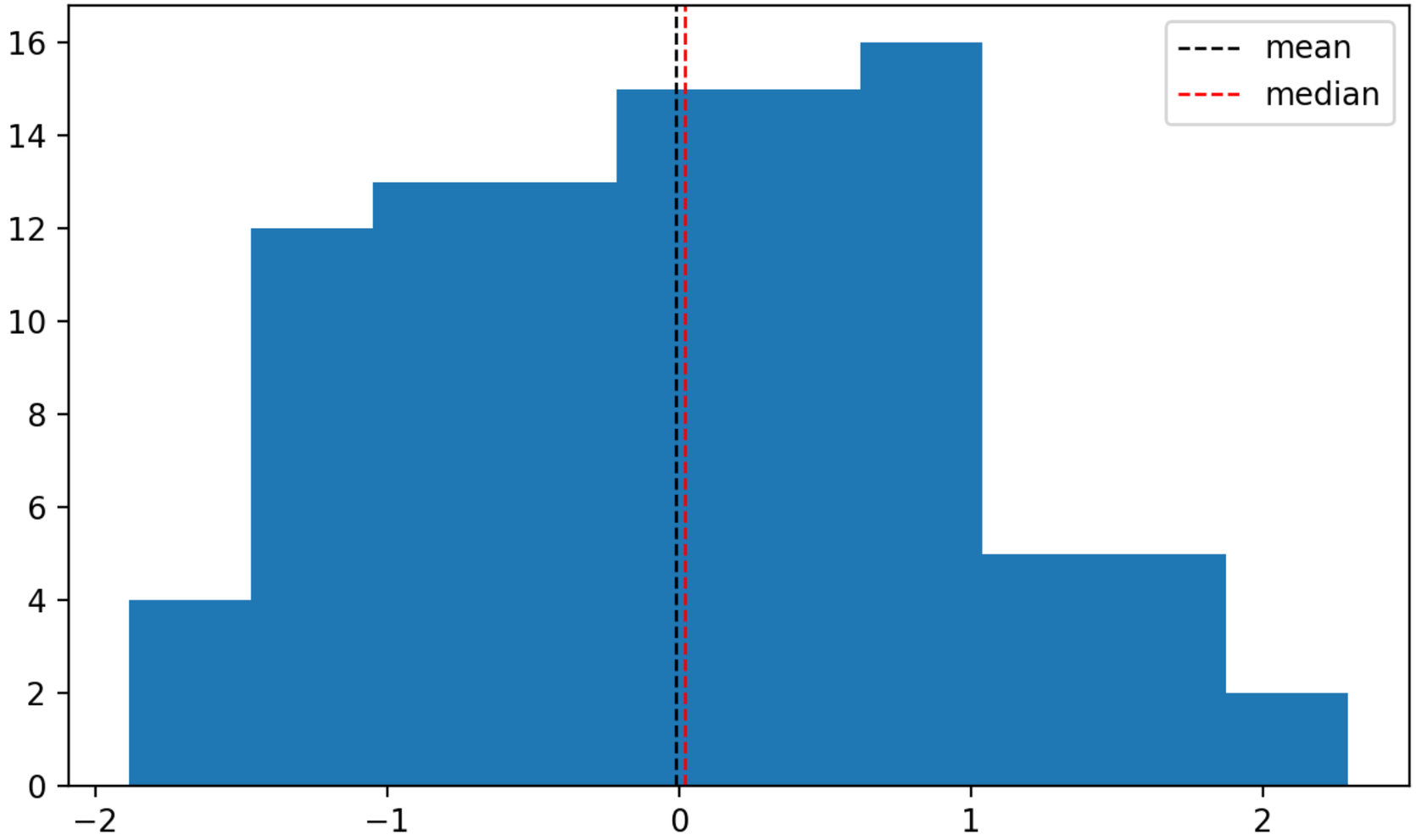
```
msleep[msleep['vore'] == "insecti"]['sleep_total'].agg([np.mean, np.median])
```

```
mean      13.22
median    18.1
Name: sleep_total, dtype: float64
```

Mean: 16.5 → 13.2

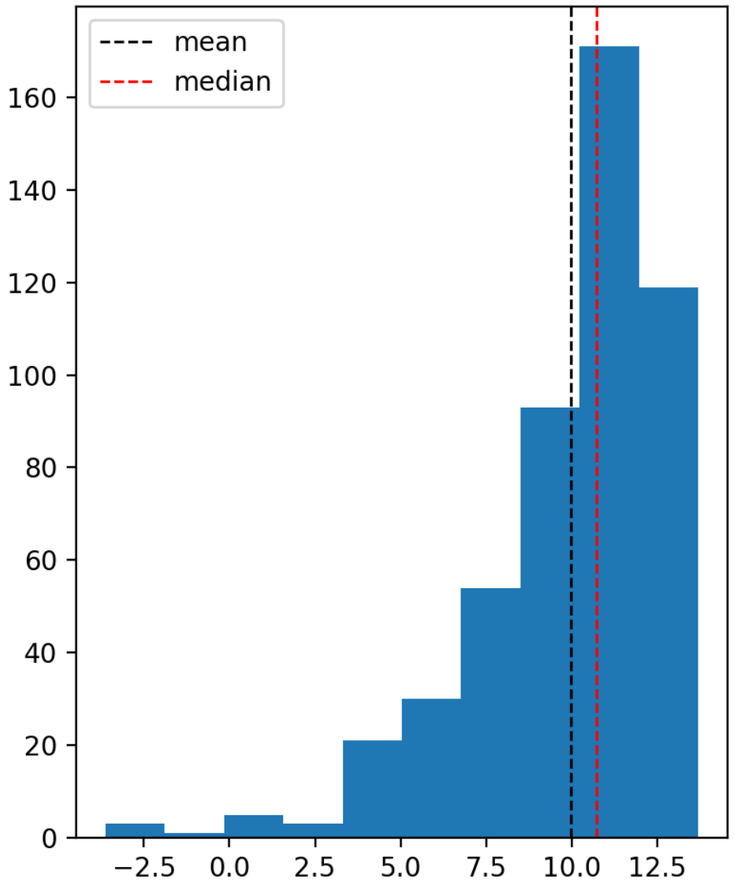
Median: 18.9 → 18.1

Which measure to use?

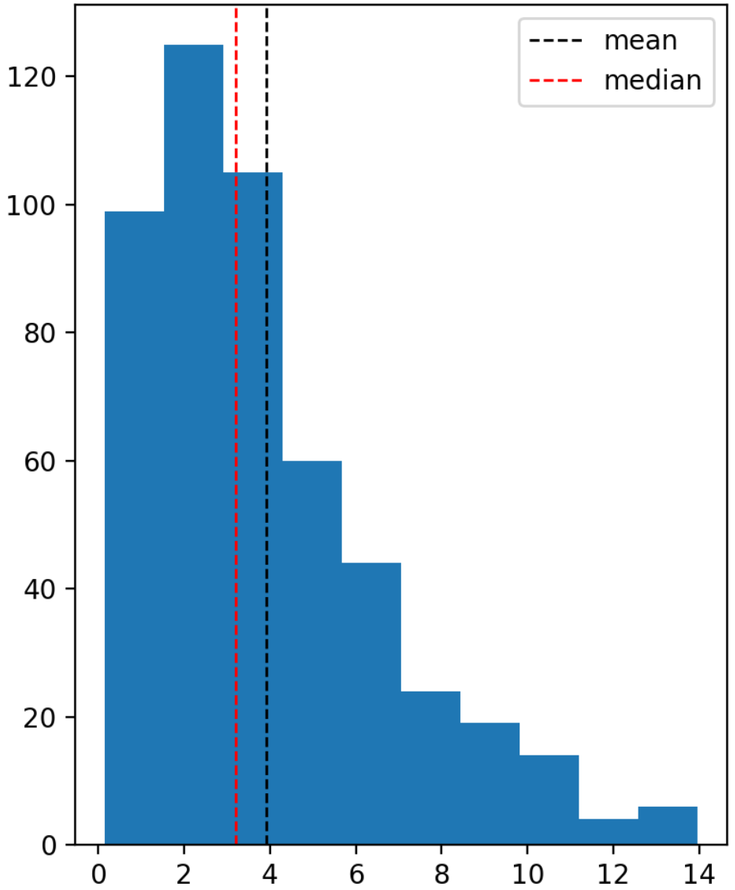


Skew

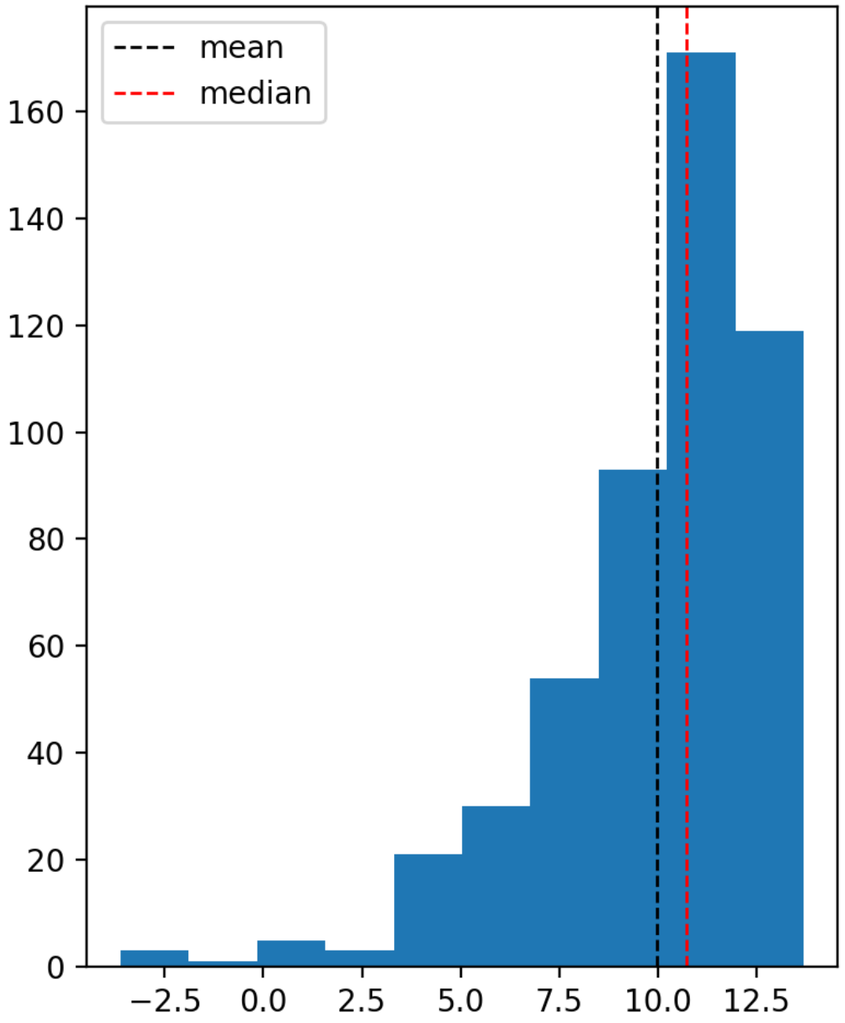
Left-skewed

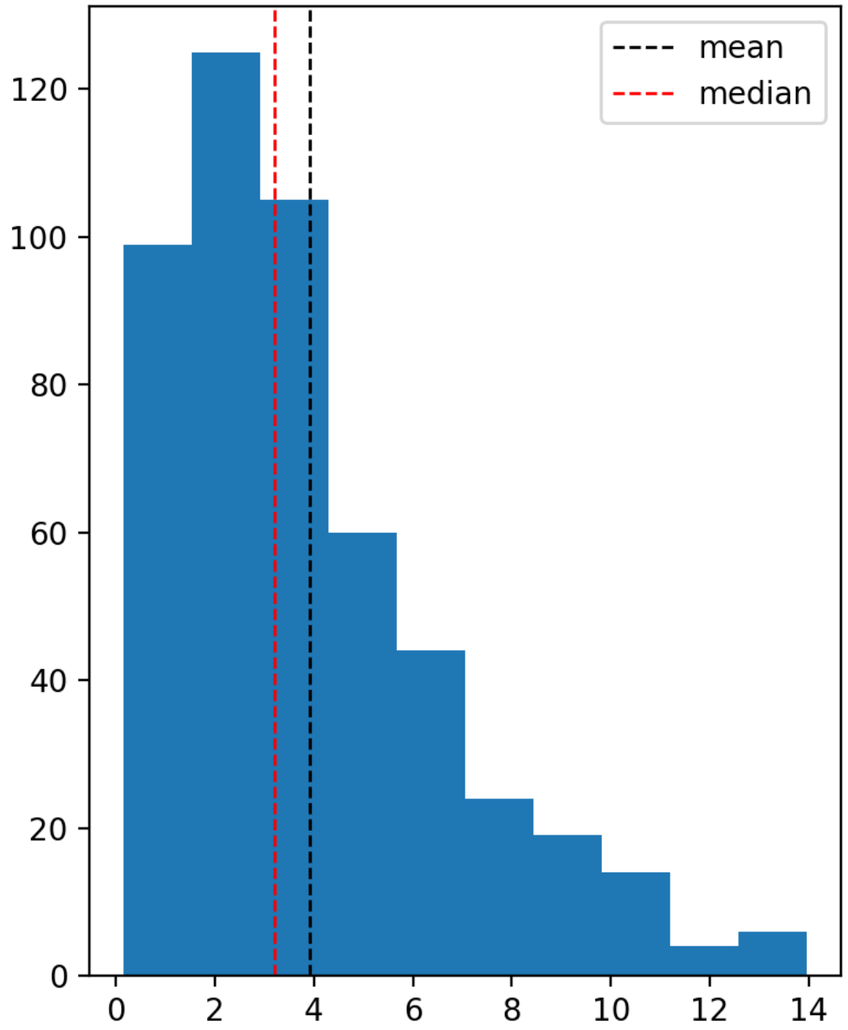


Right-skewed



Which measure to use?





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Measures of spread

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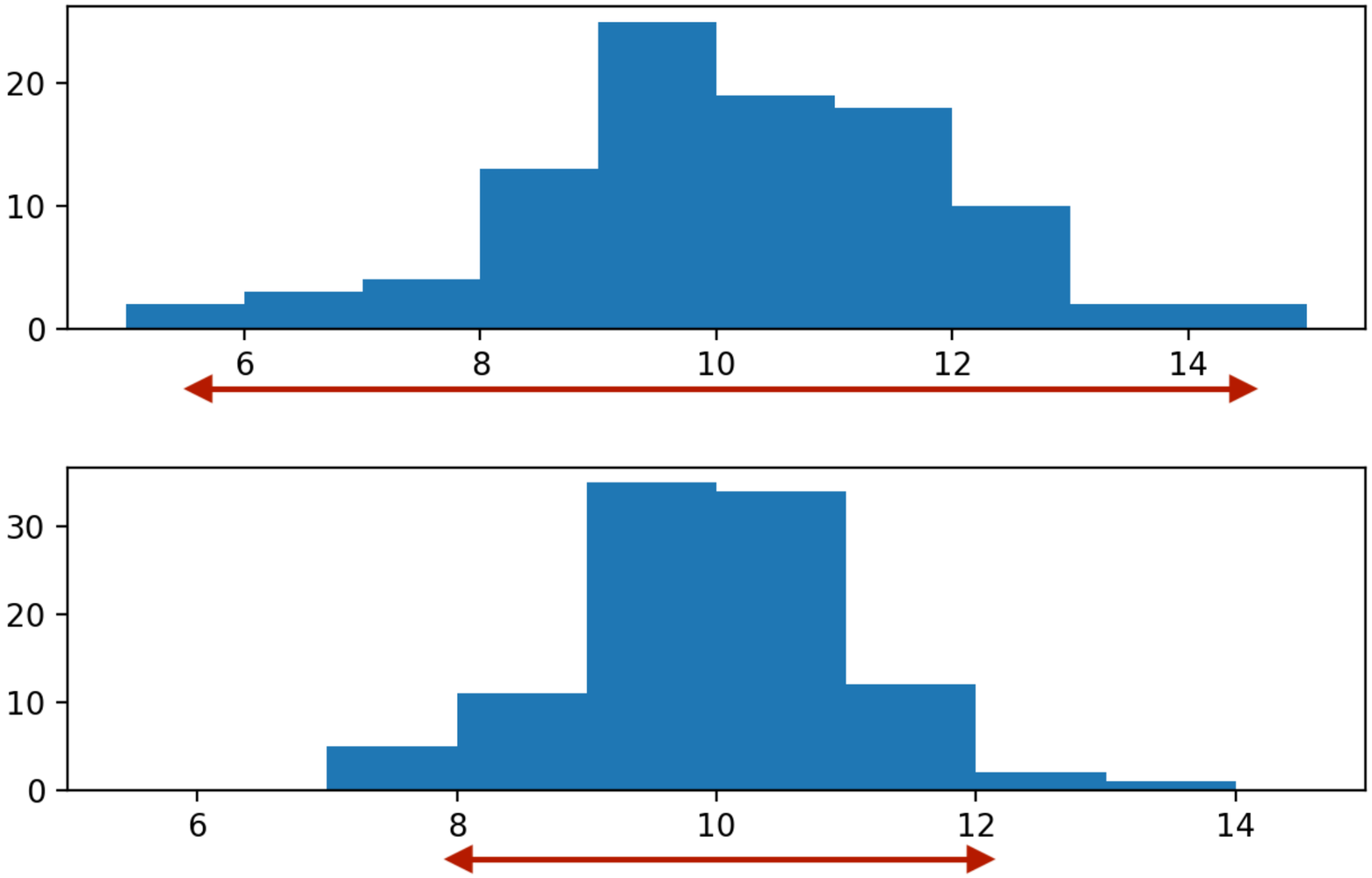
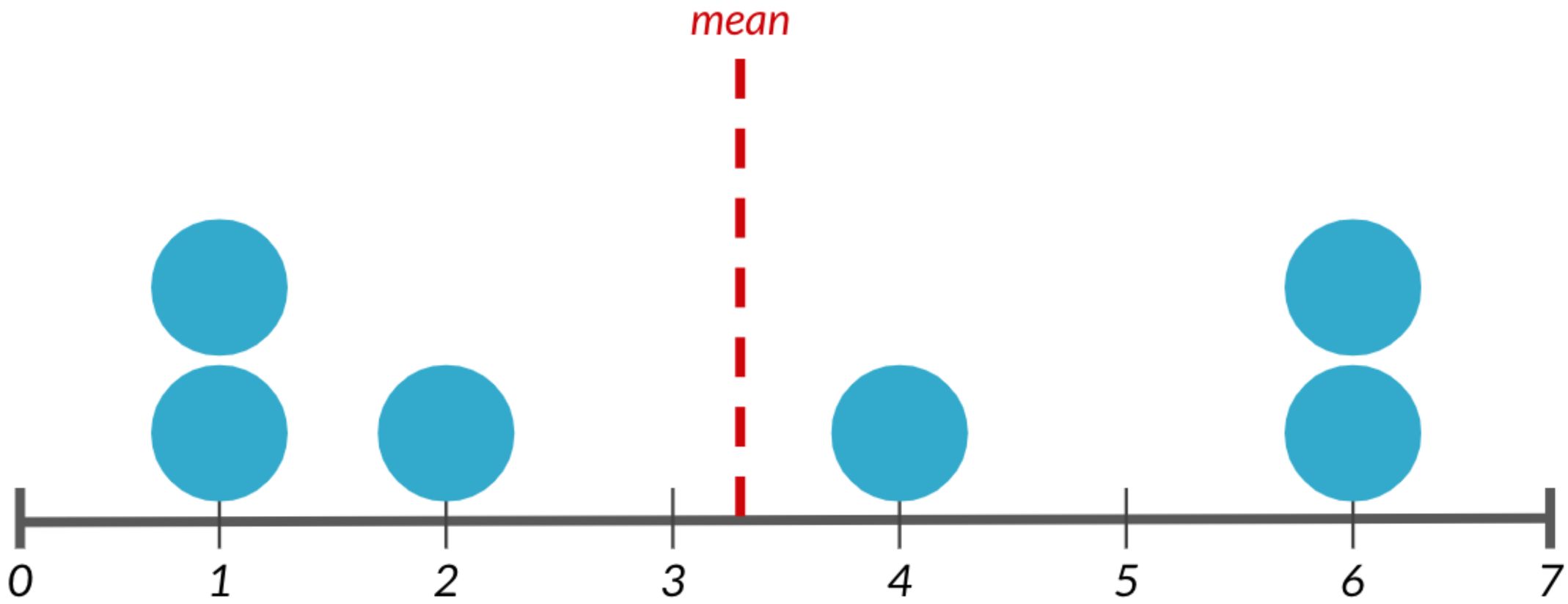
What is spread?



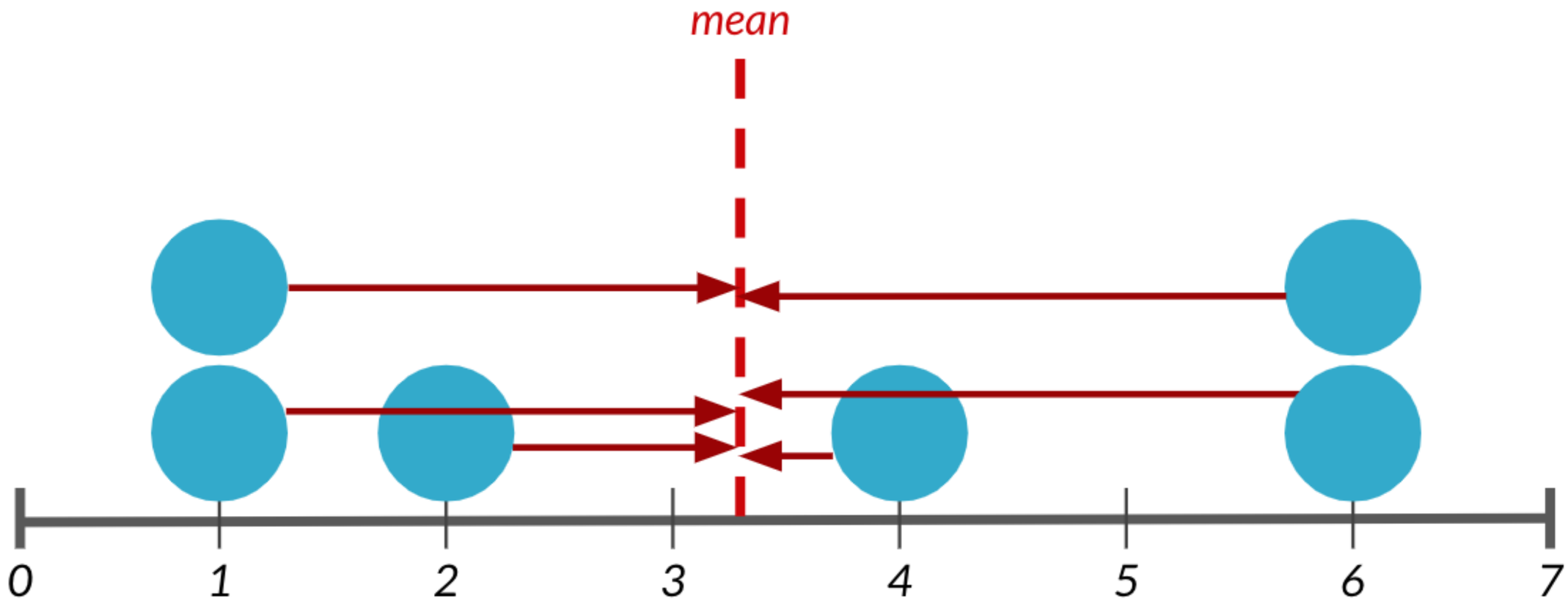
Variance

Average distance from each data point to the data's mean



Variance

Average distance from each data point to the data's mean



Calculating variance

1. Subtract mean from each data point

```
dists = msleep['sleep_total'] -
        np.mean(msleep['sleep_total'])
print(dists)
```

```
0      1.666265
1      6.566265
2      3.966265
3      4.466265
4     -6.433735
       ...
```

2. Square each distance

```
sq_dists = dists ** 2
print(sq_dists)
```

```
0       2.776439
1      43.115837
2      15.731259
3      19.947524
4      41.392945
       ...
```

Calculating variance

3. Sum squared distances

```
sum_sq_dists = np.sum(sq_dists)
print(sum_sq_dists)
```

```
1624.065542
```

4. Divide by number of data points - 1

```
variance = sum_sq_dists / (83 - 1)
print(variance)
```

```
19.805677
```

Use `np.var()`

```
np.var(msleep['sleep_total'], ddof=1)
```

```
19.805677
```

Without `ddof=1` *,* ***population variance*** *is calculated instead of* ***sample variance***:

```
np.var(msleep['sleep_total'])
```

```
19.567055
```

Standard deviation

```
np.sqrt(np.var(msleep['sleep_total'], ddof=1))
```

```
4.450357
```

```
np.std(msleep['sleep_total'], ddof=1)
```

```
4.450357
```

Mean absolute deviation

```
dists = msleep['sleep_total'] - mean(msleep$sleep_total)
np.mean(np.abs(dists))
```

```
3.566701
```

Standard deviation vs. mean absolute deviation

- Standard deviation squares distances, penalizing longer distances more than shorter ones.
- Mean absolute deviation penalizes each distance equally.
- One isn't better than the other, but SD is more common than MAD.

Quantiles

```
np.quantile(msleep['sleep_total'], 0.5)
```

```
10.1
```

0.5 quantile = median

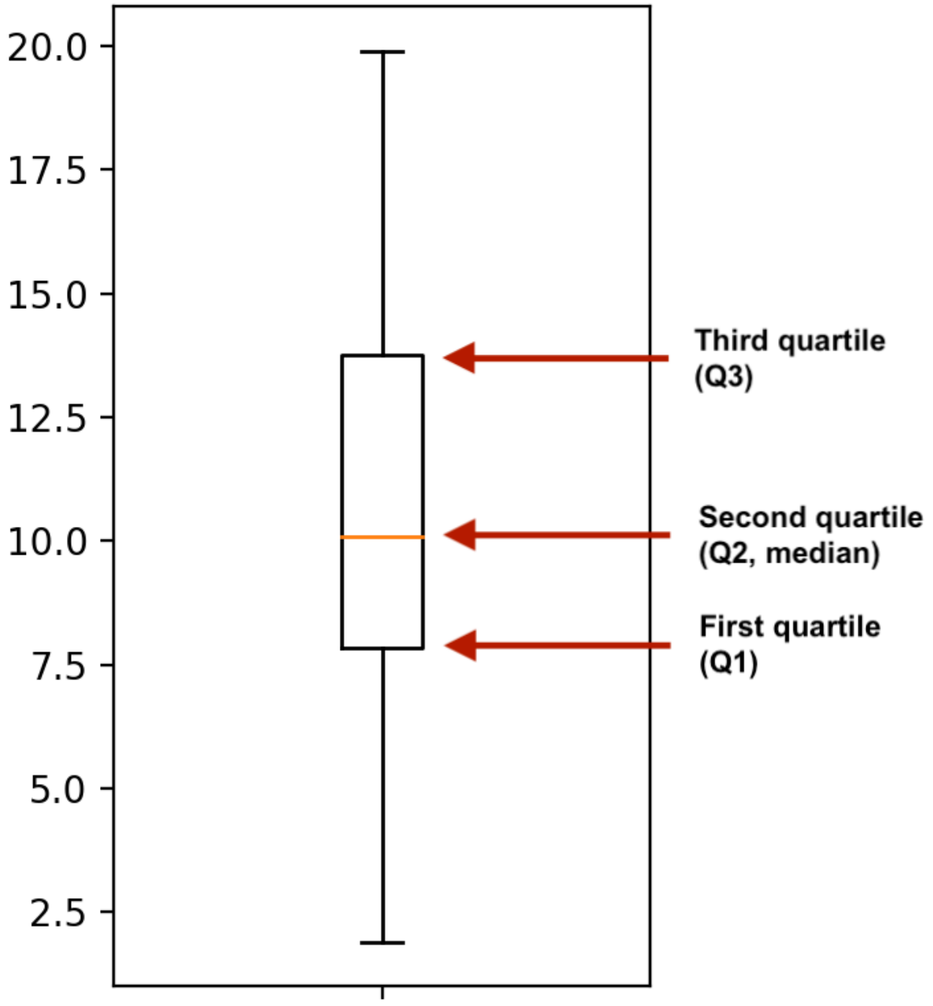
Quartiles:

```
np.quantile(msleep['sleep_total'], [0, 0.25, 0.5, 0.75, 1])
```

```
array([ 1.9 ,  7.85, 10.1 , 13.75, 19.9 ])
```

Boxplots use quartiles

```
import matplotlib.pyplot as plt
plt.boxplot(msleep['sleep_total'])
plt.show()
```



Quantiles using np.linspace()

```
np.quantile(msleep['sleep_total'], [0, 0.2, 0.4, 0.6, 0.8, 1])
```

```
array([ 1.9 ,  6.24,  9.48, 11.14, 14.4 , 19.9 ])
```

`np.linspace(start, stop, num)`

```
np.quantile(msleep['sleep_total'], np.linspace(0, 1, 5))
```

```
array([ 1.9 ,  7.85, 10.1 , 13.75, 19.9 ])
```

Interquartile range (IQR)

Height of the box in a boxplot

```
np.quantile(msleep['sleep_total'], 0.75) - np.quantile(msleep['sleep_total'], 0.25)
```

```
5.9
```

```
from scipy.stats import iqr
iqr(msleep['sleep_total'])
```

```
5.9
```

Outliers

Outlier: data point that is substantially different from the others

How do we know what a substantial difference is? A data point is an outlier if:

- $\text{data} < \text{Q1} - 1.5 \times \text{IQR}$ or
- $\text{data} > \text{Q3} + 1.5 \times \text{IQR}$

Finding outliers

```
from scipy.stats import iqr
iqr = iqr(msleep['bodywt'])
lower_threshold = np.quantile(msleep['bodywt'], 0.25) - 1.5 * iqr
upper_threshold = np.quantile(msleep['bodywt'], 0.75) + 1.5 * iqr
```

```
msleep[(msleep['bodywt'] < lower_threshold) | (msleep['bodywt'] > upper_threshold)]
```

```
                   name   vore  sleep_total    bodywt
4                   Cow  herbi          4.0   600.000
20        Asian elephant  herbi          3.9  2547.000
22                 Horse  herbi          2.9   521.000
...
```

All in one go

```
msleep['bodywt'].describe()
```

```
count      83.000000
mean      166.136349
std       786.839732
min         0.005000
25%         0.174000
50%         1.670000
75%        41.750000
max      6654.000000
Name: bodywt, dtype: float64
```

Let's practice!

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