

# Correlation

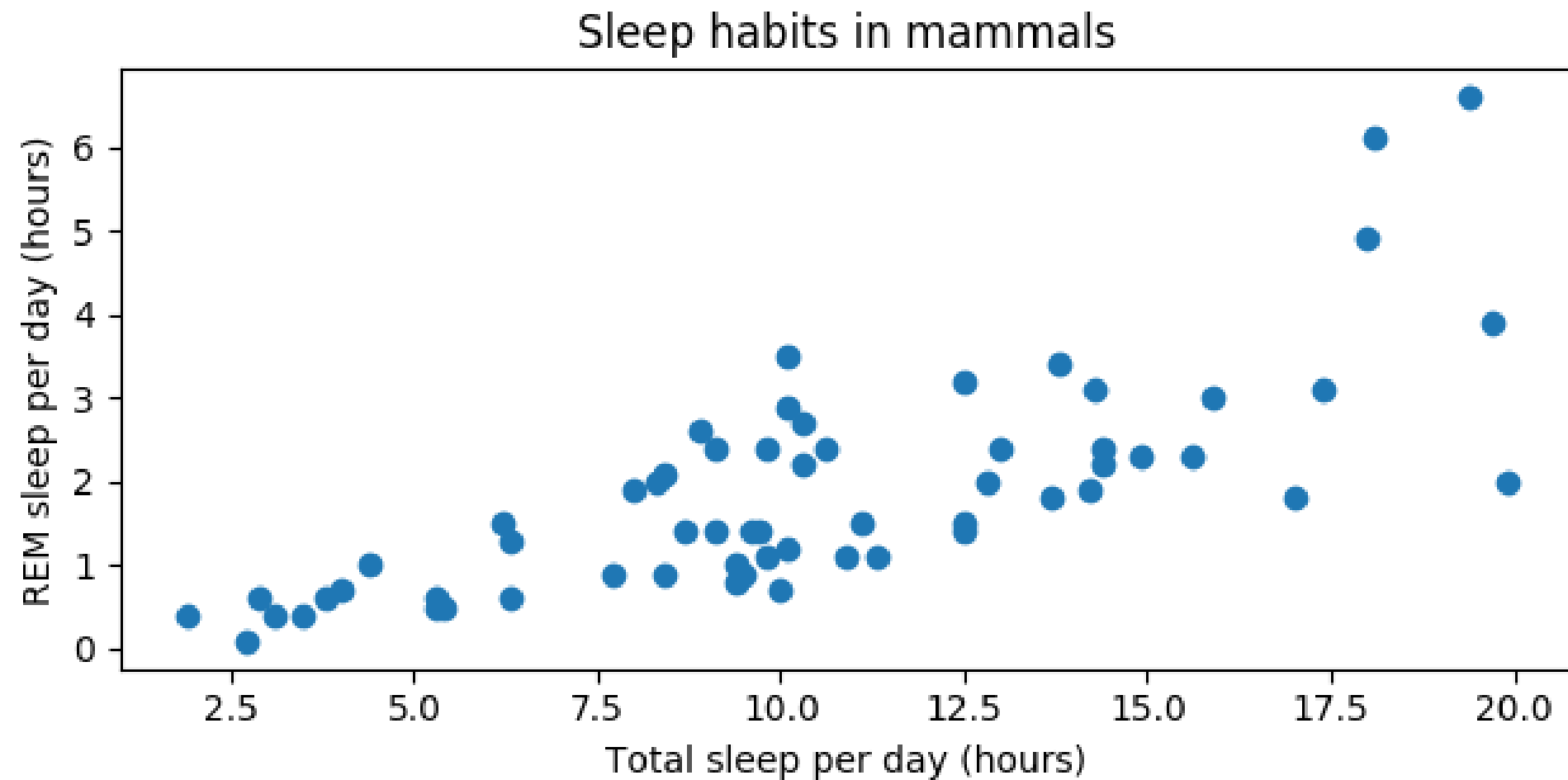
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# Relationships between two variables



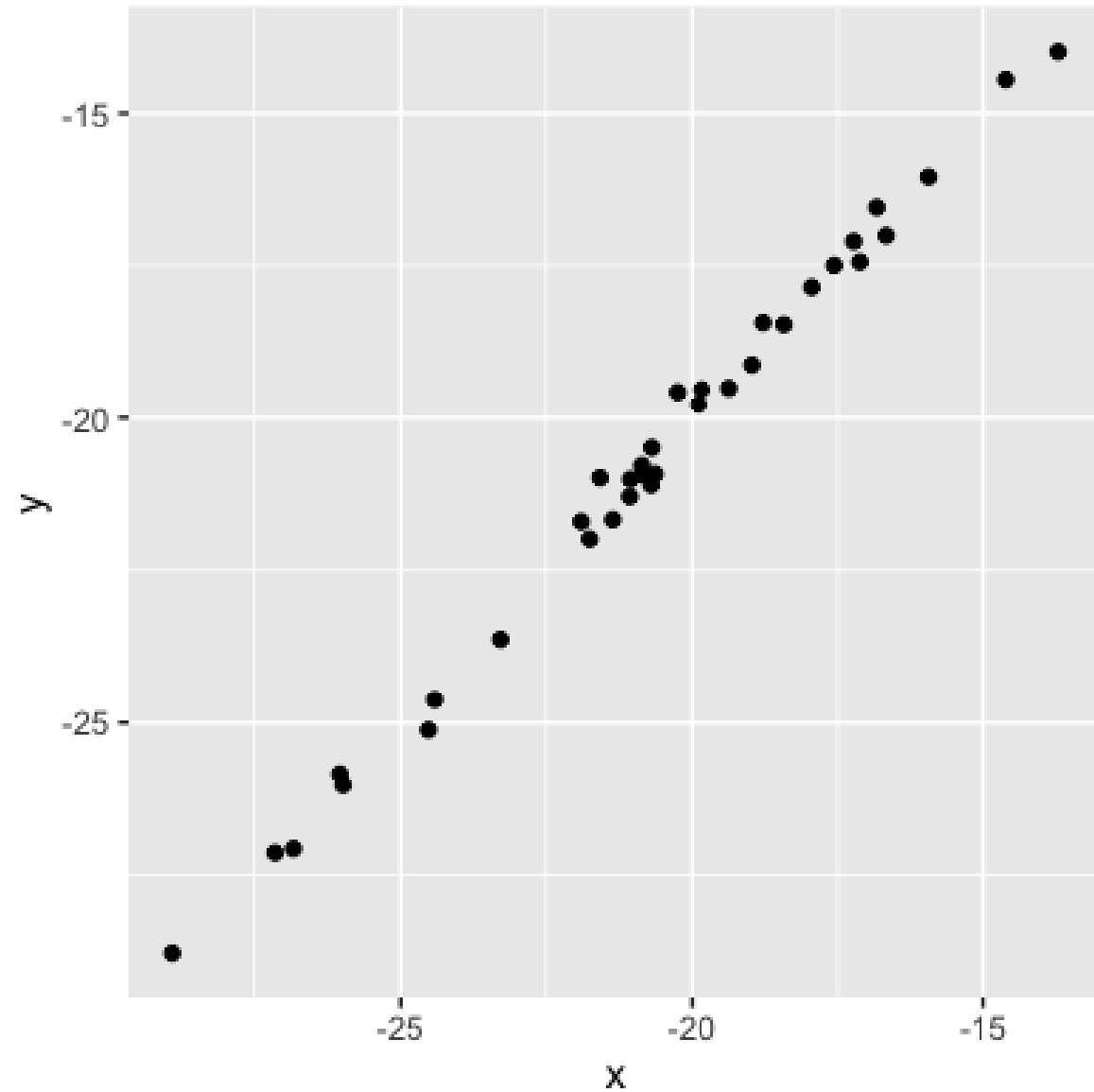
- $x$  = explanatory/independent variable
- $y$  = response/dependent variable

# Correlation coefficient

- Quantifies the linear relationship between two variables
- Number between -1 and 1
- Magnitude corresponds to strength of relationship
- Sign (+ or -) corresponds to direction of relationship

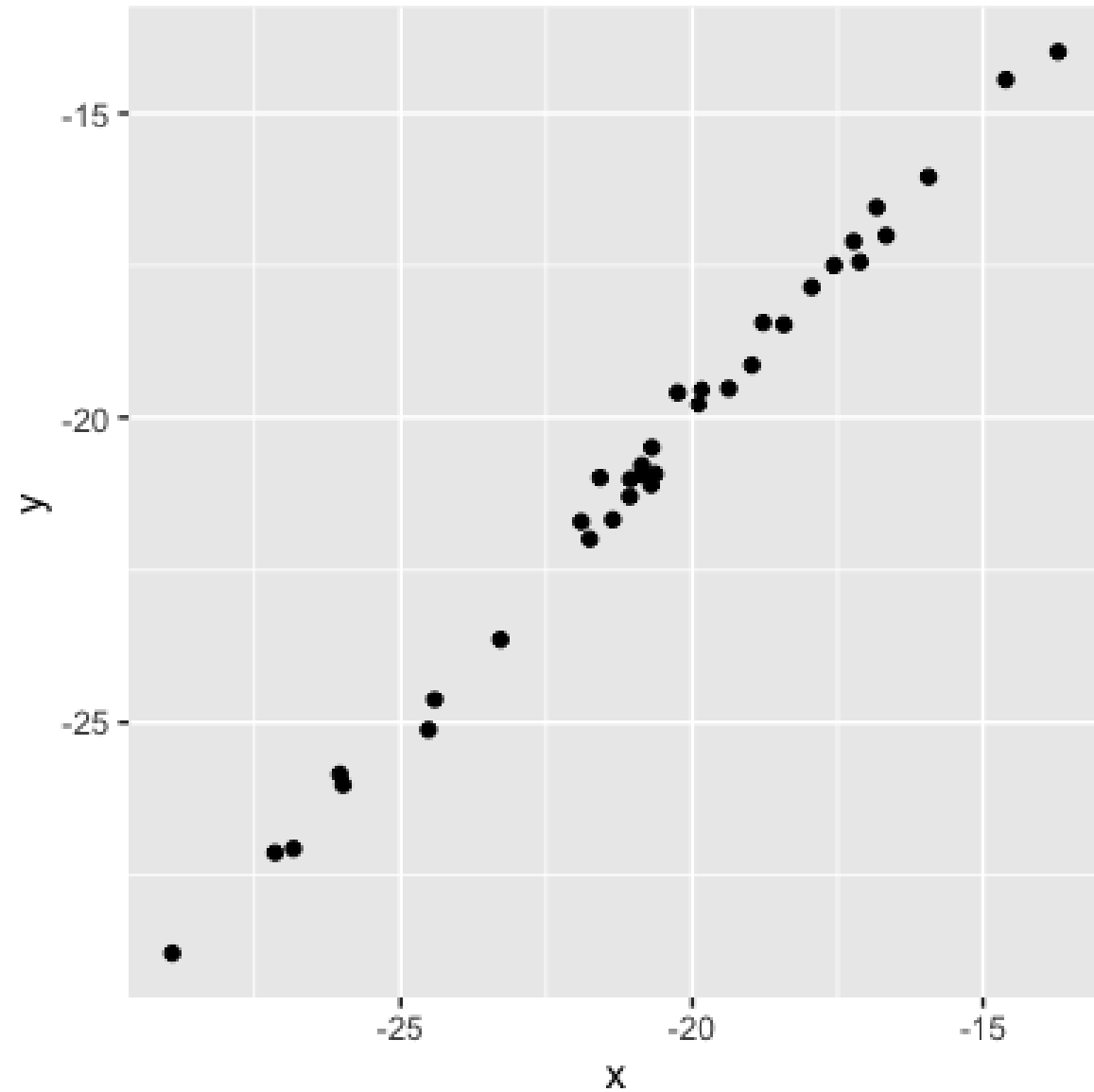
# Magnitude = strength of relationship

0.99 (very strong relationship)

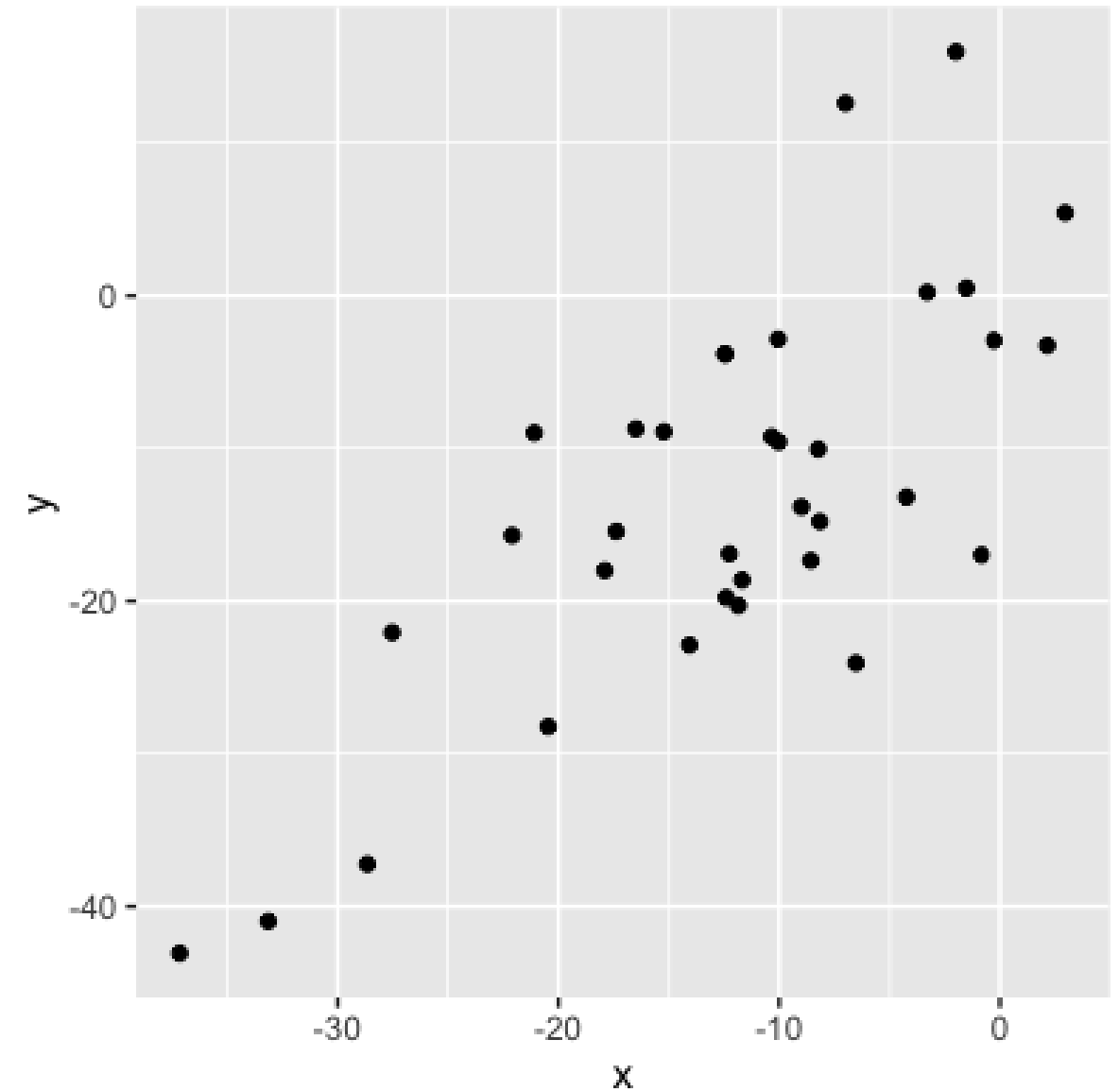


# Magnitude = strength of relationship

0.99 (very strong relationship)

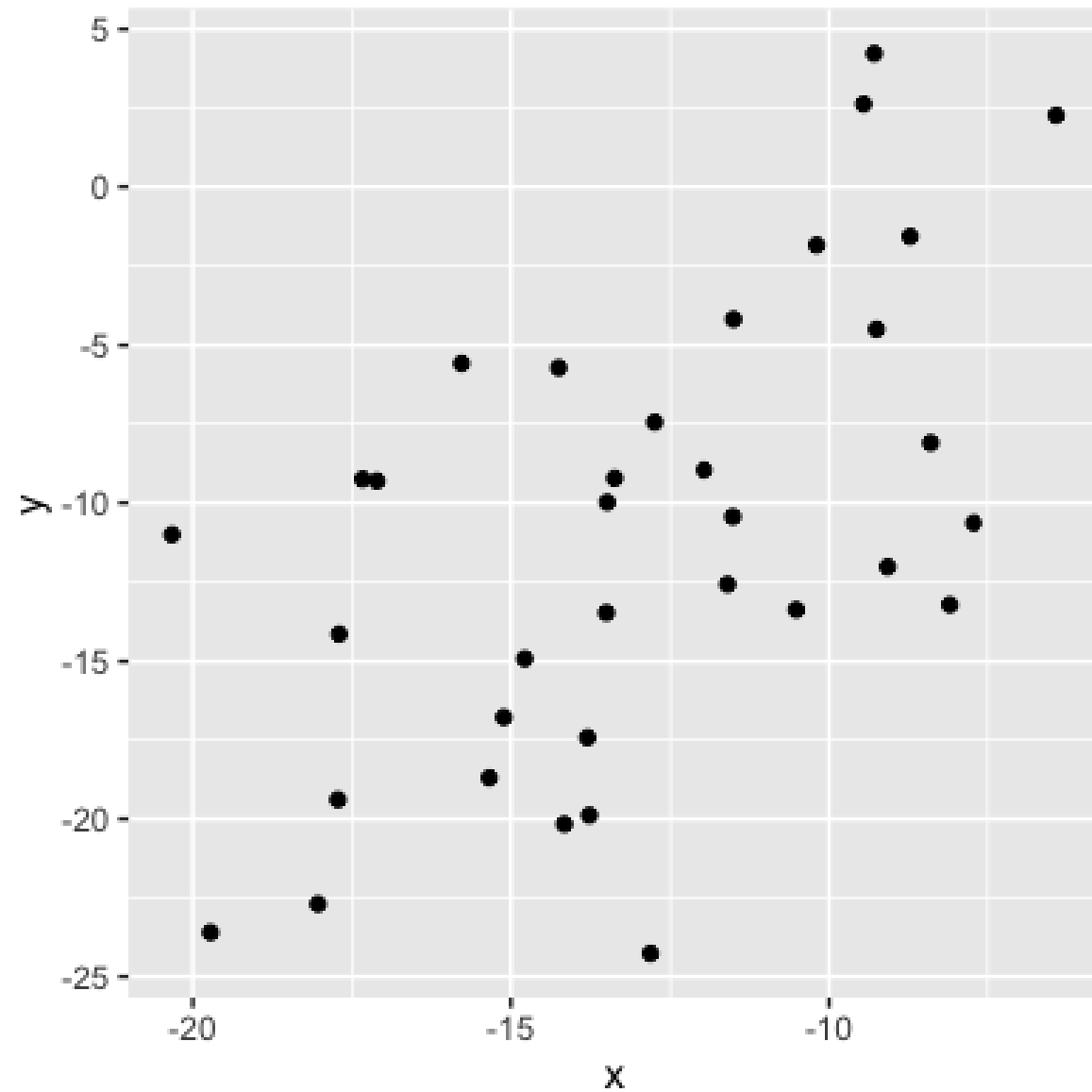


0.75 (strong relationship)



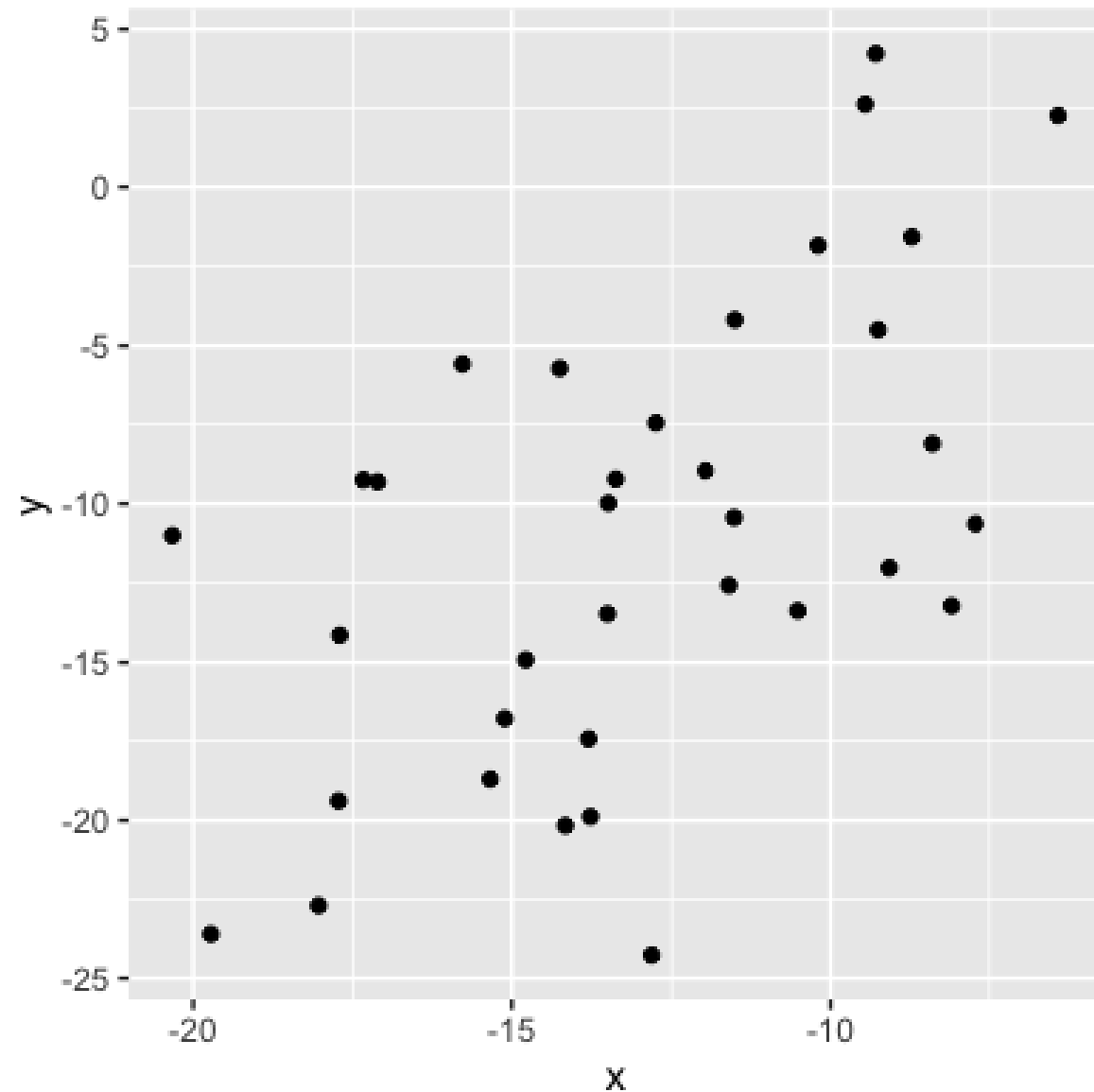
# Magnitude = strength of relationship

0.56 (moderate relationship)

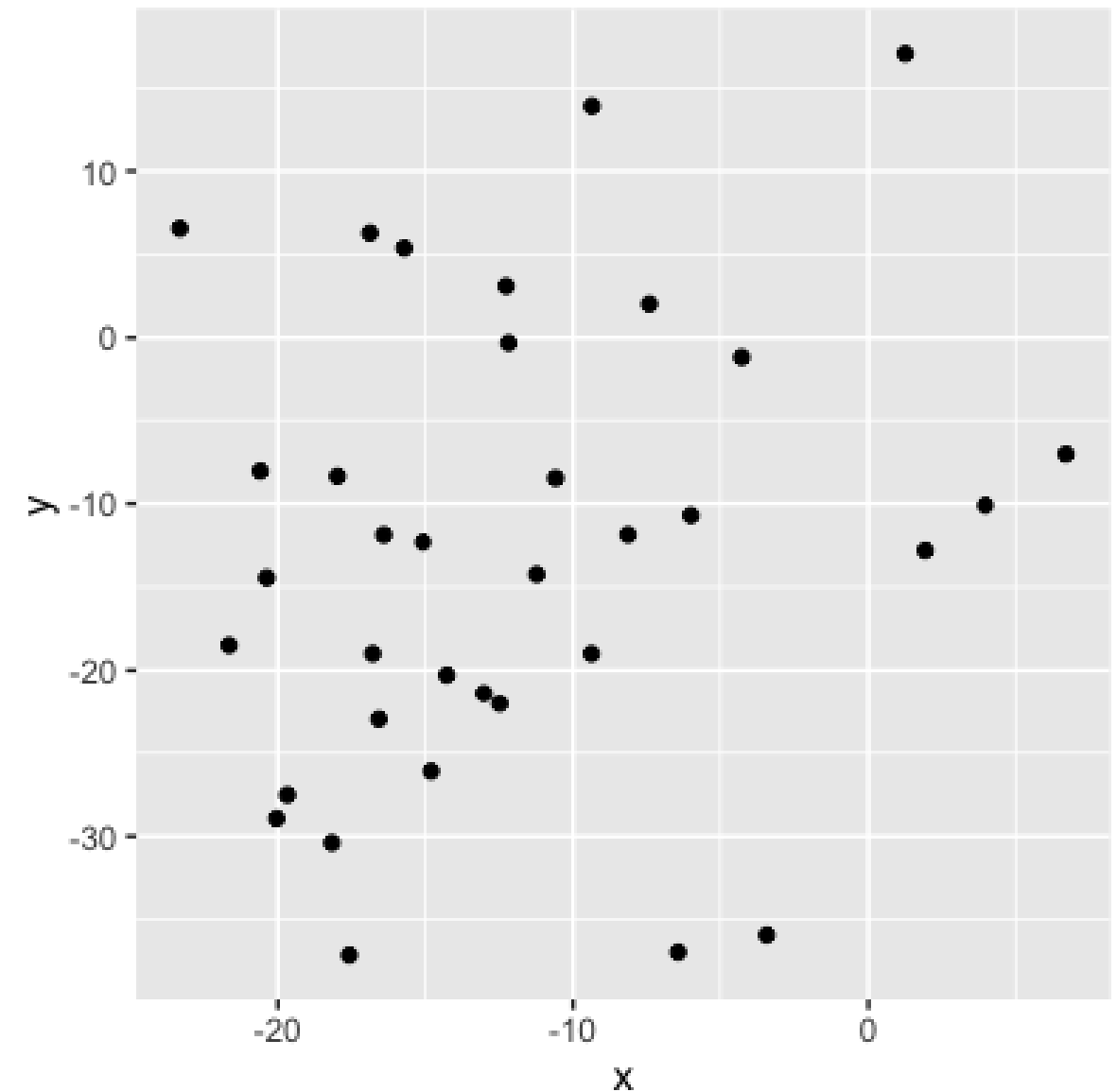


# Magnitude = strength of relationship

0.56 (moderate relationship)



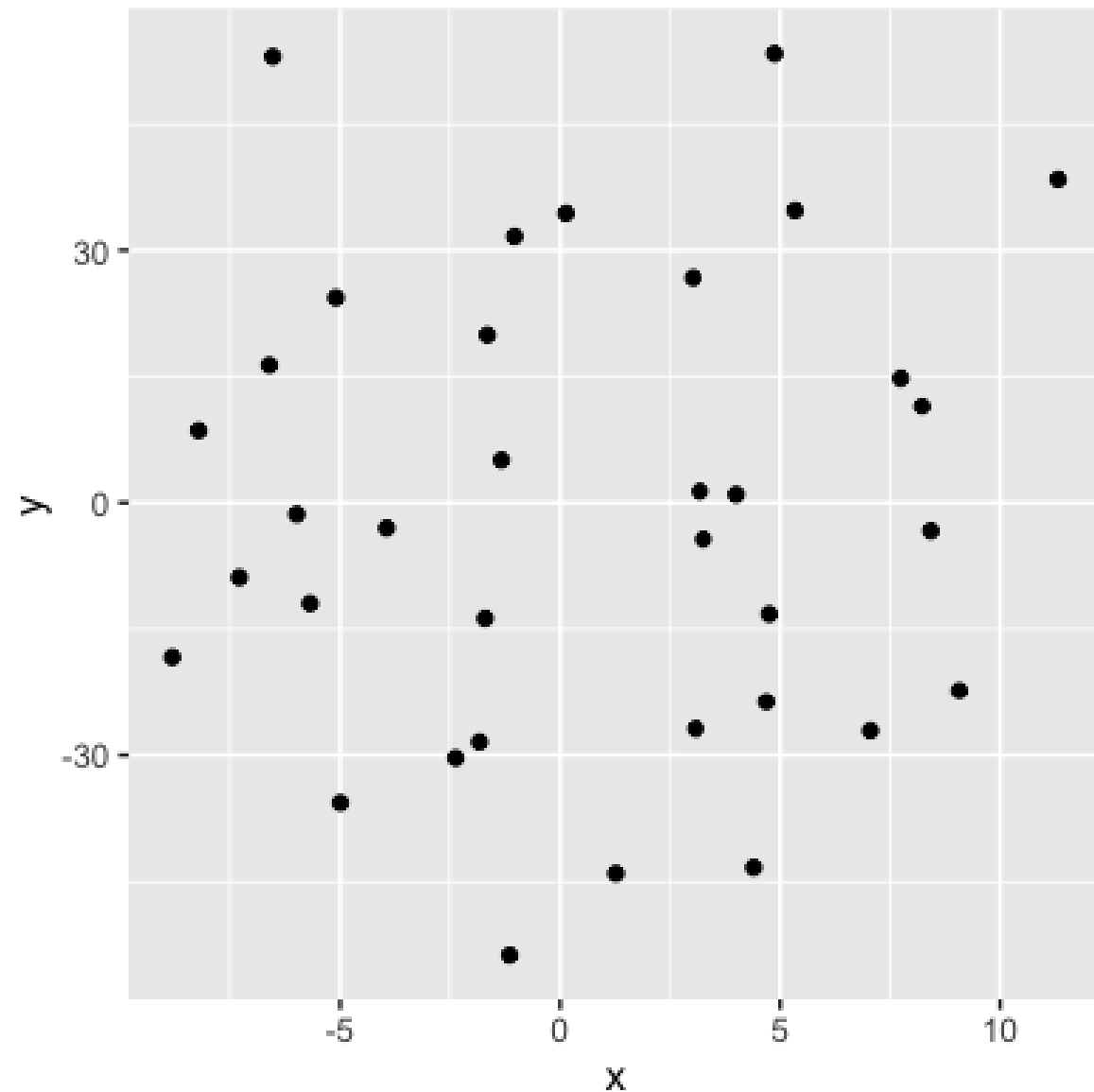
0.21 (weak relationship)



# Magnitude = strength of relationship

0.04 (no relationship)

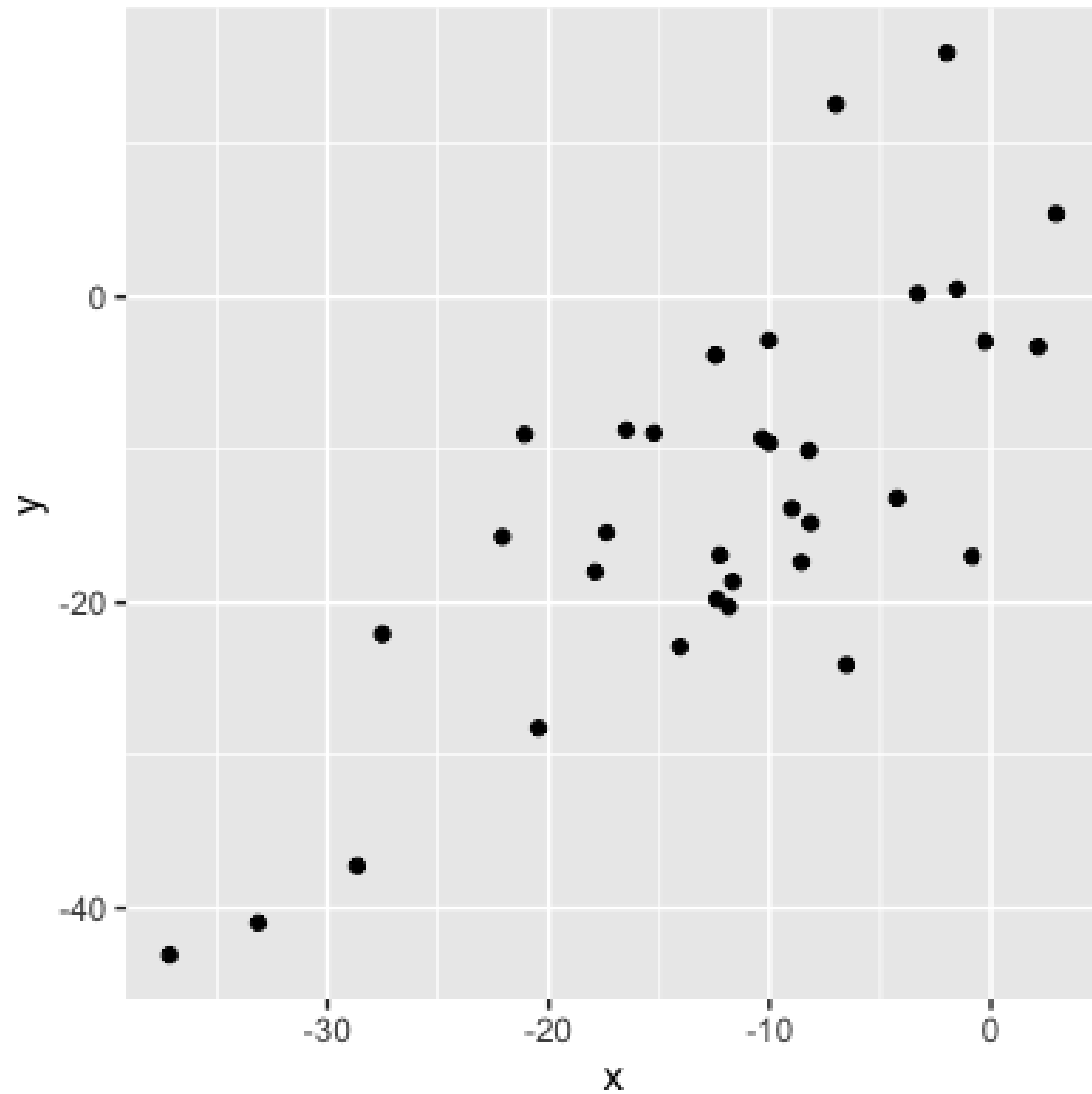
- Knowing the value of `x` doesn't tell us anything about `y`



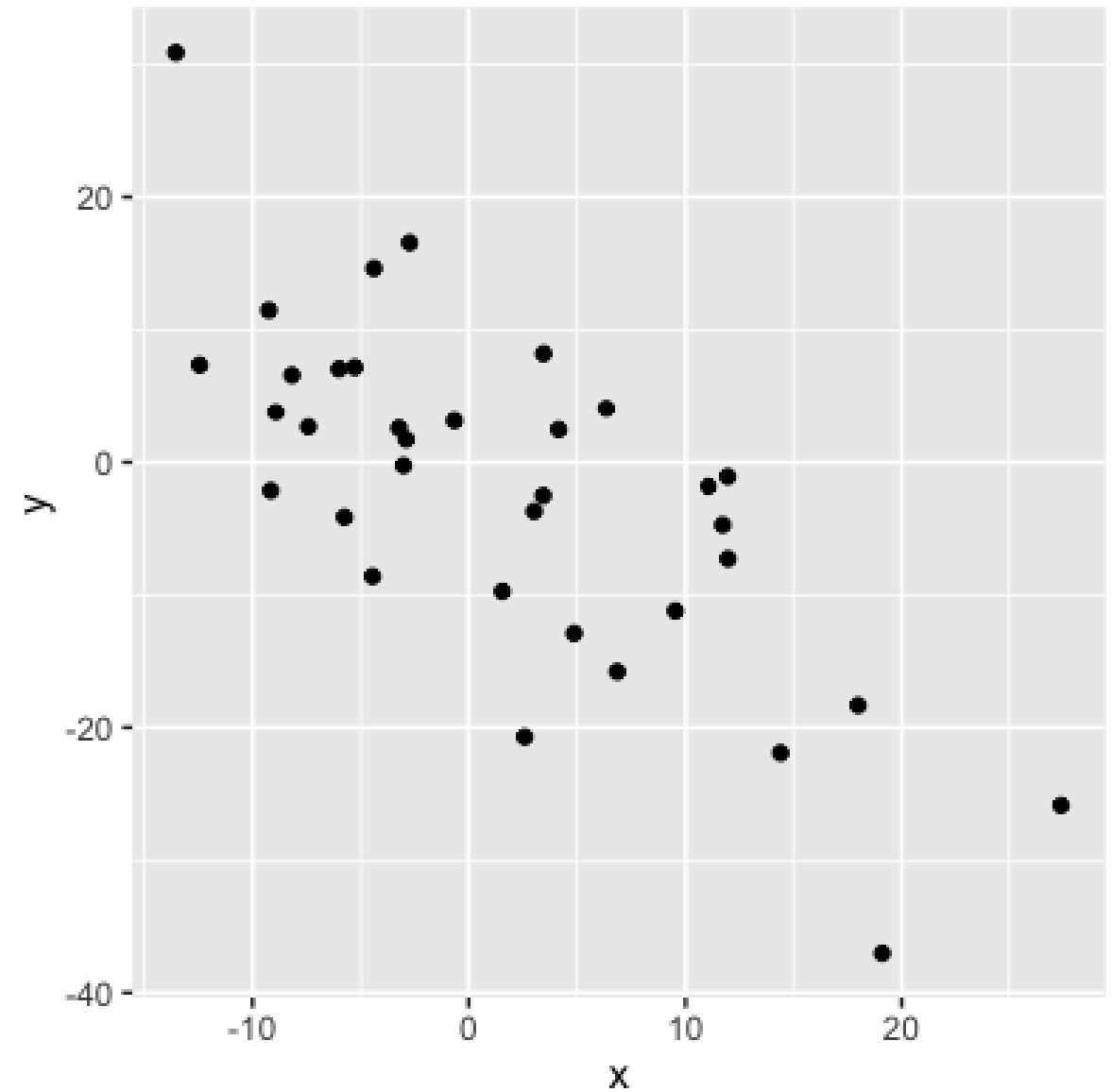


# Sign = direction

*0.75: as  $x$  increases,  $y$  increases*

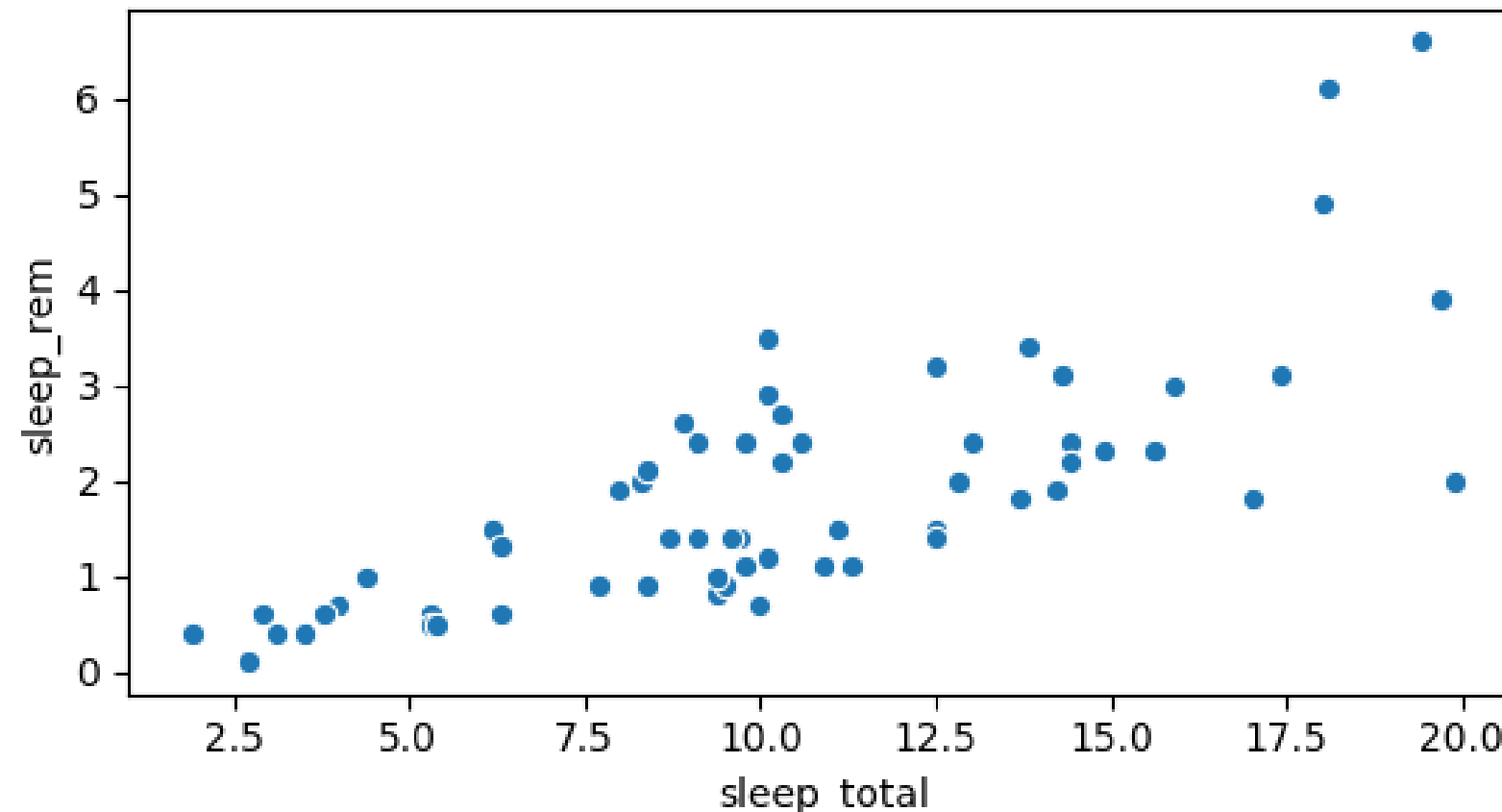


*-0.75: as  $x$  increases,  $y$  decreases*



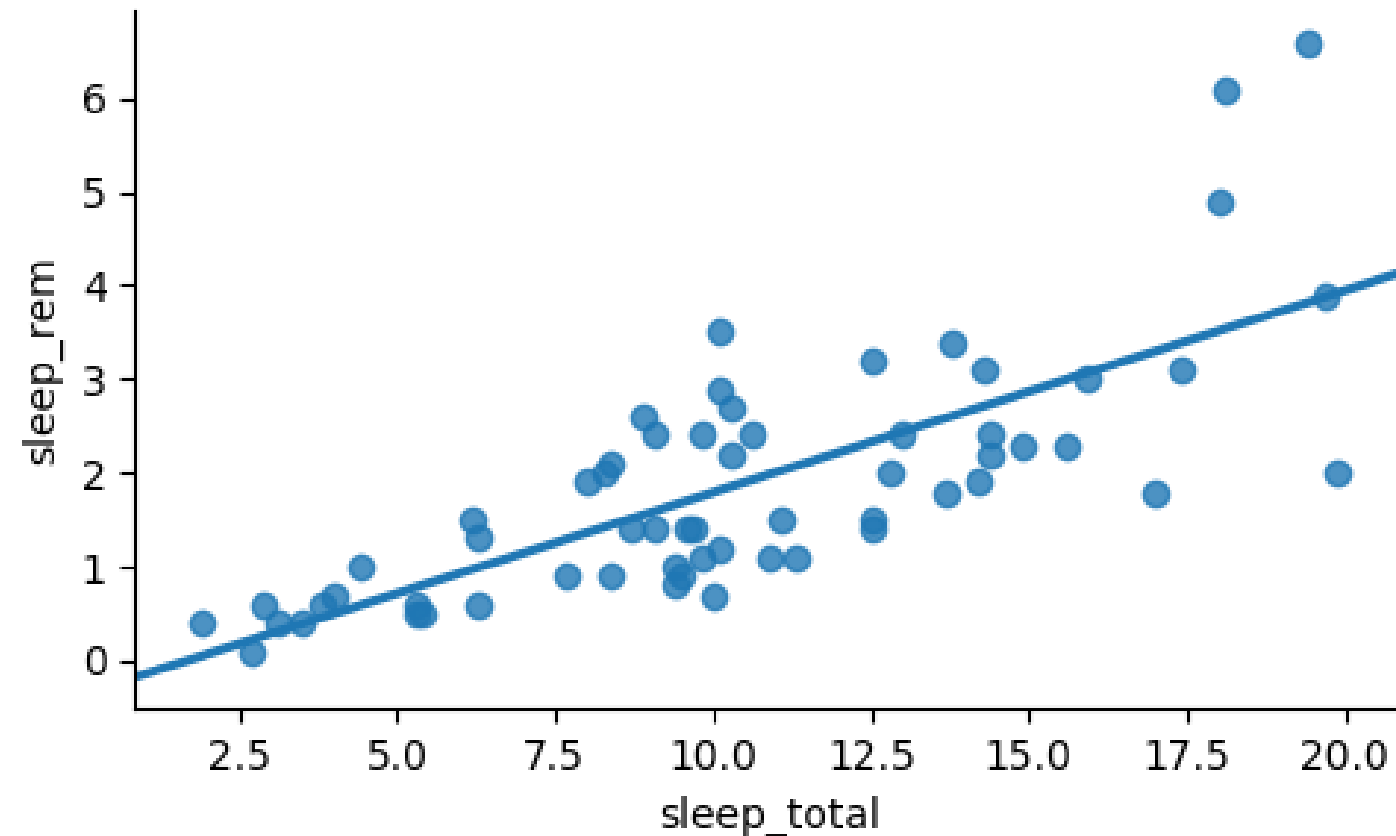
# Visualizing relationships

```
import seaborn as sns
sns.scatterplot(x="sleep_total", y="sleep_rem", data=msleep)
plt.show()
```



# Adding a trendline

```
import seaborn as sns
sns.lmplot(x="sleep_total", y="sleep_rem", data=msleep, ci=None)
plt.show()
```



# Computing correlation

```
msleep['sleep_total'].corr(msleep['sleep_rem'])
```

```
0.751755
```

```
msleep['sleep_rem'].corr(msleep['sleep_total'])
```

```
0.751755
```

# Many ways to calculate correlation

- Used in this course: Pearson product-moment correlation ( $r$ )
  - Most common
  - $\bar{x}$  = mean of  $x$
  - $\sigma_x$  = standard deviation of  $x$

$$r = \sum_{i=1}^n \frac{(x_i - \bar{x})(y_i - \bar{y})}{\sigma_x \times \sigma_y}$$

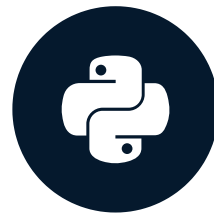
- Variations on this formula:
  - Kendall's tau
  - Spearman's rho

# Let's practice!

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# Correlation caveats

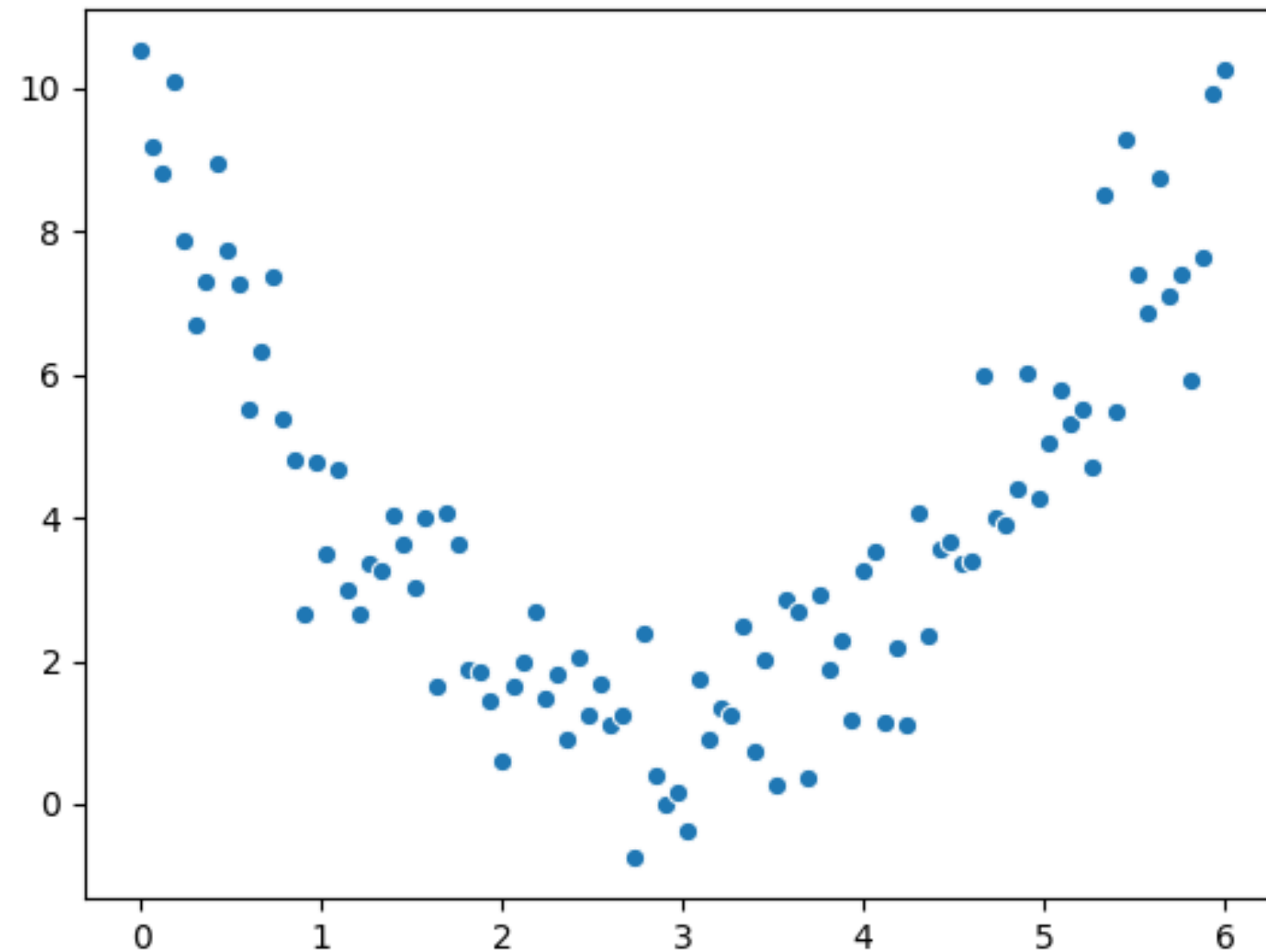
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# Non-linear relationships

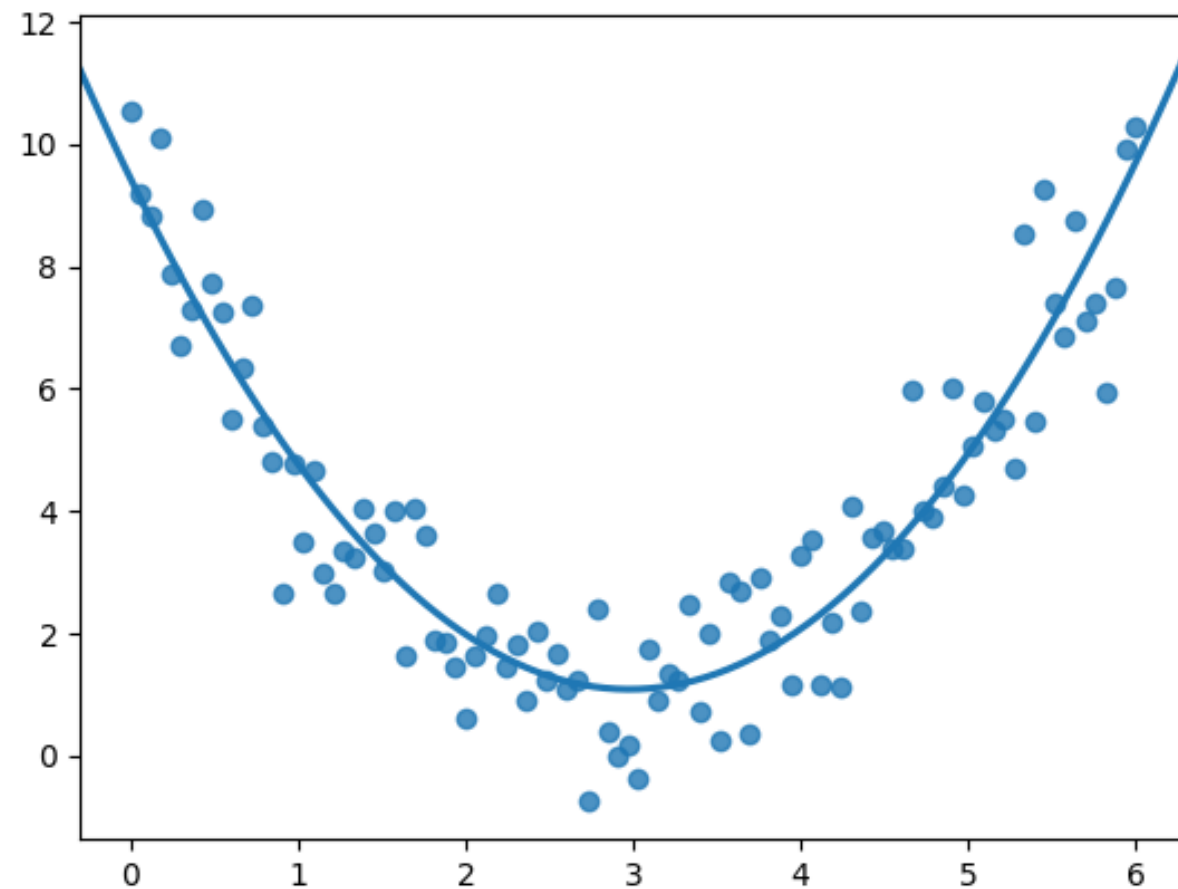


$$r = 0.18$$

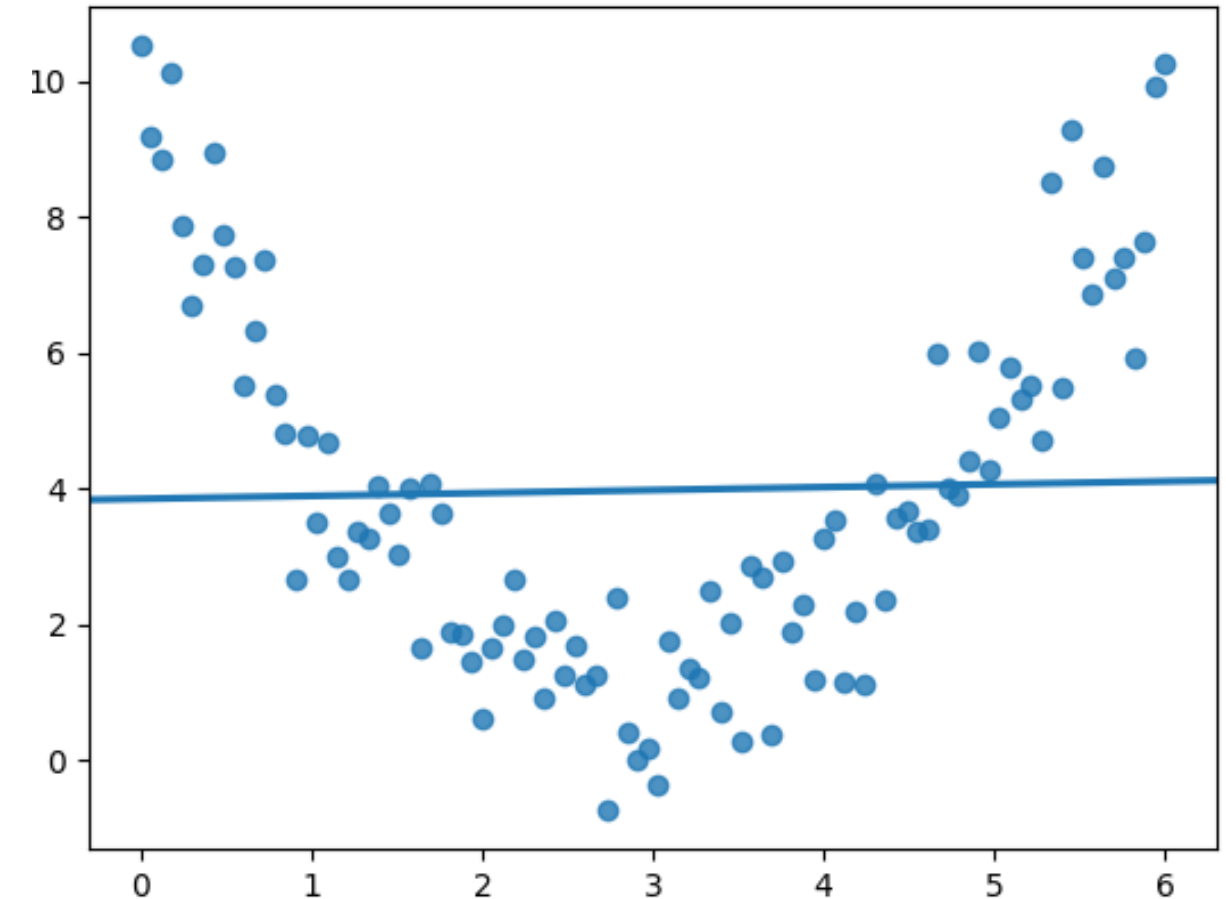


# Non-linear relationships

*What we see:*



*What the correlation coefficient sees:*



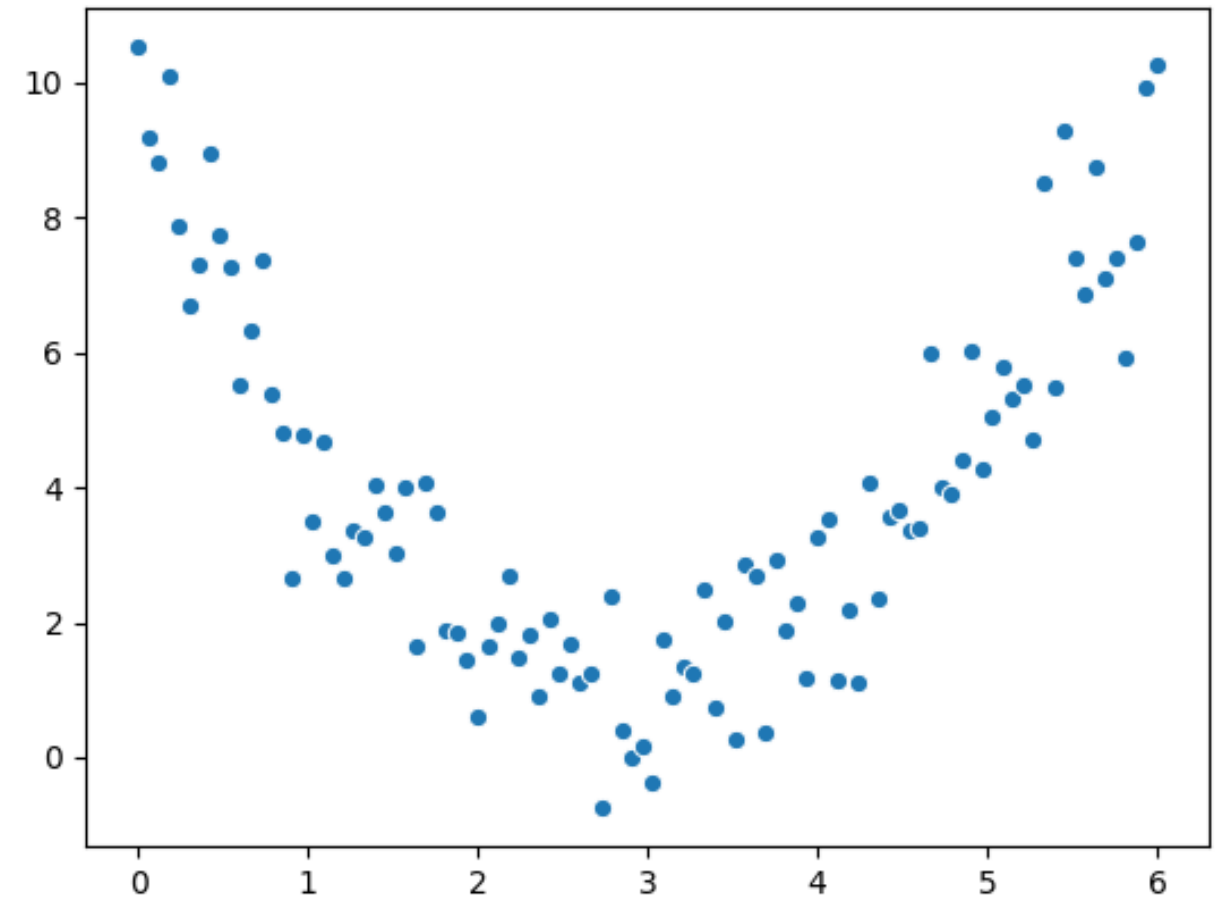
# Correlation only accounts for linear relationships

Correlation shouldn't be used blindly

```
df['x'].corr(df['y'])
```

```
0.081094
```

*Always* visualize your data

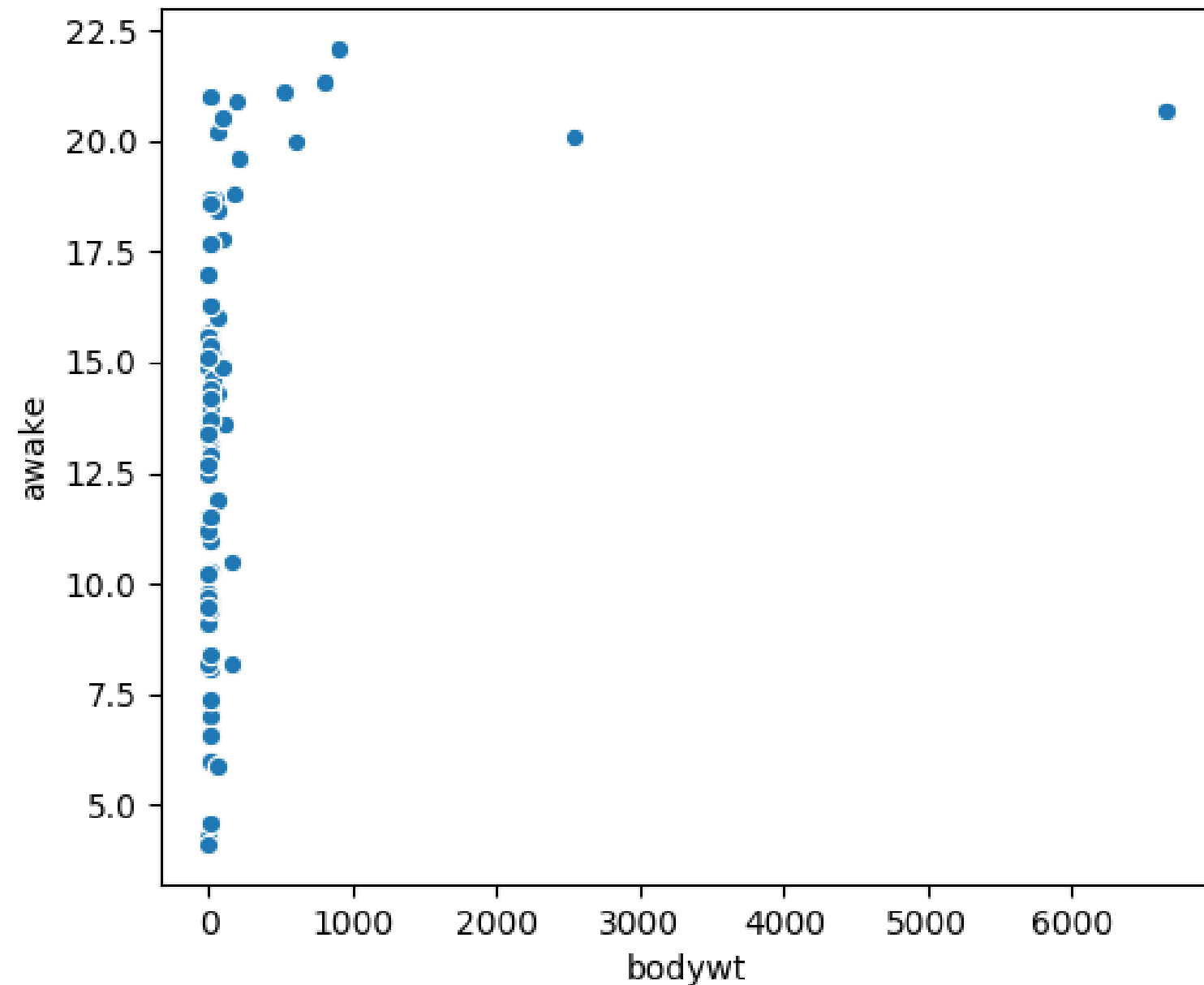


# Mammal sleep data

```
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

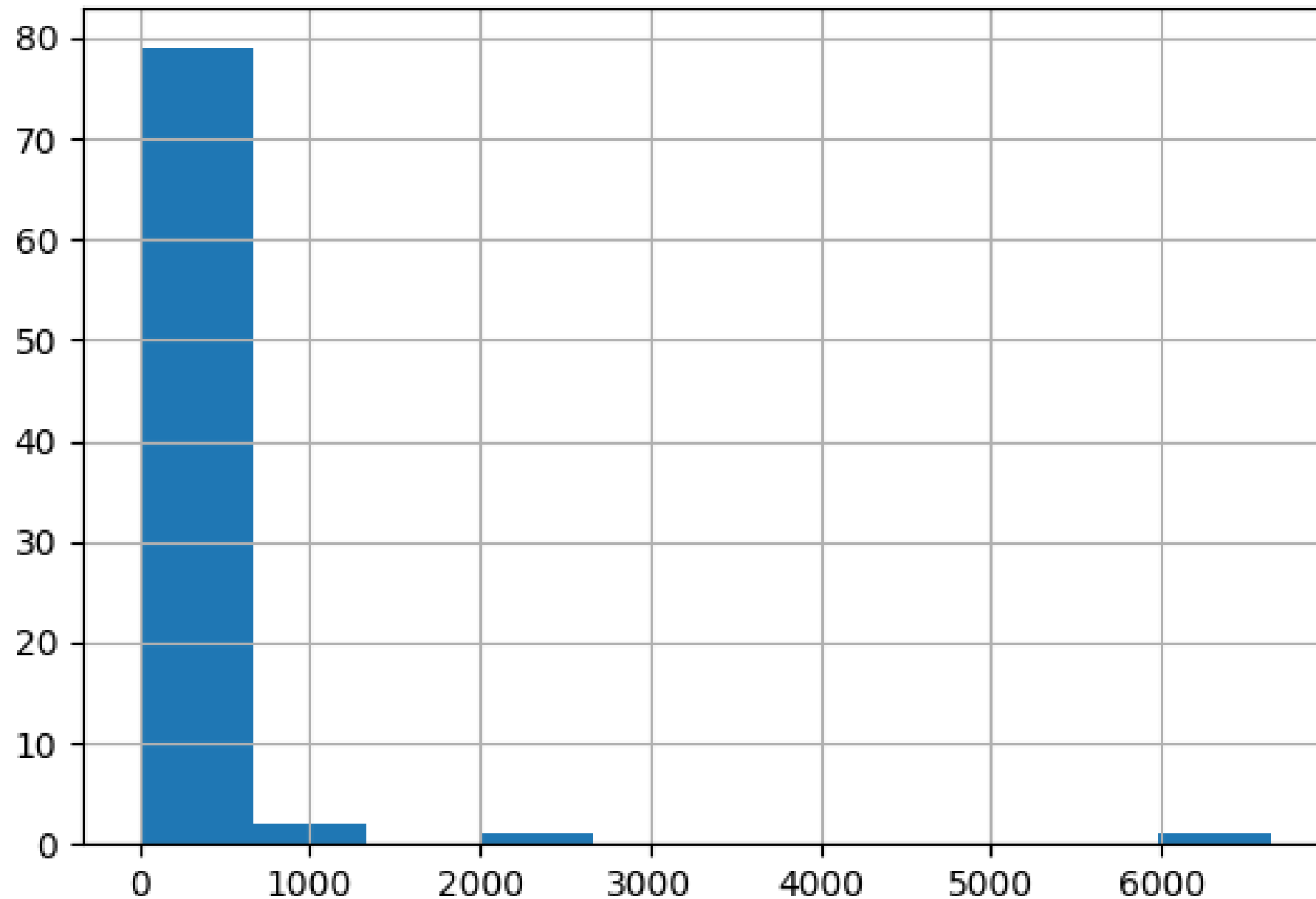
# Body weight vs. awake time



```
msleep['bodywt'].corr(msleep['awake'])
```

```
0.3119801
```

# Distribution of body weight



# Log transformation

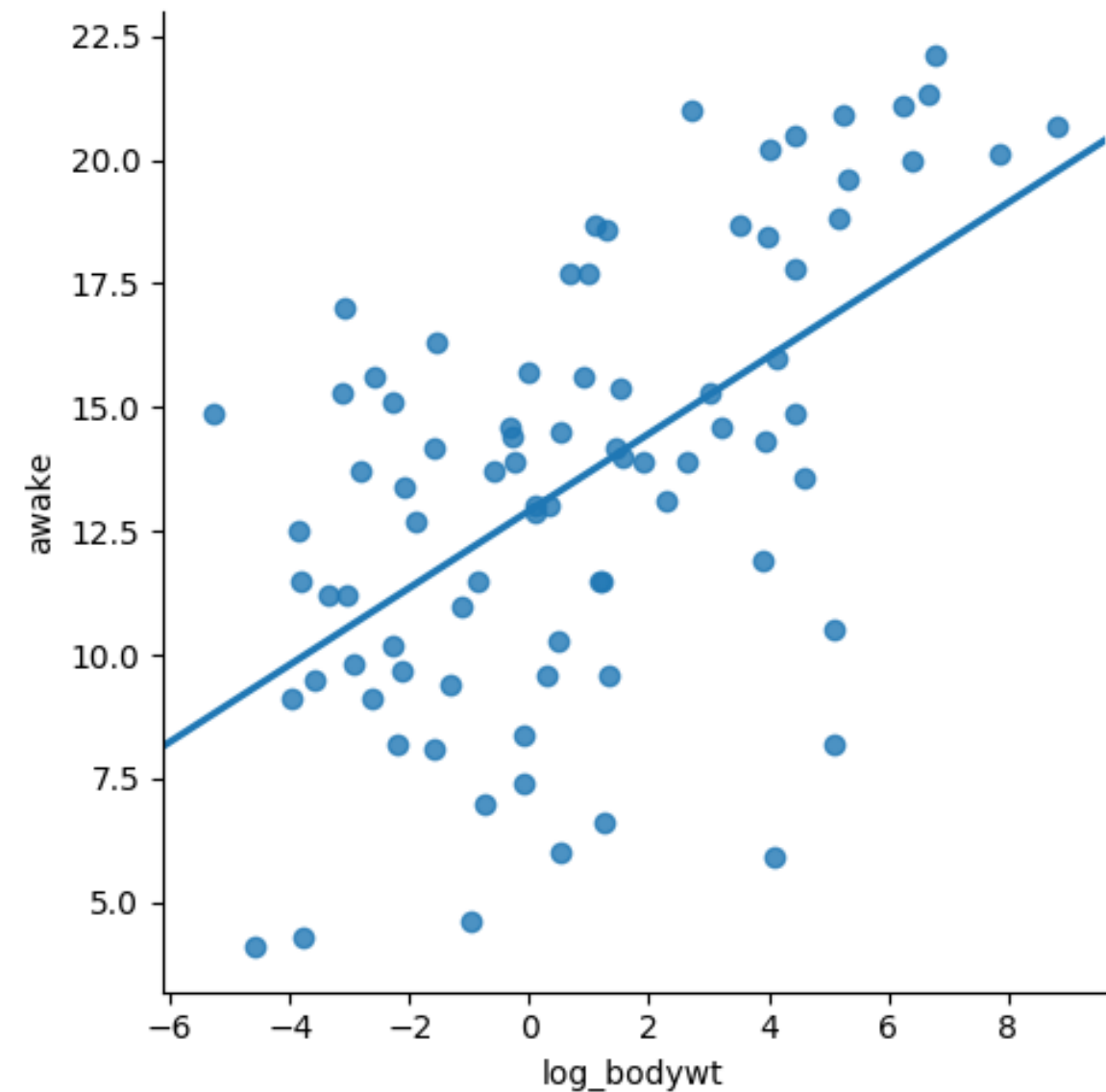
```
msleep['log_bodywt'] = np.log(msleep['bodywt'])

sns.lmplot(x='log_bodywt',
           y='awake',
           data=msleep,
           ci=None)

plt.show()
```

```
msleep['log_bodywt'].corr(msleep['awake'])
```

```
0.5687943
```



# Other transformations

- Log transformation (  $\log(x)$  )
- Square root transformation (  $\sqrt{x}$  )
- Reciprocal transformation (  $1 / x$  )
- Combinations of these, e.g.:
  - $\log(x)$  and  $\log(y)$
  - $\sqrt{x}$  and  $1 / y$

# Why use a transformation?

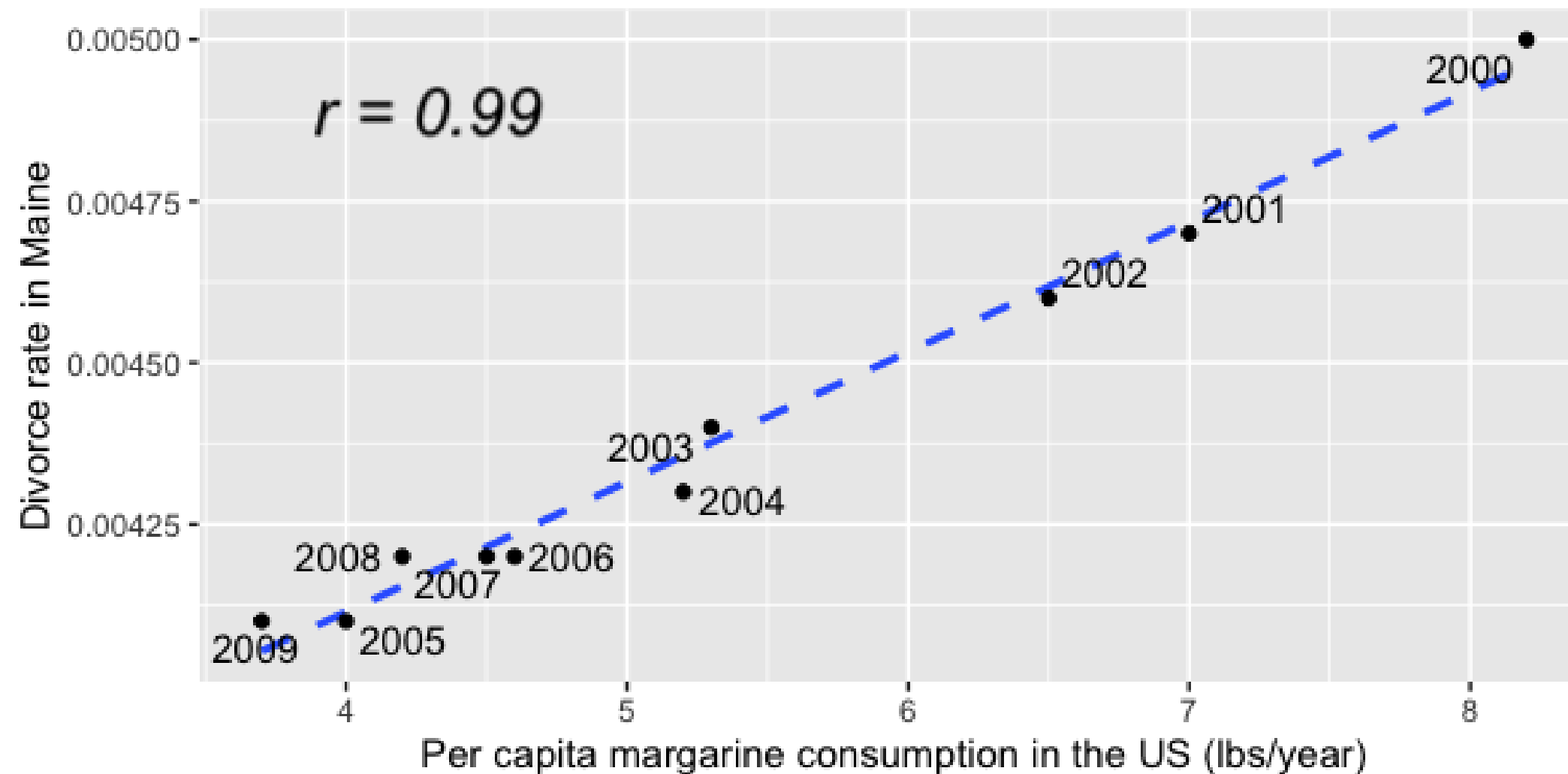
- Certain statistical methods rely on variables having a linear relationship
  - Correlation coefficient
  - Linear regression

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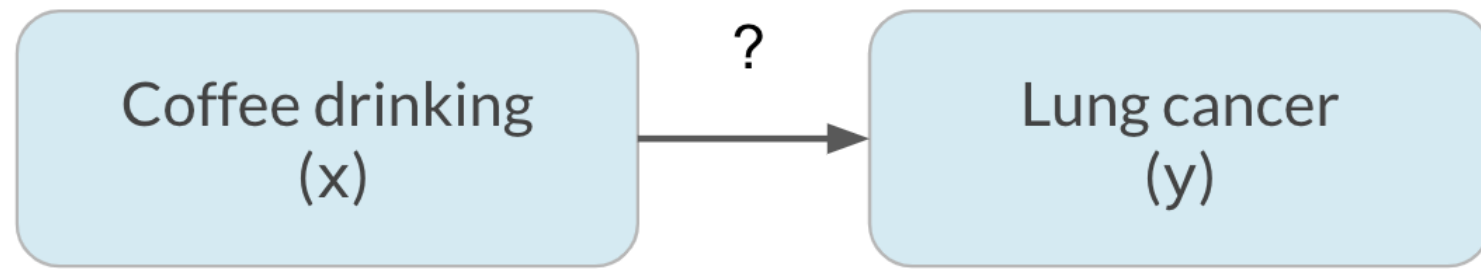


# Correlation does not imply causation

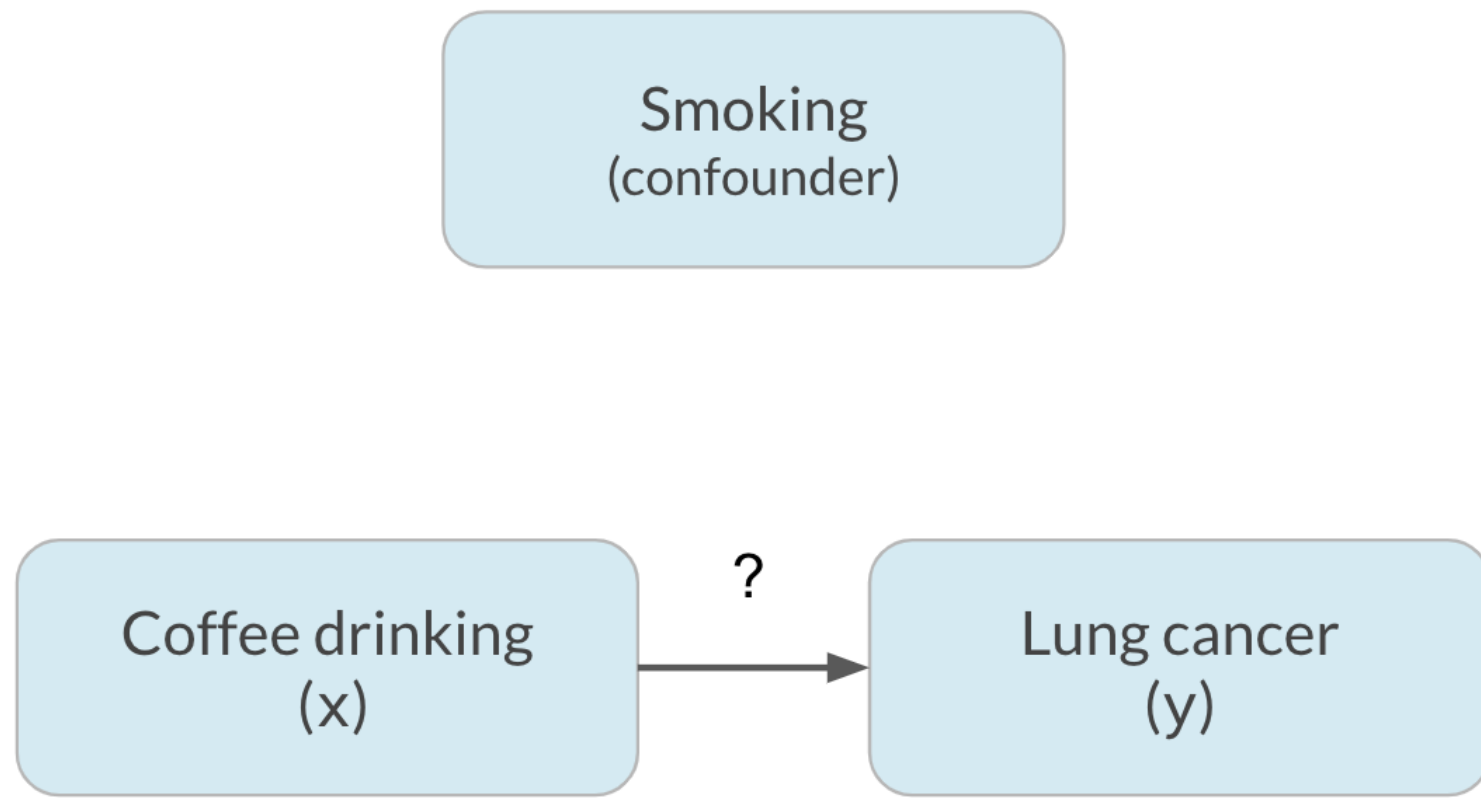
$x$  is correlated with  $y$  does not mean  $x$  causes  $y$



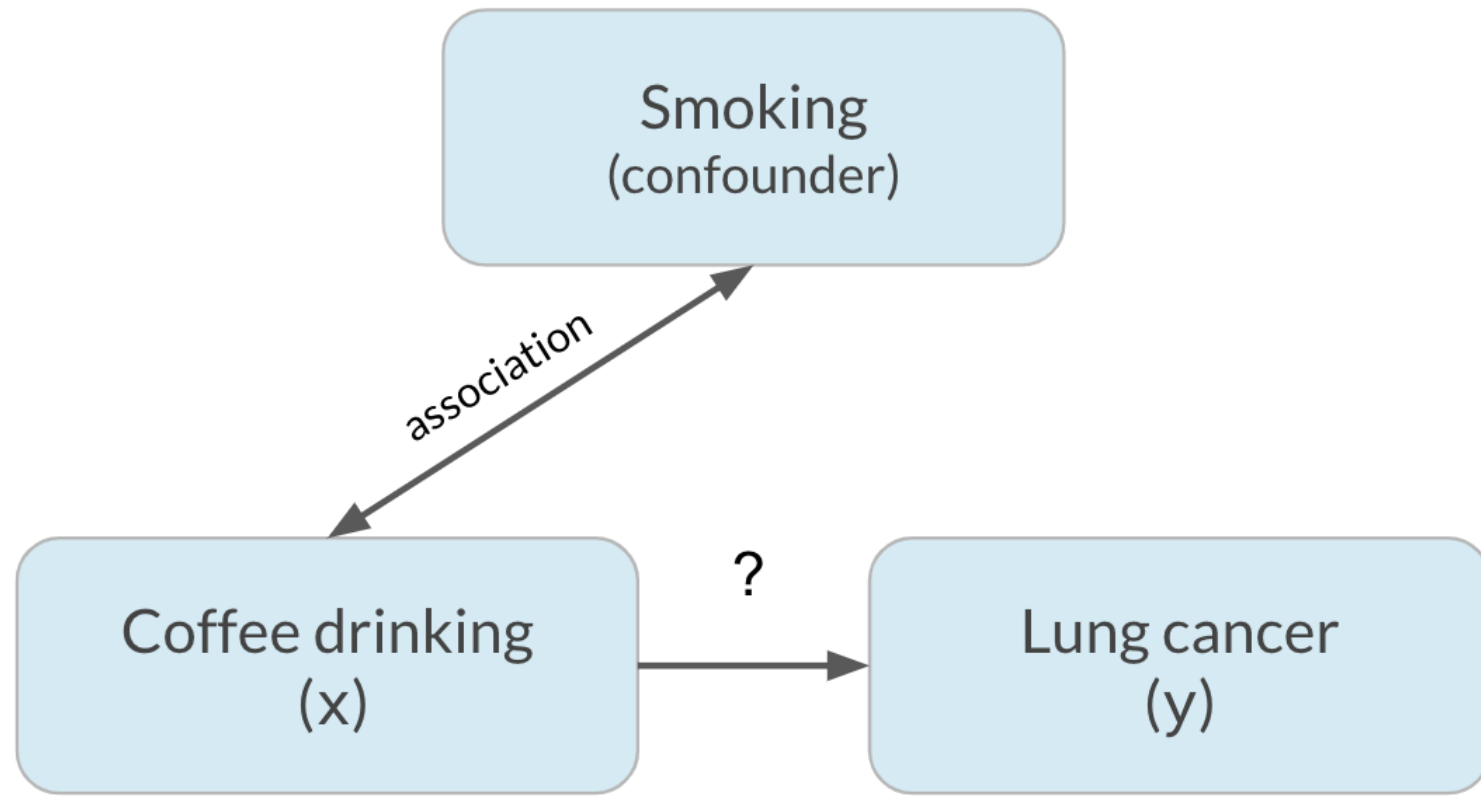
# Confounding



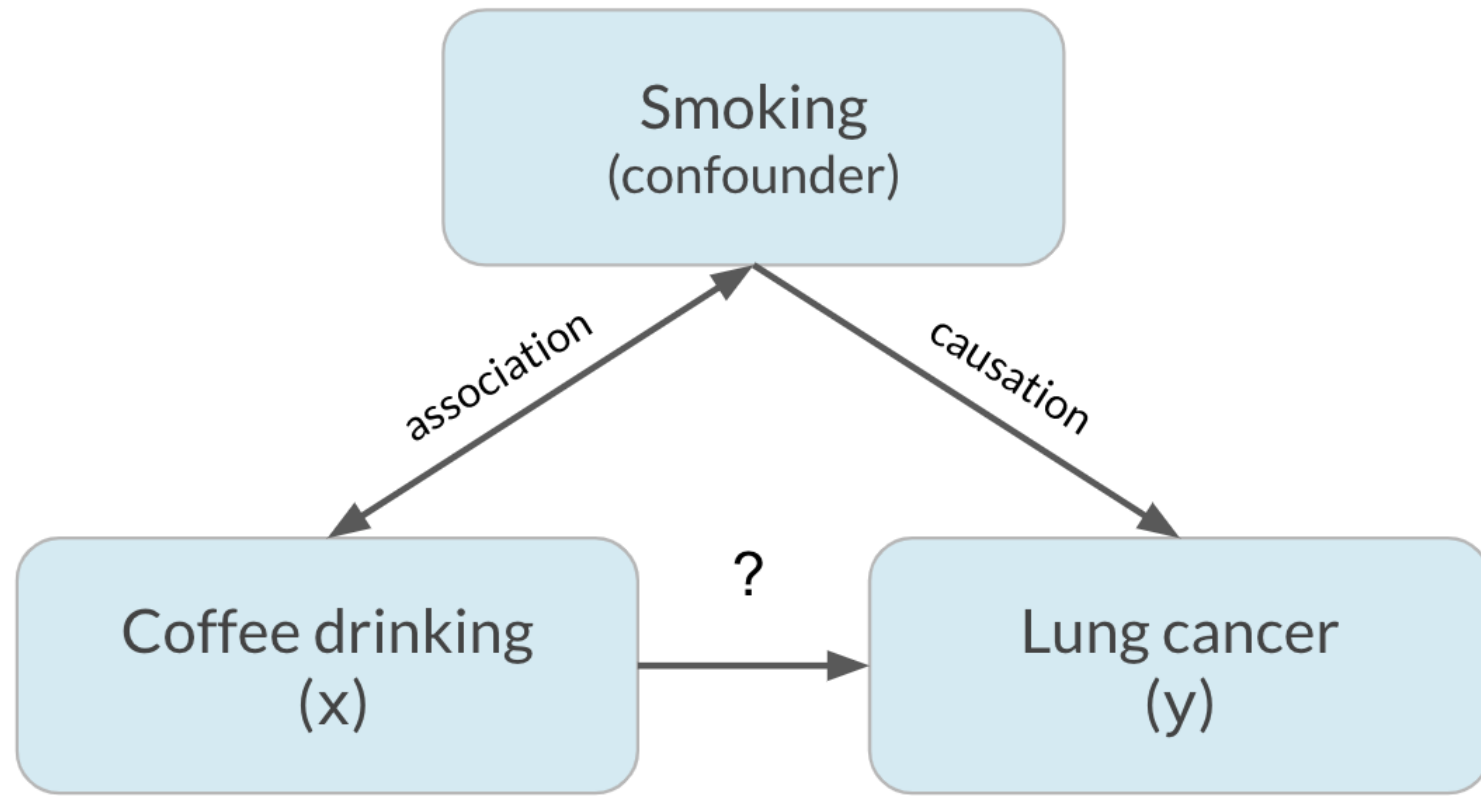
# Confounding



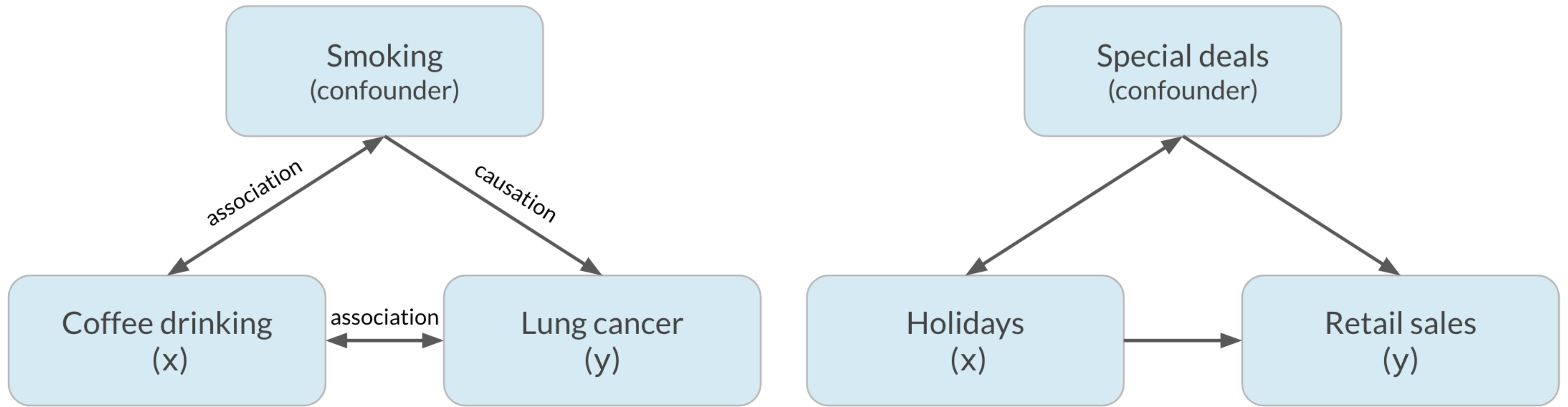
# Confounding



# Confounding



# Confounding

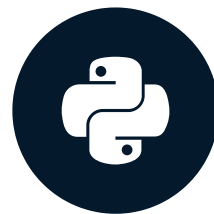


# Let's practice!

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# Design of experiments

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# Vocabulary

Experiment aims to answer: *What is the effect of the treatment on the response?*

- Treatment: explanatory/independent variable
- Response: response/dependent variable

E.g.: *What is the effect of an advertisement on the number of products purchased?*

- Treatment: advertisement
- Response: number of products purchased

# Controlled experiments

- Participants are assigned by researchers to either treatment group or control group
  - Treatment group sees advertisement
  - Control group does not
- Groups should be comparable so that causation can be inferred
- If groups are not comparable, this could lead to confounding (bias)
  - Treatment group average age: 25
  - Control group average age: 50
  - Age is a potential confounder

# The gold standard of experiments will use...

- Randomized controlled trial
  - Participants are assigned to treatment/control *randomly*, not based on any other characteristics
  - Choosing randomly helps ensure that groups are comparable
- Placebo
  - Resembles treatment, but has no effect
  - Participants will not know which group they're in
  - In clinical trials, a sugar pill ensures that the effect of the drug is actually due to the drug itself and not the idea of receiving the drug

# The gold standard of experiments will use...

- Double-blind trial
  - Person administering the treatment/running the study doesn't know whether the treatment is real or a placebo
  - Prevents bias in the response and/or analysis of results

*Fewer opportunities for bias = more reliable conclusion about causation*

# Observational studies

- Participants are not assigned randomly to groups
  - Participants assign themselves, usually based on pre-existing characteristics
- Many research questions are not conducive to a controlled experiment
  - You can't force someone to smoke or have a disease
  - You can't make someone have certain past behavior
- Establish association, not causation
  - Effects can be confounded by factors that got certain people into the control or treatment group
  - There are ways to control for confounders to get more reliable conclusions about association

# Longitudinal vs. cross-sectional studies

## Longitudinal study

- Participants are followed over a period of time to examine effect of treatment on response
- Effect of age on height is not confounded by generation
- More expensive, results take longer

## Cross-sectional study

- Data on participants is collected from a single snapshot in time
- Effect of age on height is confounded by generation
- Cheaper, faster, more convenient

# Let's practice!

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# Congratulations!

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# Overview

## Chapter 1

- What is statistics?
- Measures of center
- Measures of spread

## Chapter 3

- Normal distribution
- Central limit theorem
- Poisson distribution

## Chapter 2

- Measuring chance
- Probability distributions
- Binomial distribution

## Chapter 4

- Correlation
- Controlled experiments
- Observational studies

# Build on your skills

- [Introduction to Linear Modeling in Python](#)

# Congratulations!

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