Welcome to the course!

EXPERIMENTAL DESIGN IN PYTHON

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Experimental design

Data

- Allows us to answer questions

How do we get answers?

- Need rigorous methods

Approach

- Build hypotheses with exploratory data analysis
- Test hypotheses with statistical tests

Mapping variables

Variable types

- Discrete: Finite set of possible values (Ex: True or False)
- Continuous: Any value (Ex: Measurement)

Mapping

- X or Y axes
- Change color with `fill` or `color` arguments

Making plots with plotnine

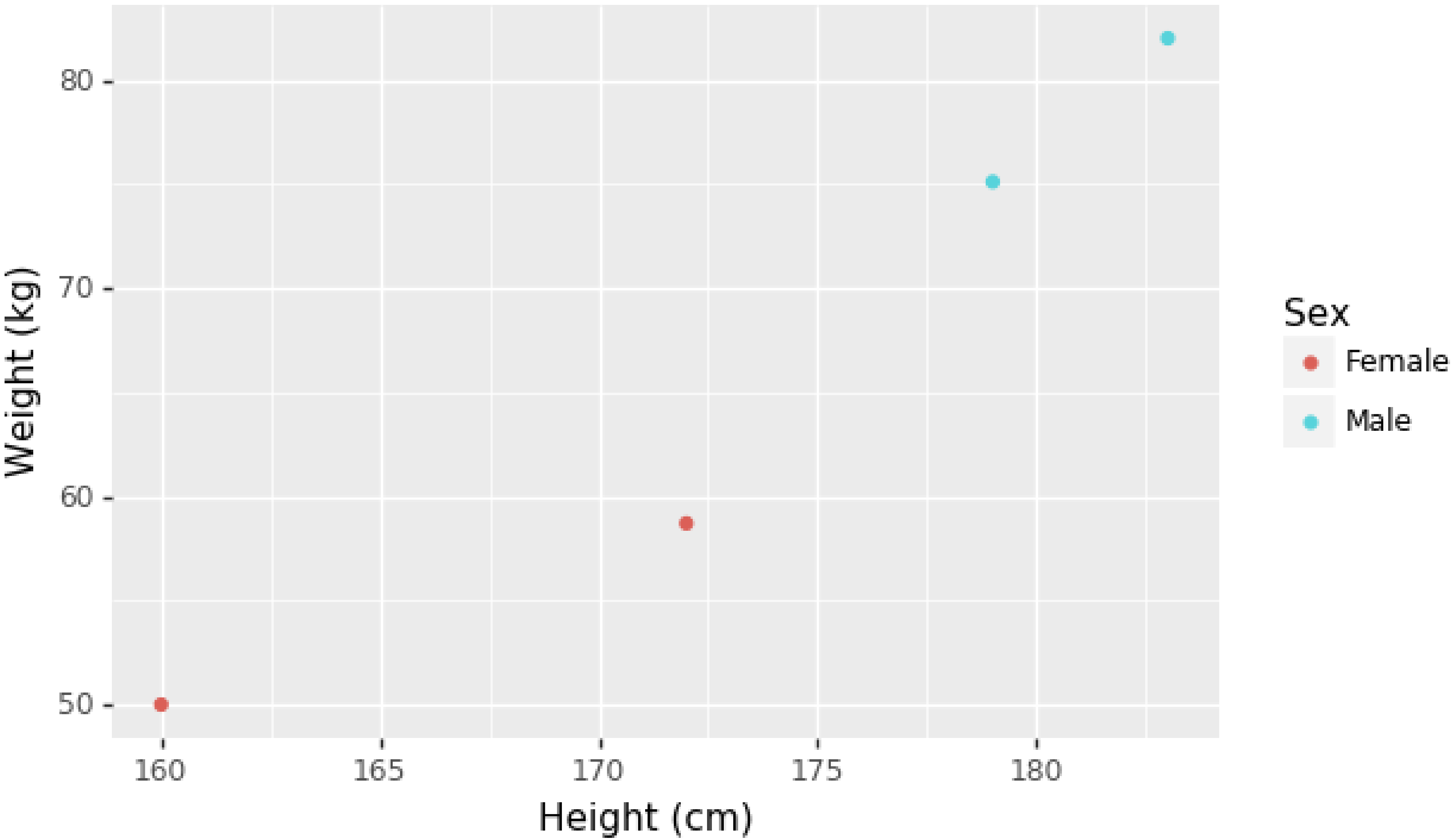
1. Call `ggplot()` function and give it a DataFrame
2. Assign mapping of variables with `aes()`
3. Specify a geometry

```
import plotnine as p9

(p9.ggplot([pandas DataFrame])+

p9.aes(
    x='variable to put on X-axis',
    y='variable to put on Y-axis',
    color='variable ')+

p9.geom_point()
)
```

Scatter plot

`geom_point()`

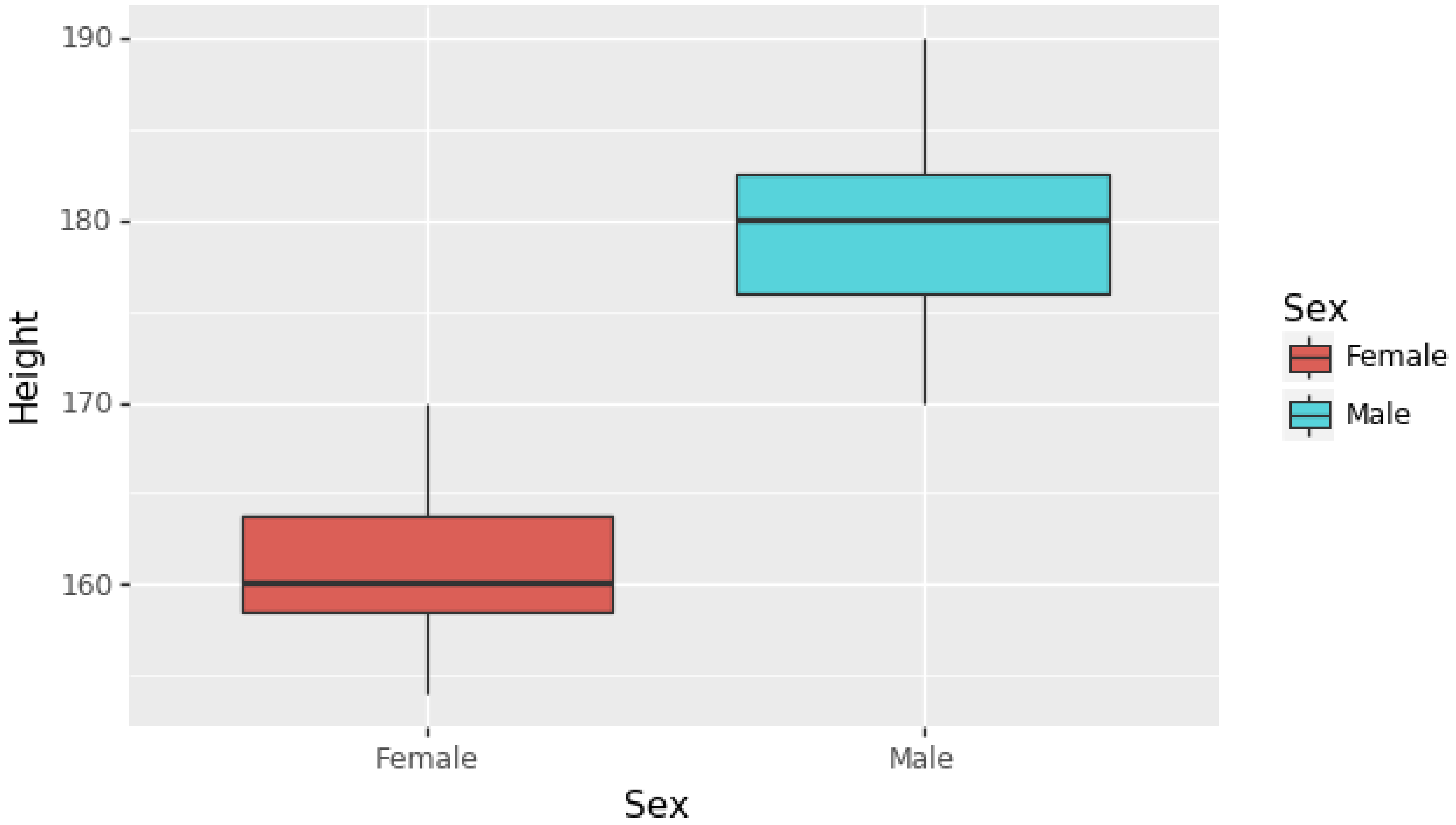
```
import plotnine as p9
import pandas as pd

df = pd.DataFrame(data= {'Sex': ["Male", "Male", "Female","Female"] ,
                         "Height (cm)": [183, 179, 160, 172],
                         "Weight (kg)": [82,75.1,  50, 58.7]})

print(p9.ggplot(df)+ p9.aes(x='Height (cm)',y='Weight (kg)', color='Sex')+ p9.geom_point())
```


80
70
60
50
Weight (kg)
160
165
170
175
180
Height (cm)
Sex
Female
Male

Boxplot

`geom_boxplot()`

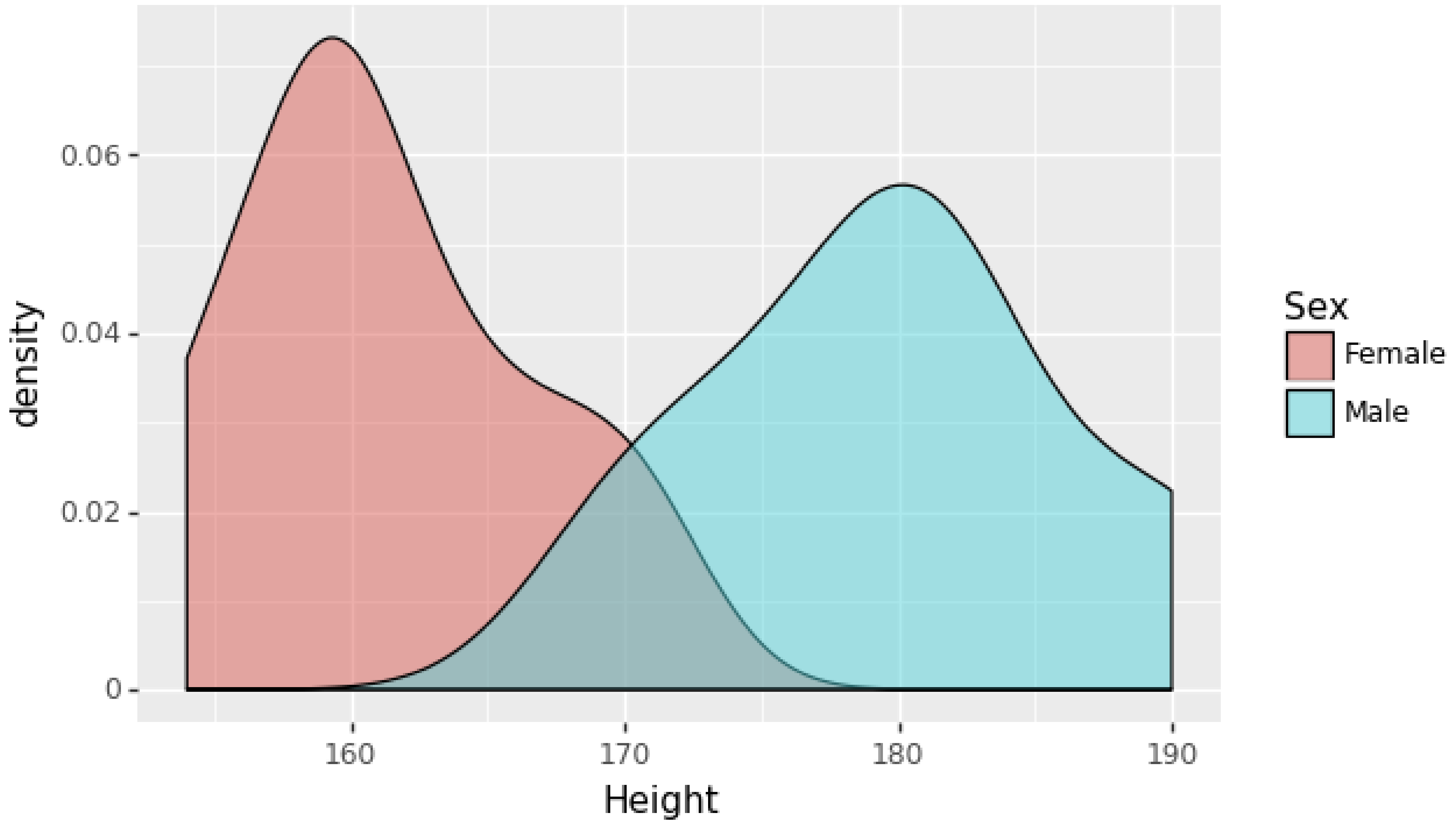
```
import plotnine as p9
import pandas as pd

df = pd.DataFrame(data= {'Sex': ["Male", "Male","Male", "Male","Male", "Male",
"Female","Female", "Female","Female", "Female","Female"] ,
                         "Height": [183, 179, 190, 181, 170, 175,
                         160, 165, 158, 154, 170, 160]})

(p9.ggplot(df)+ p9.aes(x='Sex',y='Height', fill='Sex')+ p9.geom_boxplot())
```


190
180
170
160
Height
Female
Male
Sex
Sex
Female
Male

Density plot

`geom_density()`

```
import plotnine as p9
import pandas as pd
df = pd.DataFrame(data= {'Sex': ["Male", "Male","Male", "Male","Male", "Male",
"Female","Female", "Female","Female", "Female","Female"] ,
                         "Height": [183, 179, 190, 181, 170, 175,
                         160, 165, 158, 154, 170, 160]})
(p9.ggplot(df)+ p9.aes(x='Height', fill='Sex') + p9.geom_density(alpha=0.5))
```


density
0.06
0.04
0.02
0
160
170
180
190
Height
Sex
Female
Male

Let's practice!

EXPERIMENTAL DESIGN IN PYTHON

Our first hypothesis test - Student's t-test

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From observed pattern to reliable result

Data contains patterns

- Some expected
- Others surprising
- Random variation also

Dealing with this

- How do we go from observation to result?

Are these groups different?

Weights of two groups of adults

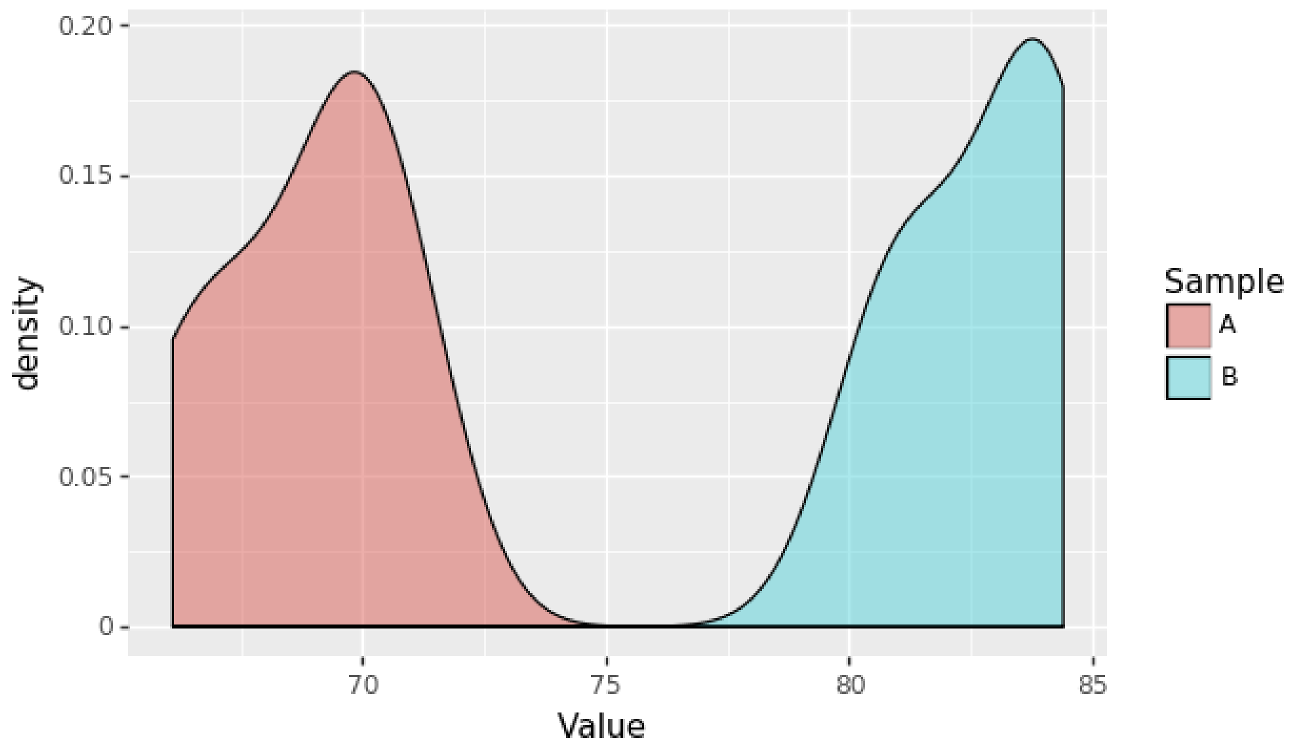
Sample A:

```
[66.1, 69.8,67.7,69.6,71.1]
```

Sample B:

```
[83.7,81.5, 80.6, 83.9, 84.4]
```

```
(p9.ggplot(df)+
p9.aes('Value', fill='Sample')+
p9.geom_density(alpha=0.5))
```

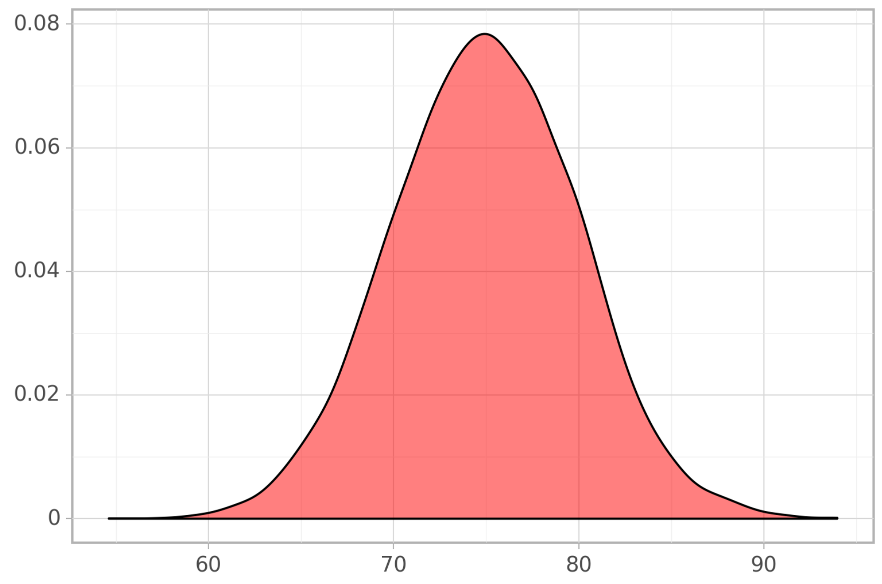


Two hypotheses

Null hypothesis

A = B

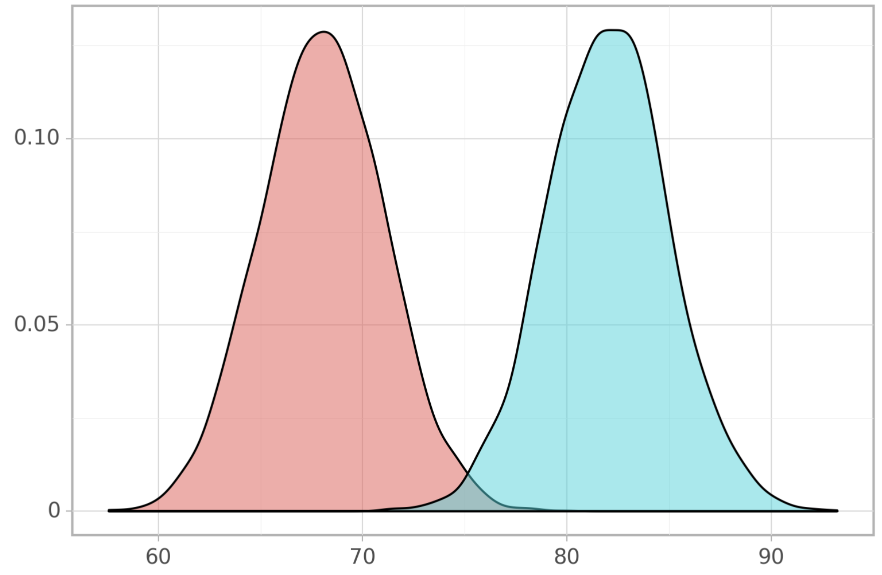
- Observed patterns are the product of random chance



Alternative hypothesis

A != B

- Difference between samples represents a real difference between the populations



Some statistical terms

p-value

- Likelihood of pattern under **null hypothesis**

alpha

- Crucial threshold of p-value
- Usually *alpha < 0.05: reject null hypothesis*

below a 5% probability that random chance would produce the pattern observed, it's usually safe to reject the null hypothesis.

Student's t-test

- Invented by William Sealy Gosset
- Two basic types:

One-sample: Mean of population different from a given value?

Two-sample: Two means equal?

Coding a t-test

```
from scipy import stats


stats.ttest_ind(Sample_A, Sample_B)
```

Implementing a one-sample t-test

```
from scipy import stats

Sample_A = df[df.Sample == "A"]

t_result = stats.ttest_1sample(Sample_A, 65)

alpha = 0.05

if (t_result[1] < alpha):
    print("mean(A) != 65")
```

if $p < 0.05$

```
mean(A) != 65
```

Implementing a two-sample t-test

```python
from scipy import stats

Sample_A = df[df.Sample == "A"]
Sample_B = df[df.Sample == "B"]

t_result = stats.ttest_ind(Sample_A, Sample_B)

alpha = 0.05

if (t_result[1] < alpha):
    print("A and B are different!")
```

```
A and B are different!
```

Now let's try it out!

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Testing proportion and correlation

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Hypothesis tests

t-test:

- Compare means of continuous variables

Chi-square:

- Examine proportions of discrete categories

Fisher exact test:

- Examine proportions of discrete categories

Pearson test:

- Examine if continuous variables are correlated

Chi-square

Test distinguishes between:

Null hypothesis:

- Observed outcomes fit distribution
- *coin is not biased*

Alternative hypothesis:

- Observed outcomes doesn't fit distribution
- *coin is biased*

Example

Coin flipped 30 times

Expected: 15 heads, 15 tails

Observed: 24 heads, 6 tails

Expected outcomes significantly different from expected?

Implementing a simple Chi-square test

```
from scipy import stats

coins = df['Flip'].value_counts()

chi = stats.chisquare(coins)

print(chi)
```

```
Power_divergenceResult(statistic=10.8, pvalue=0.0010150009471130682)
```

Fisher exact test

Two-sample version of Chi-square test

Test distinguishes between:

Null hypothesis:

- Two samples have same distribution of outcomes

Alternative hypothesis:

- Two samples have different distribution of outcomes

Example

Two coins each flipped 30 times

Expected outcomes significantly differ?

Are these two discrete variables related?

Implementing a Fisher exact test

```python
from scipy import stats
import pandas as pd
table = pd.crosstab(df.Coin,df.Flip)
print(table)
```

```
Flip  heads  tails
Coin
1        22      8
2        17     13
```

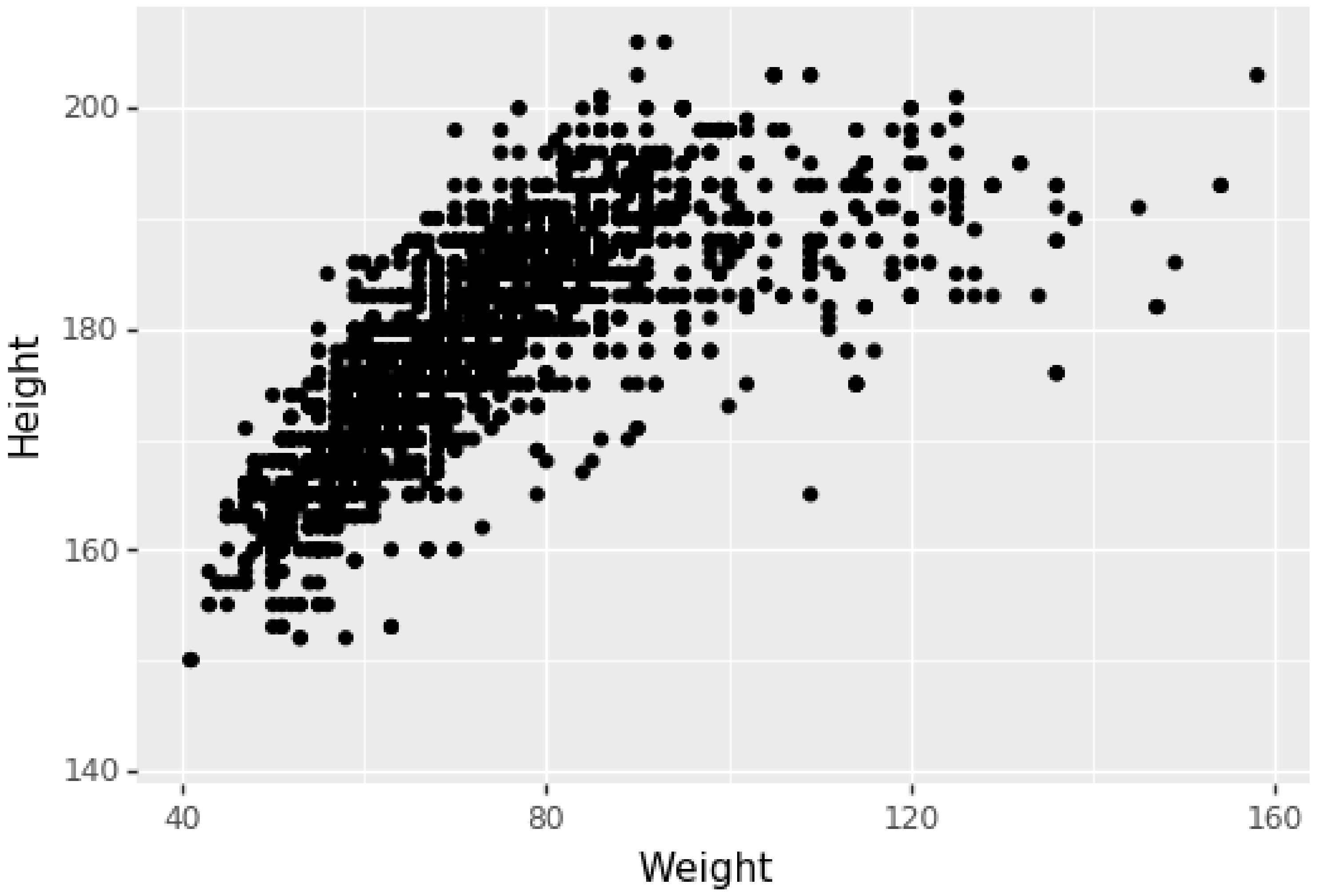
Implementing a Fisher exact test

```
chi = stats.fisher_exact(table, alternative='two-sided')
print(chi[1])
```

```
0.421975381019902
```

Correlation

```
import plotnine as p9
(p9.ggplot(olyAmericans)+ p9.aes(x='Weight',y='Height')+ p9.geom_point())
```



Pearson test for correlation

```
from scipy import stats
import pandas as pd


pearson = stats.pearsonr(df.Weight, df.Height)


print(pearson)
```

```
(0.7922545330545416, 0.0)
```

(Correlation coefficient, p-value)

Let's practice!

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