

# Correlation

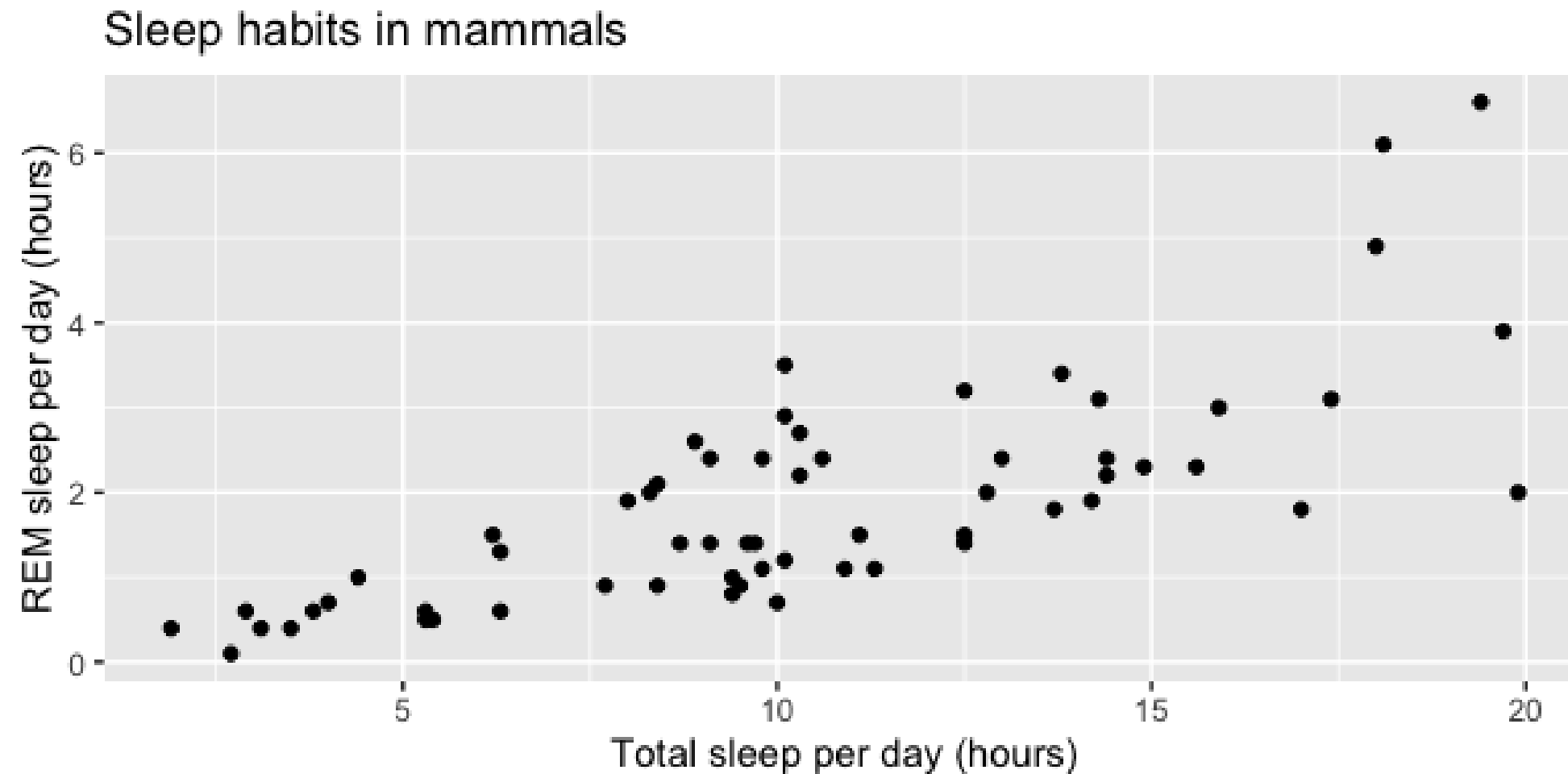
INTRODUCTION TO STATISTICS IN R



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# Relationships between two variables



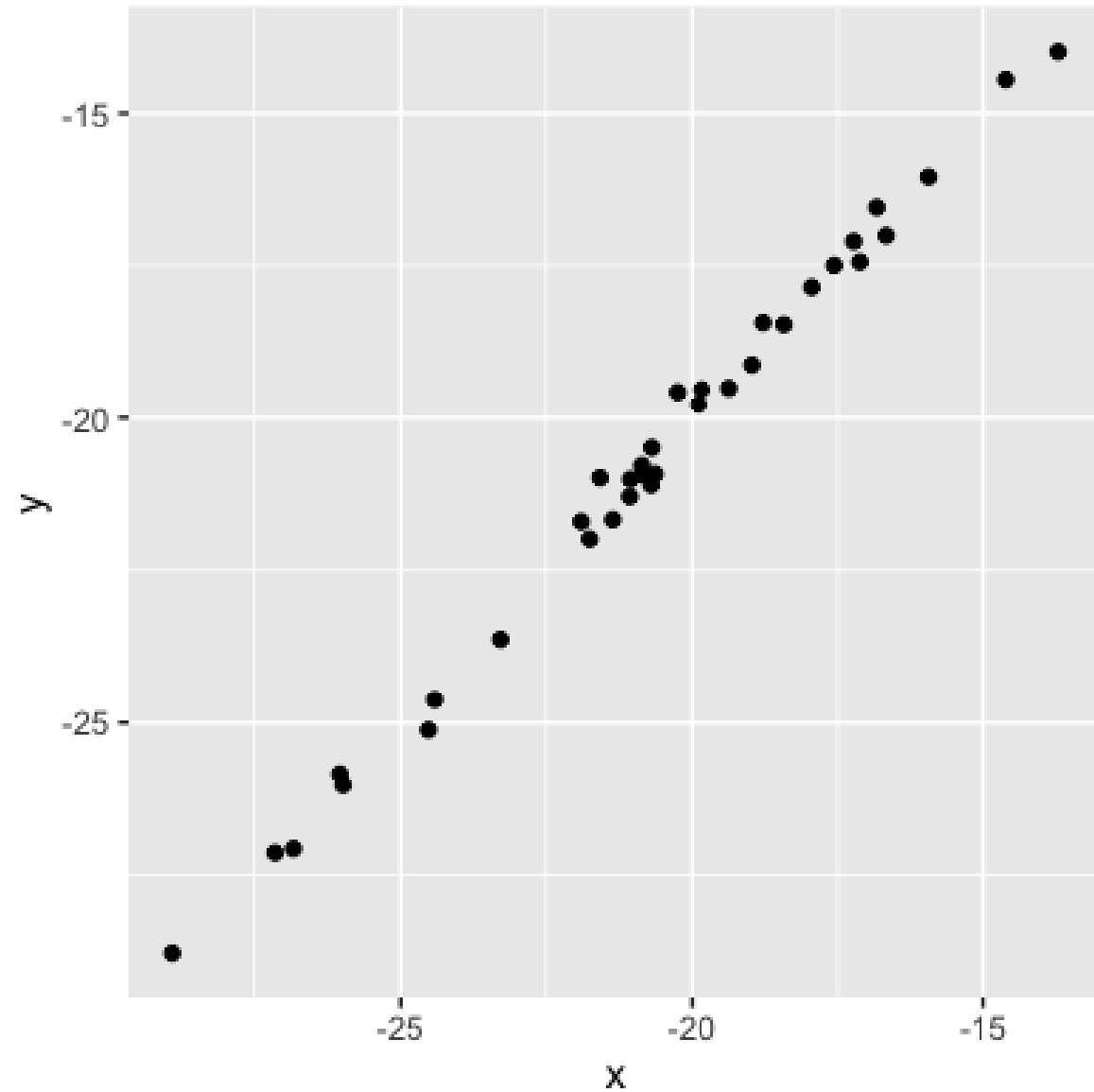
- $x$  = explanatory/independent variable
- $y$  = response/dependent variable

# 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

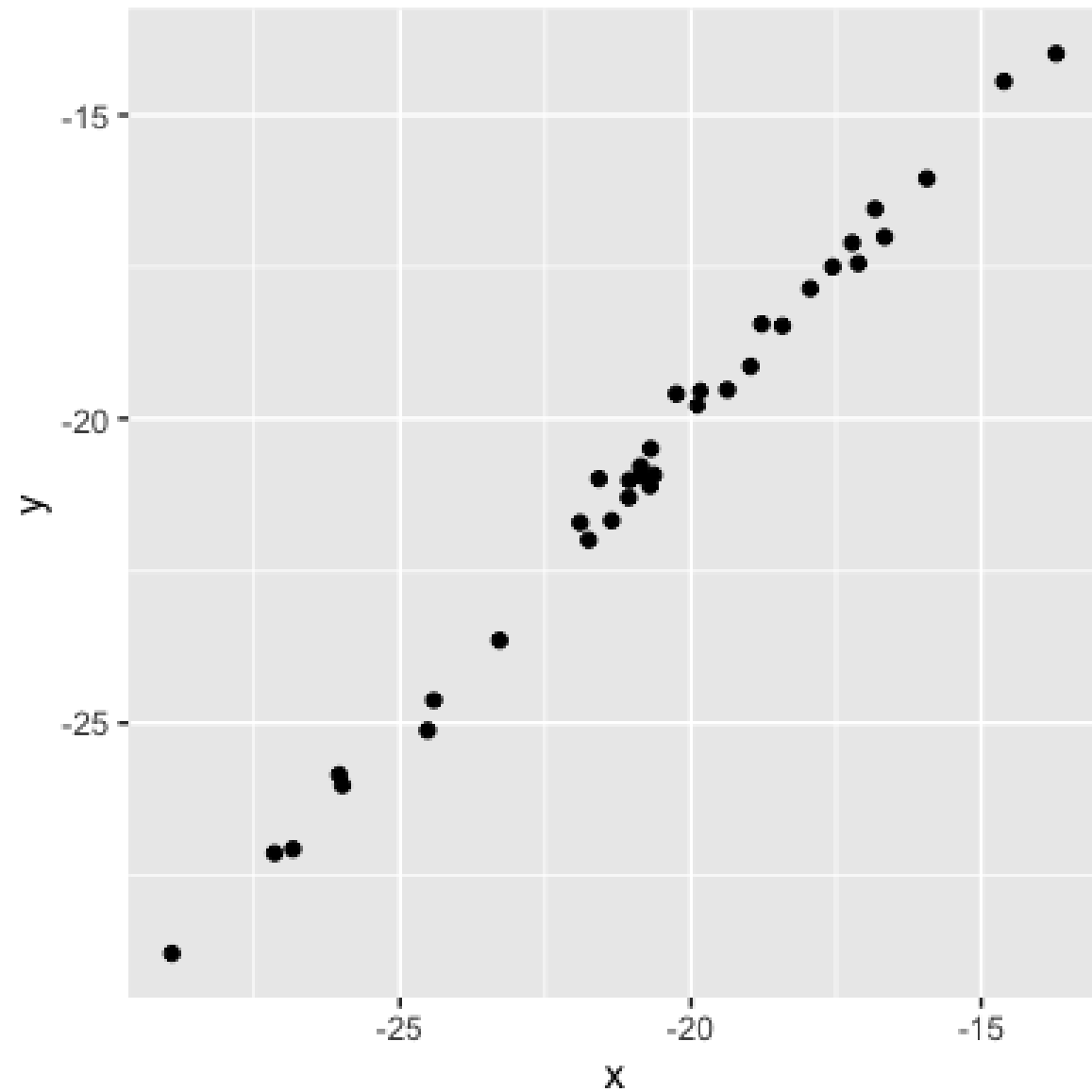
# Magnitude = strength of relationship

0.99 (very strong relationship)

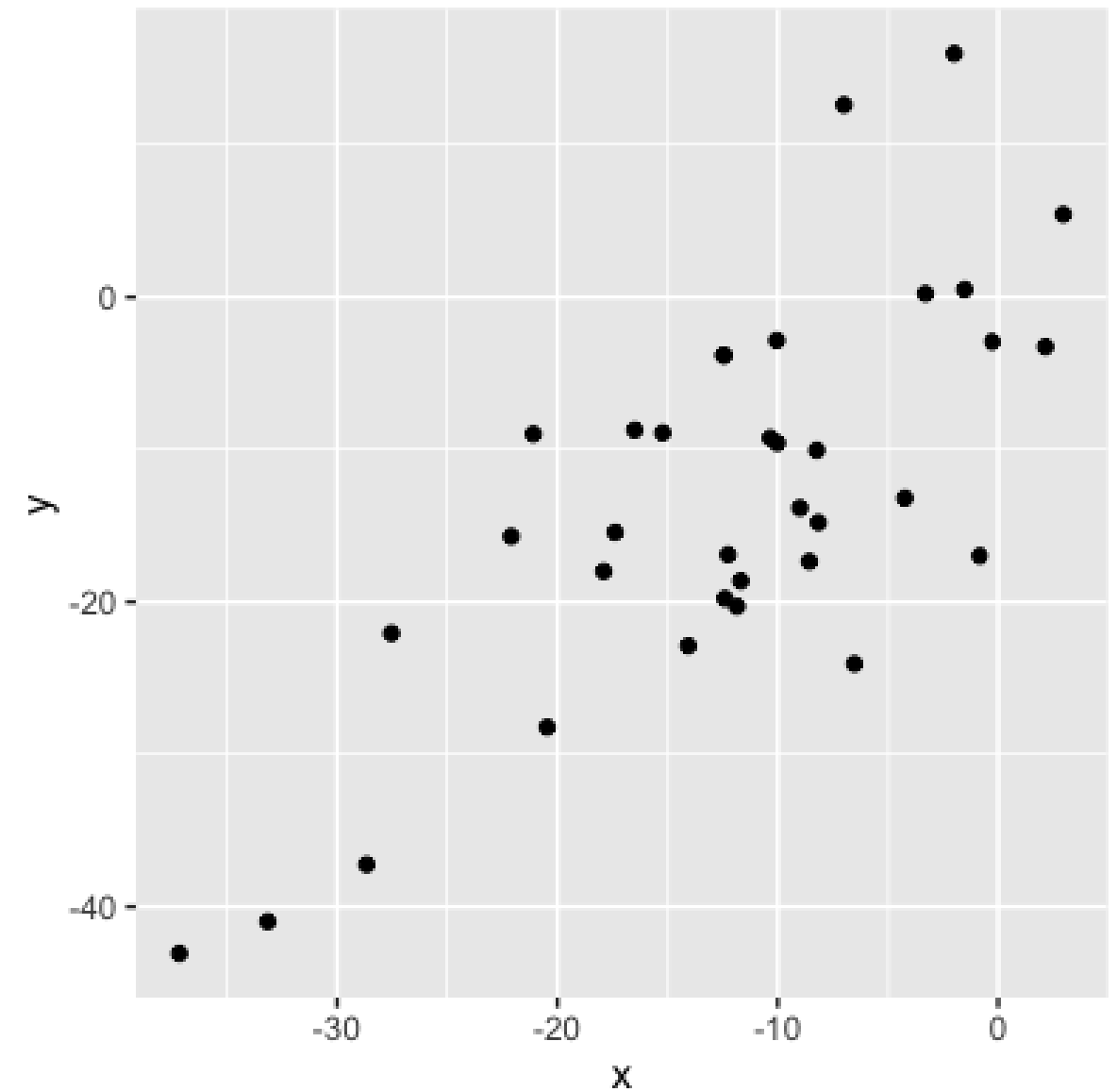


# Magnitude = strength of relationship

0.99 (very strong relationship)

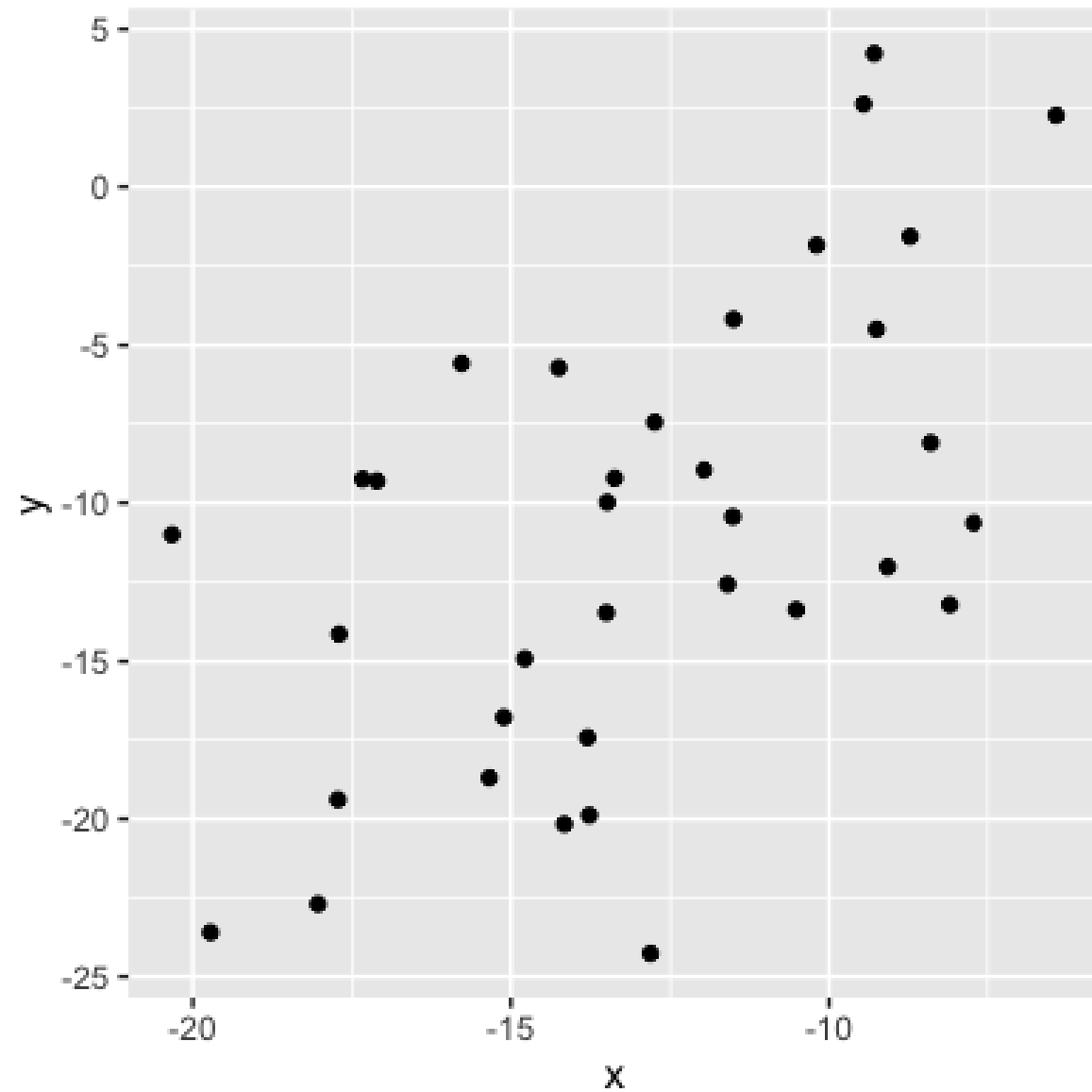


0.75 (strong relationship)



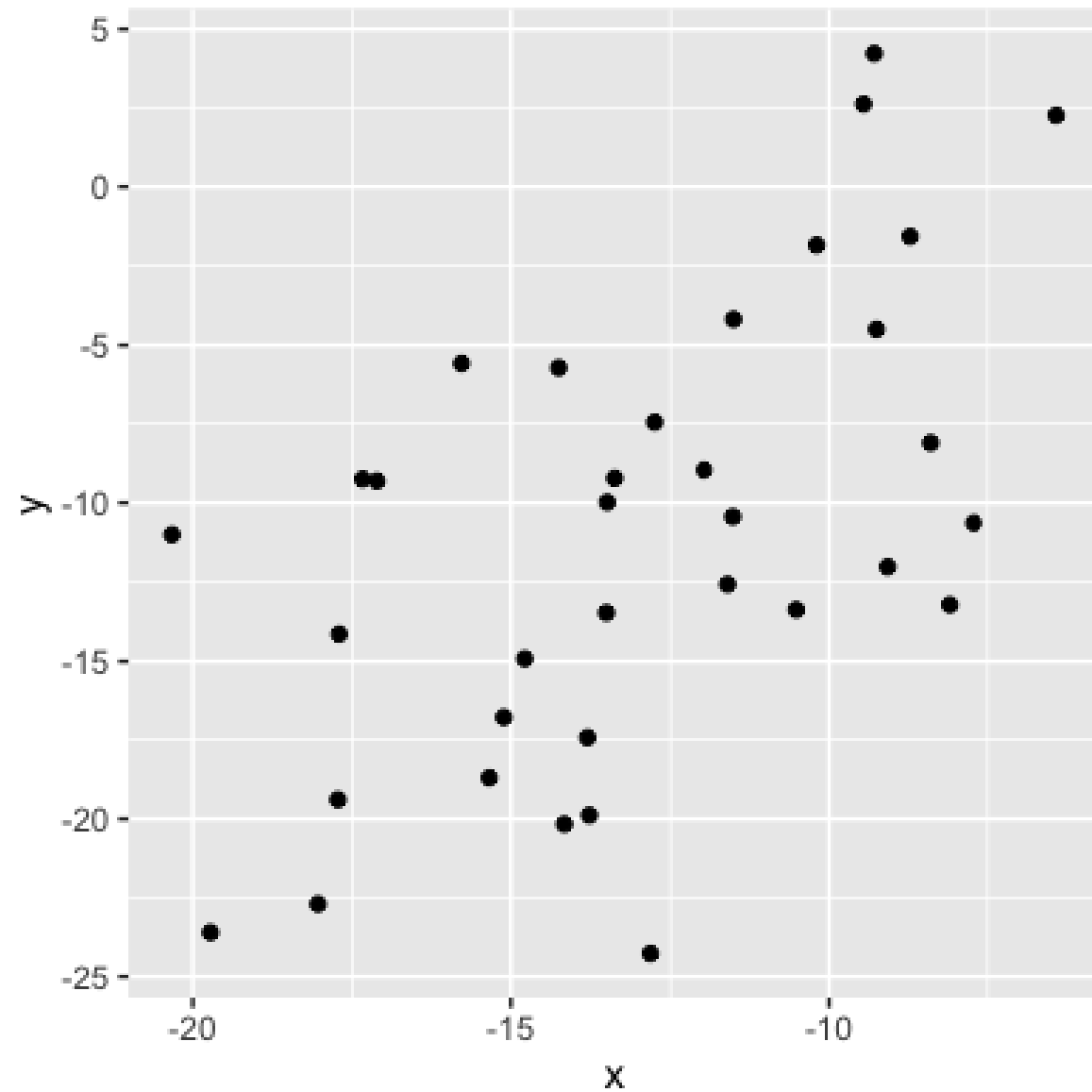
# Magnitude = strength of relationship

0.56 (moderate relationship)

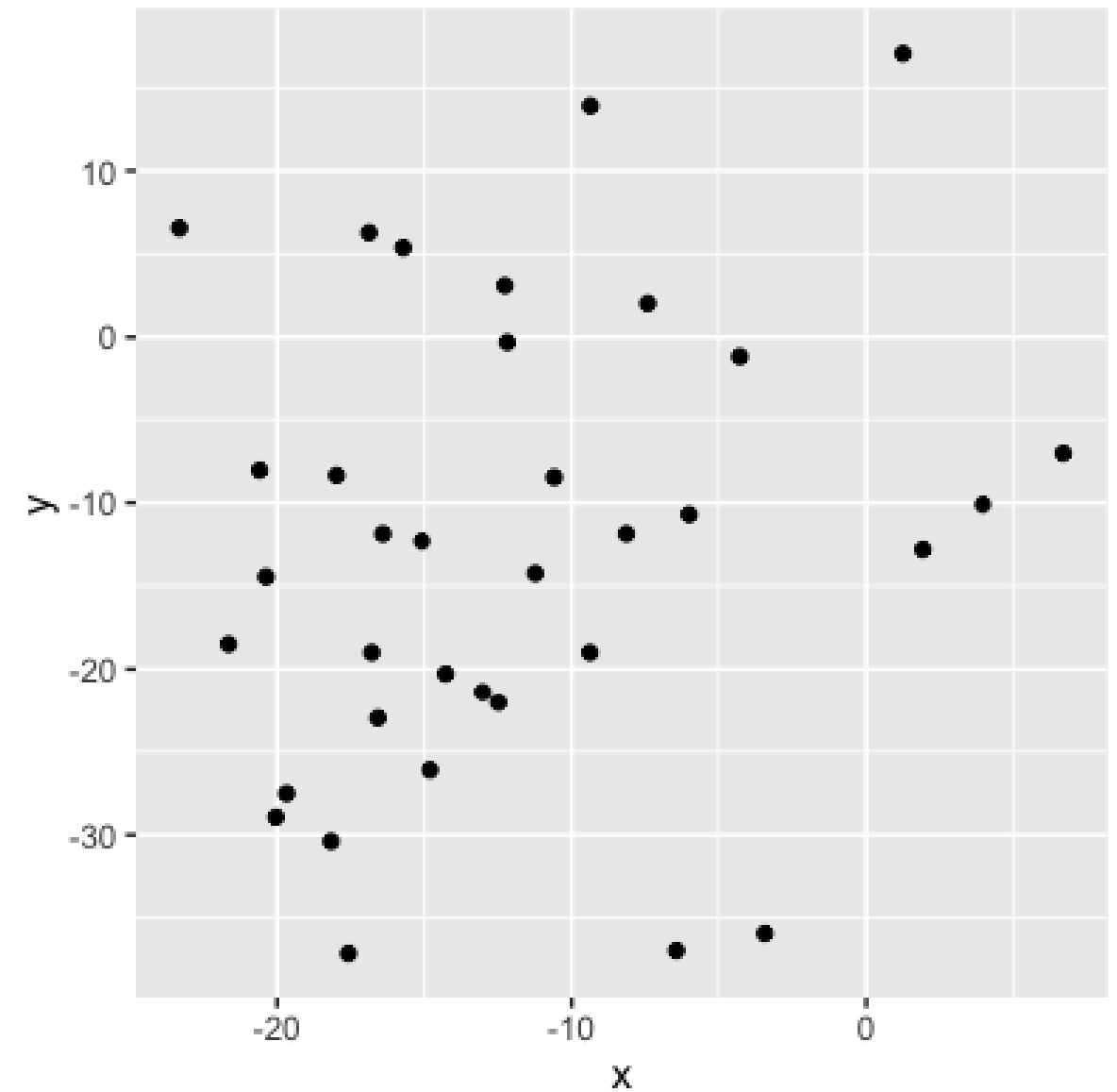


# Magnitude = strength of relationship

0.56 (moderate relationship)



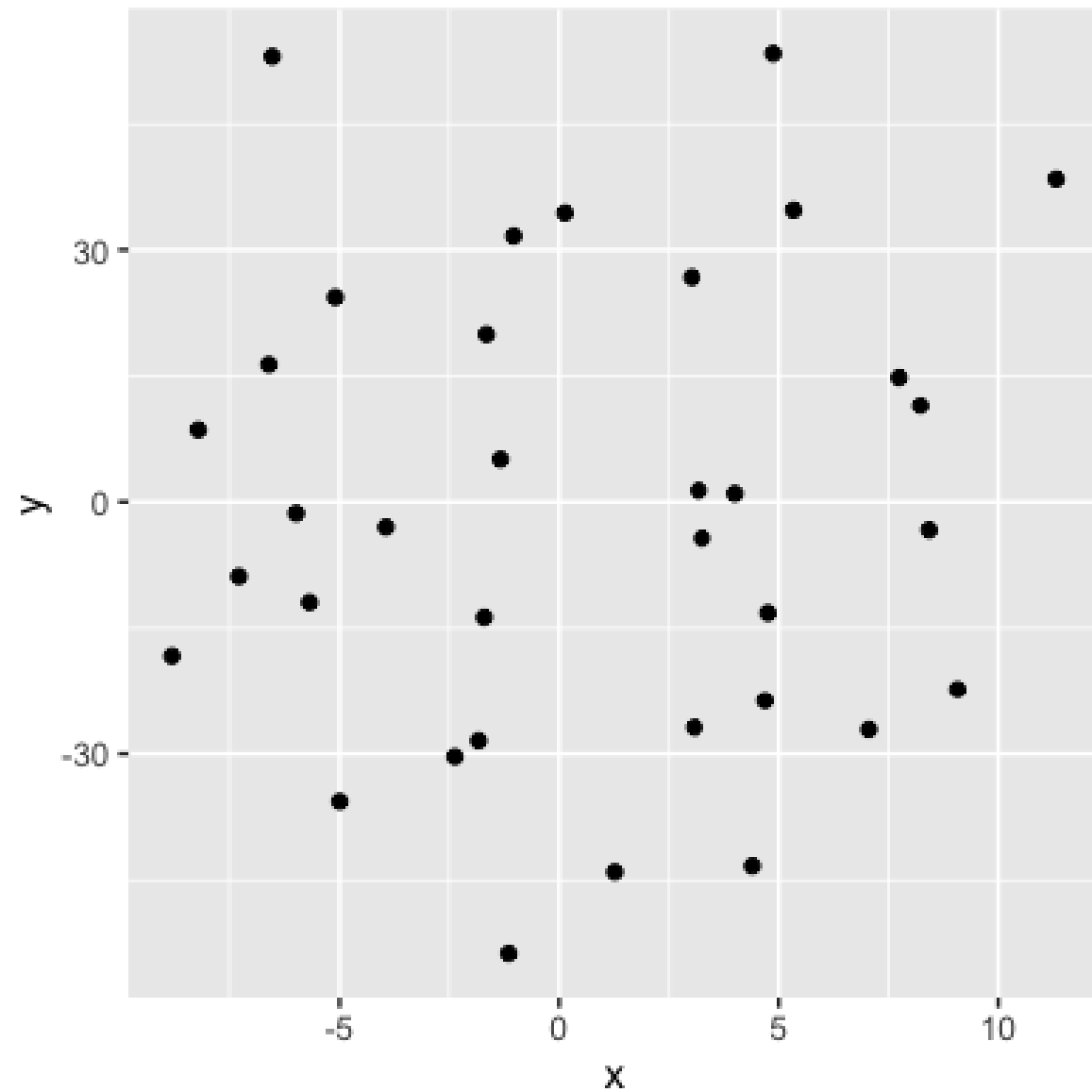
0.21 (weak relationship)



# Magnitude = strength of relationship

0.04 (no relationship)

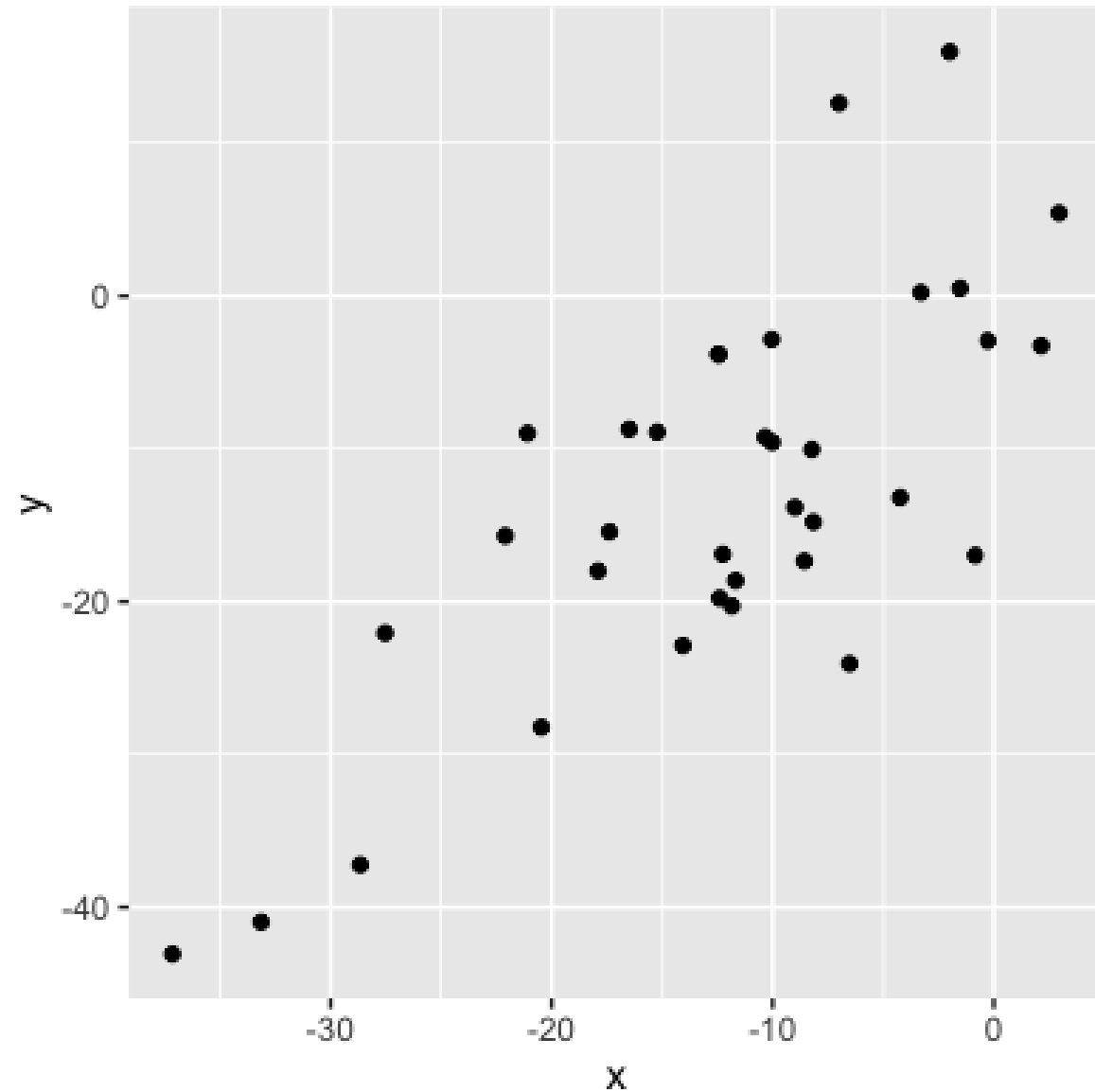
- Knowing the value of `x` doesn't tell us anything about `y`



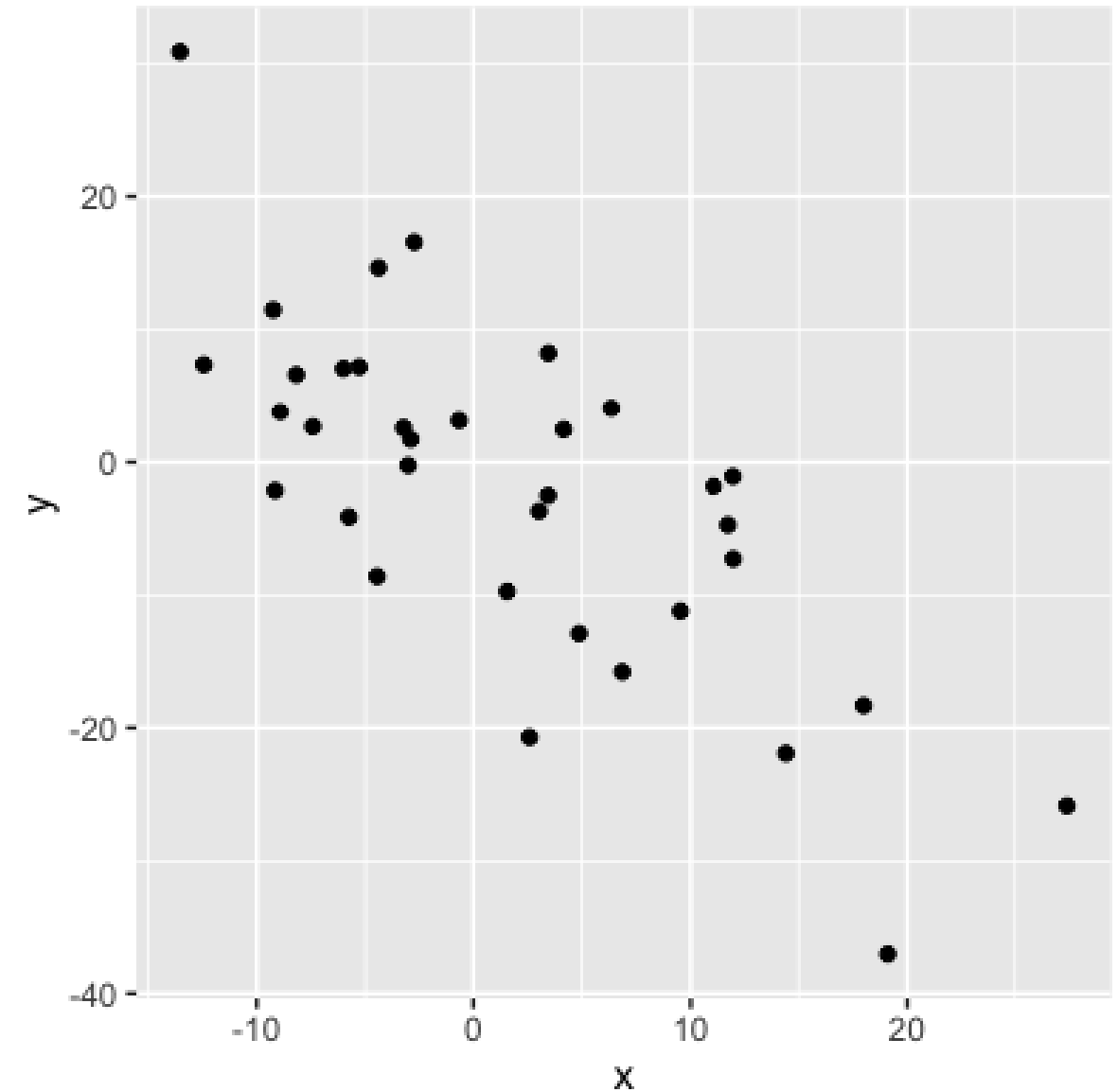


# Sign = direction

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

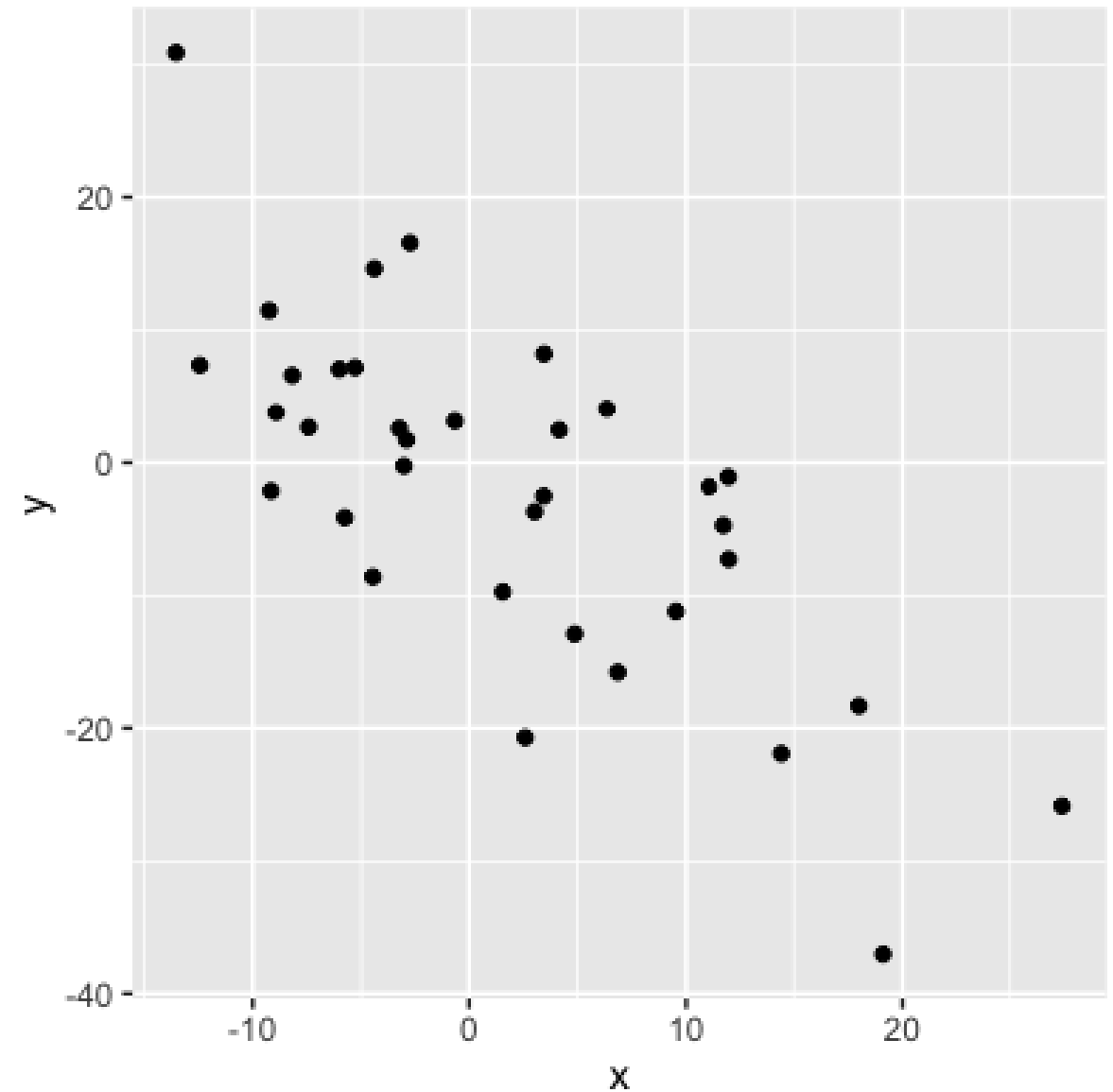


-0.75 : as **x** increases, **y** decreases



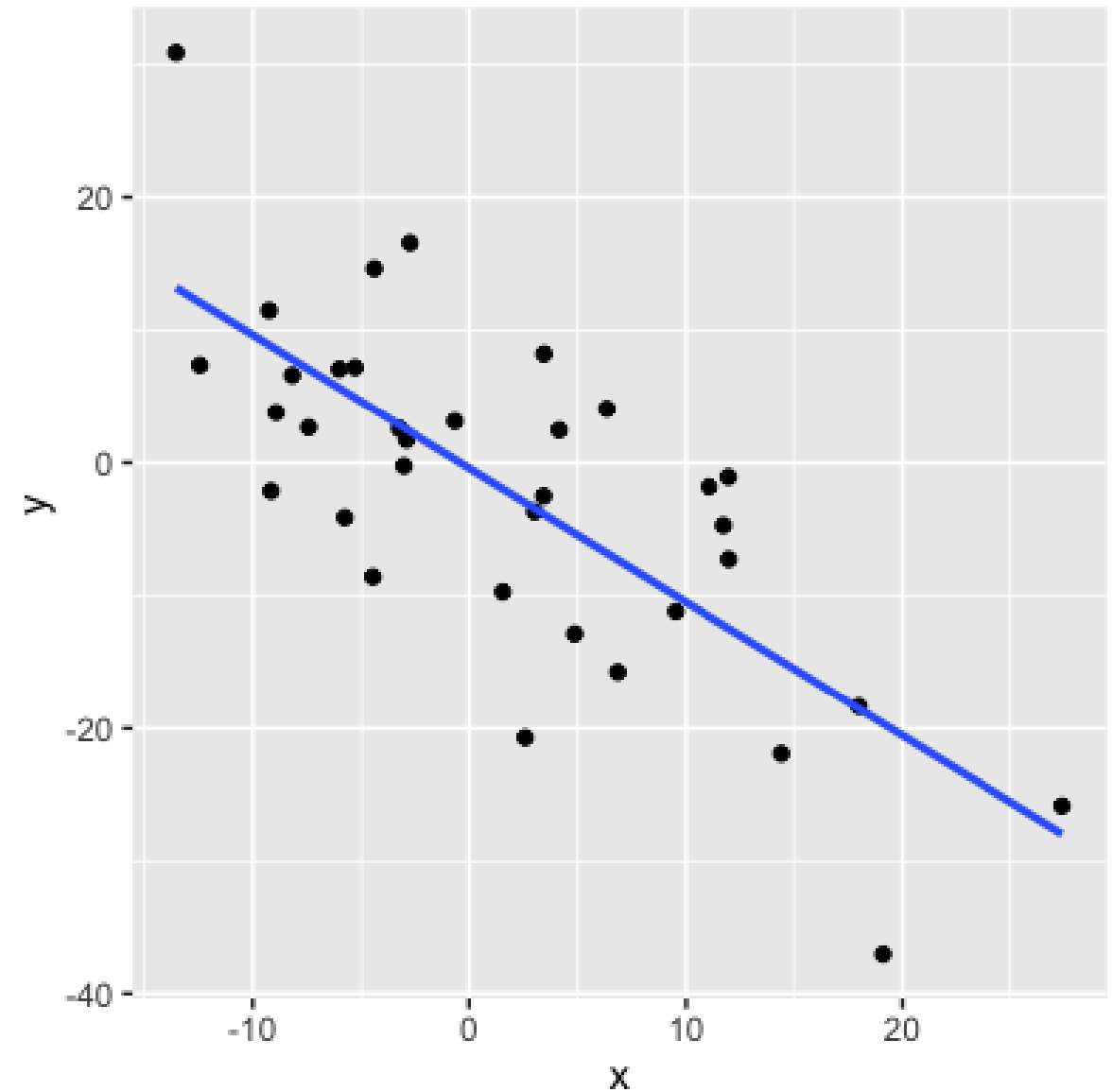
# Visualizing relationships

```
ggplot(df, aes(x, y)) +  
  geom_point()
```



# Adding a trendline

```
ggplot(df, aes(x, y)) +  
  geom_point() +  
  geom_smooth(method = "lm", se = FALSE)
```



# Computing correlation

```
cor(df$x, df$y)
```

```
-0.7472765
```

```
cor(df$y, df$x)
```

```
-0.7472765
```

# Correlation with missing values

```
df$x
```

```
-3.2508382 -9.1599807 3.4515013 4.1505899 NA 11.9806140 ...
```

```
cor(df$x, df$y)
```

```
NA
```

```
cor(df$x, df$y, use = "pairwise.complete.obs")
```

```
-0.7471757
```

# 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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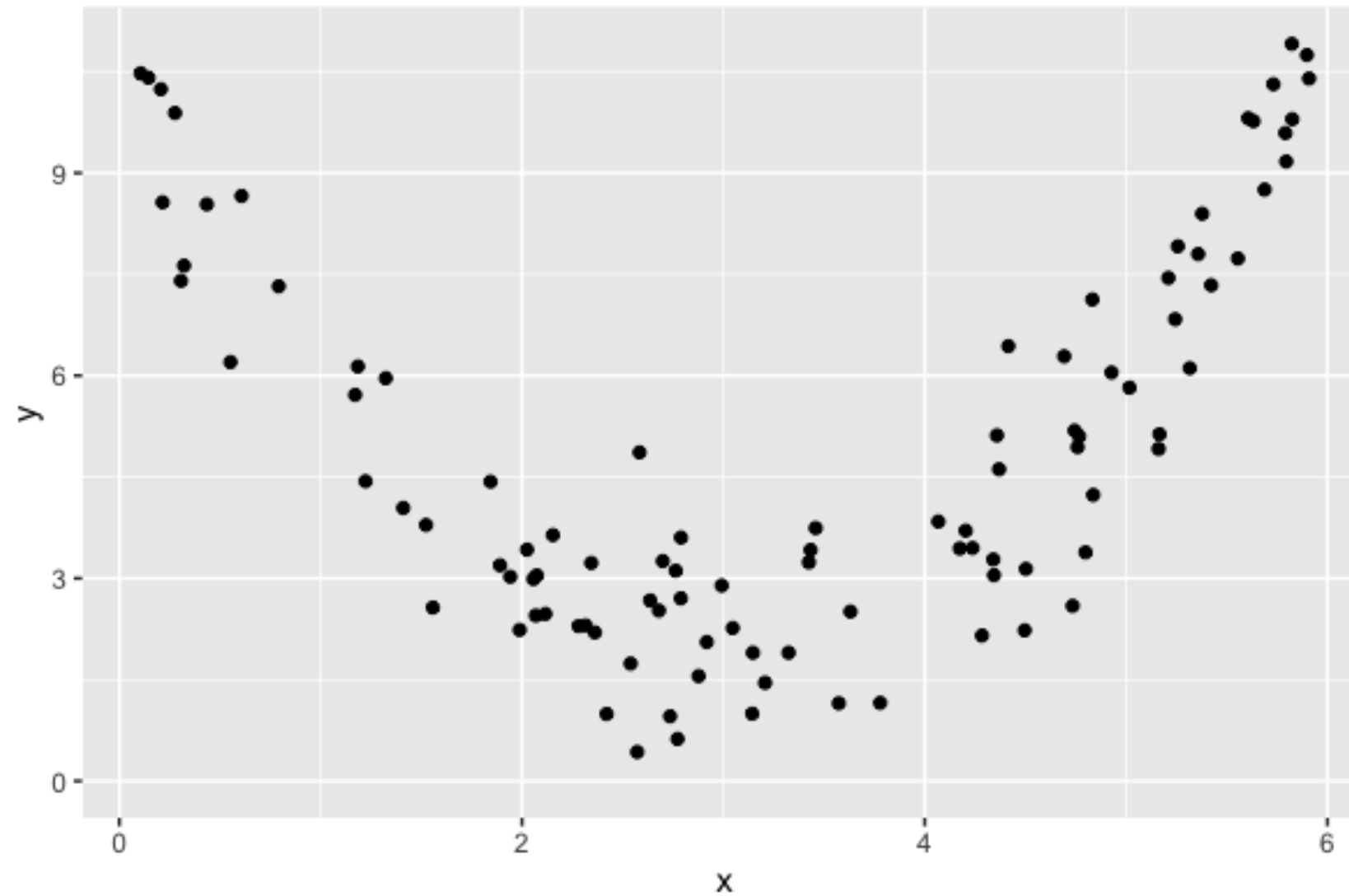


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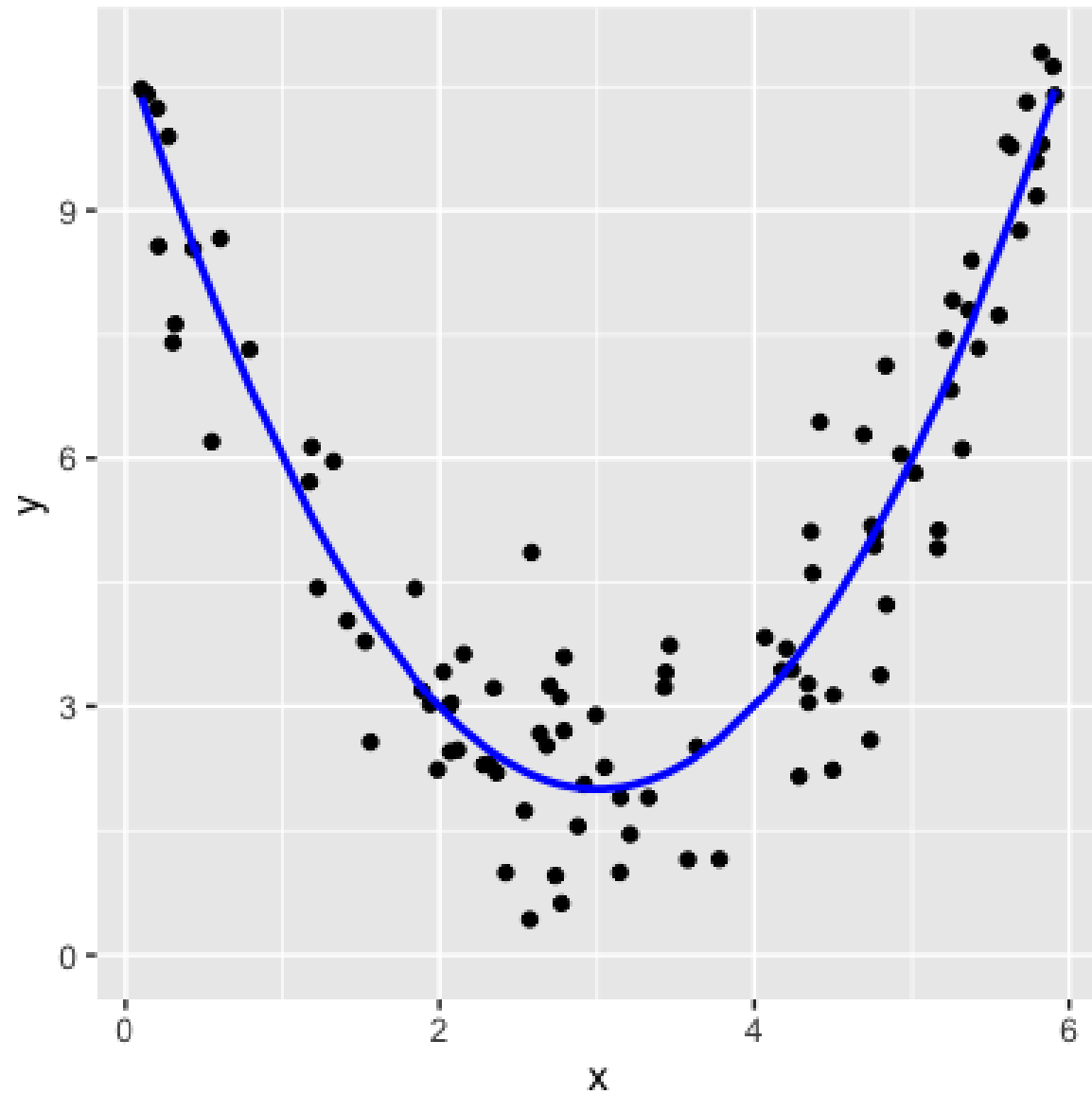
# Non-linear relationships



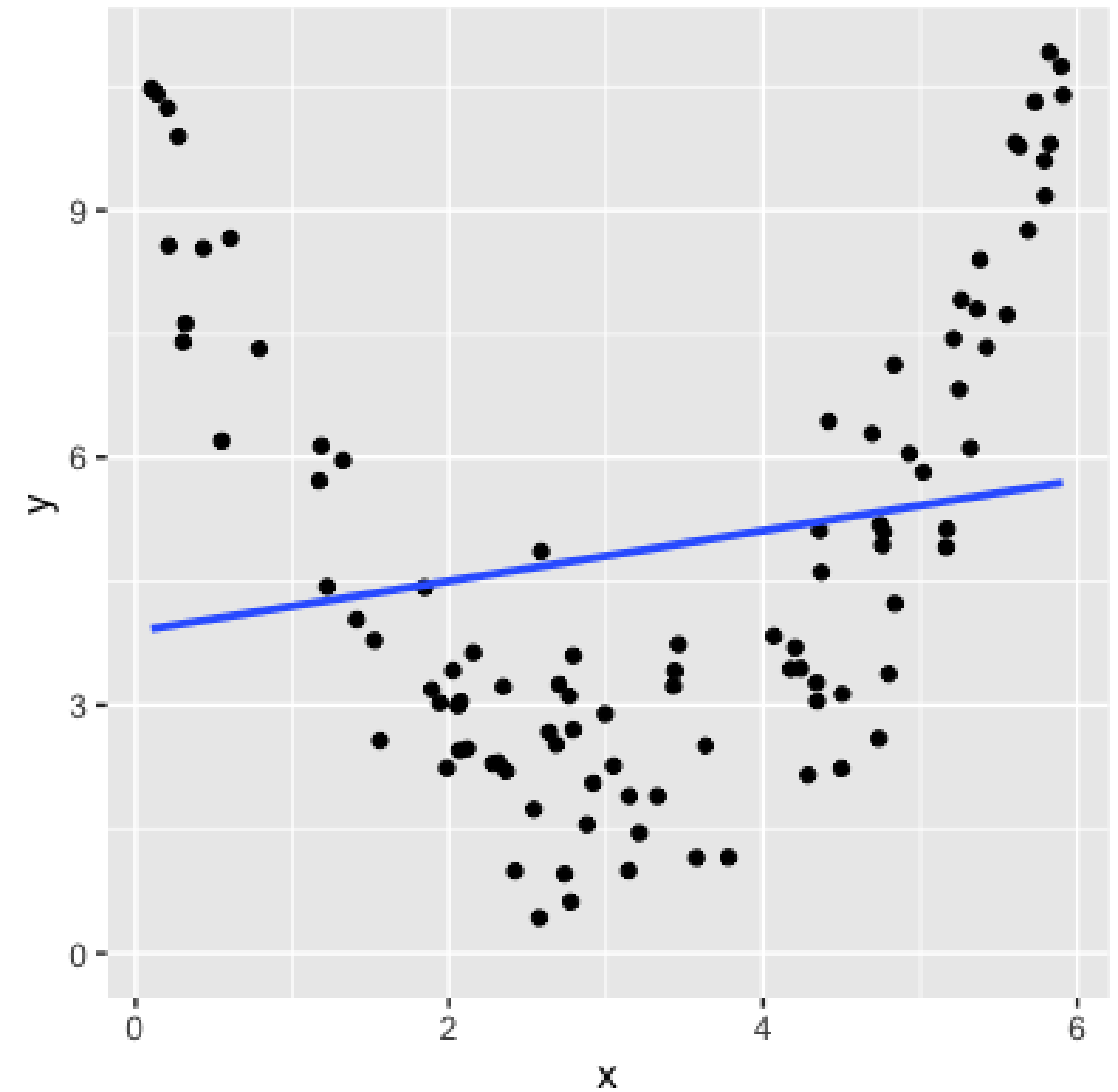
$$r = 0.18$$

# Non-linear relationships

*What we see:*



*What the correlation coefficient sees:*



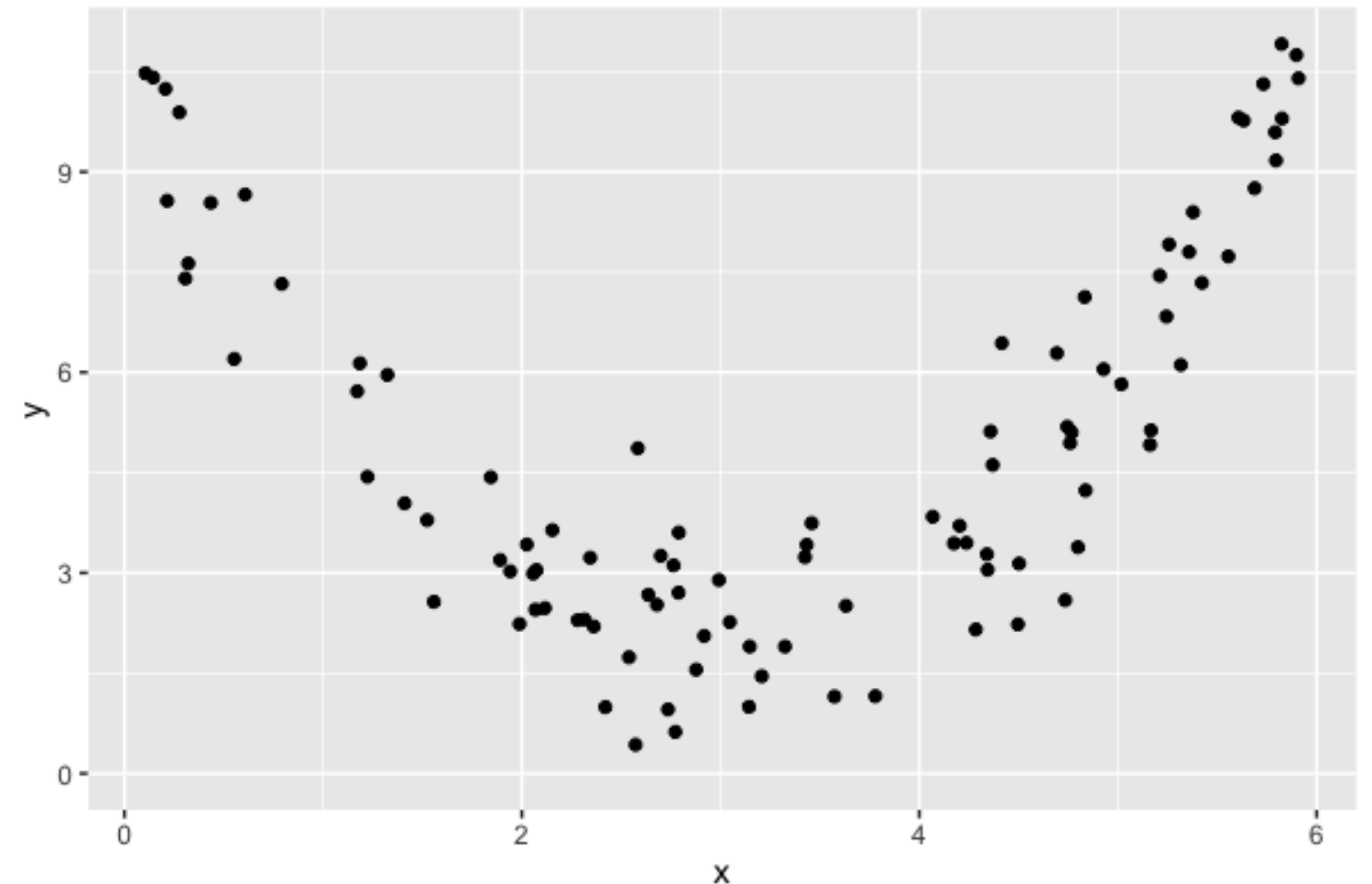
# Correlation only accounts for linear relationships

Correlation shouldn't be used blindly

```
cor(df$x, df$y)
```

0.1786163

*Always* visualize your data

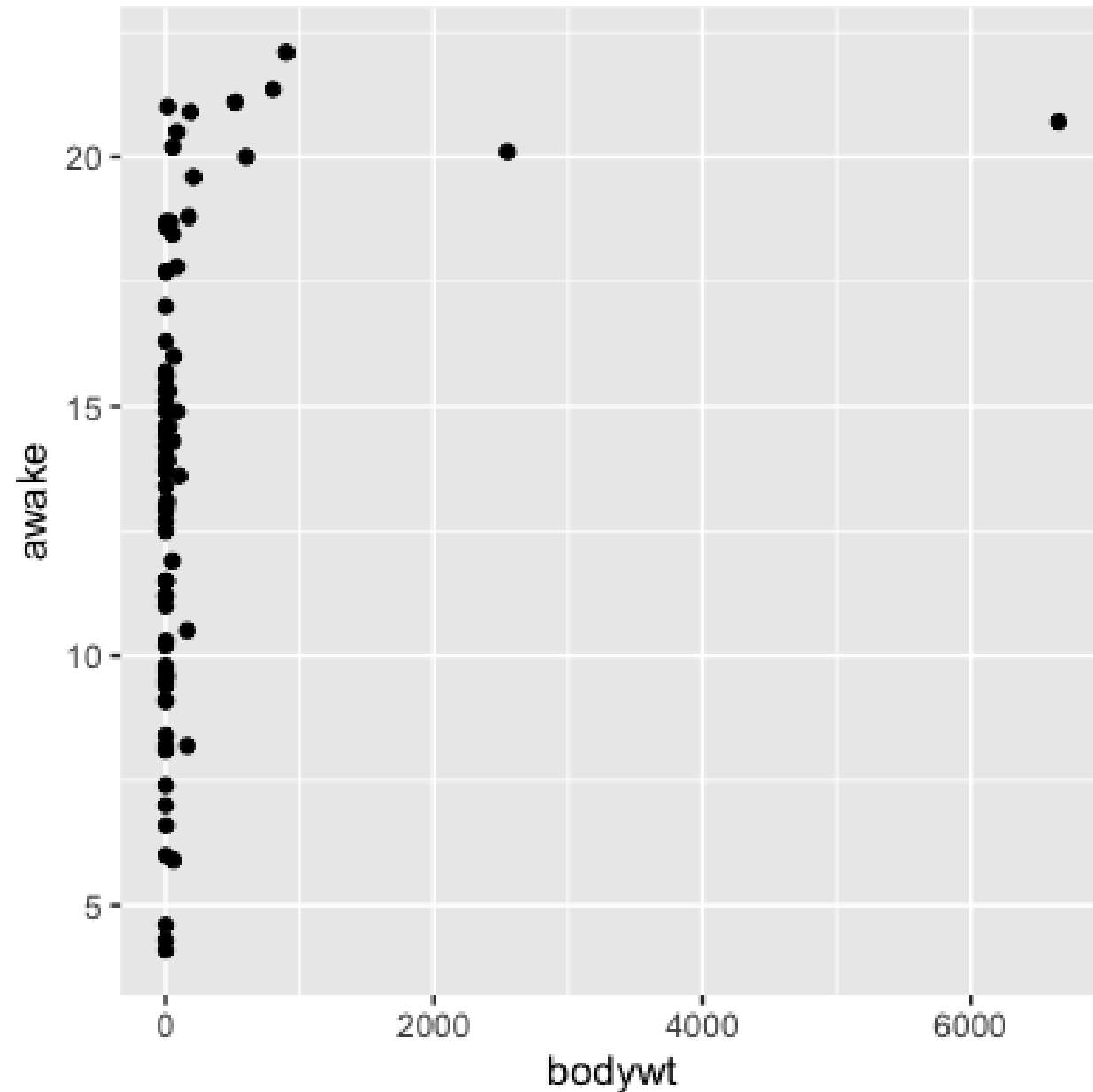


# Mammal sleep data

msleep

```
  name                vore  sleep_total  awake  bodywt
1 Cheetah             carni      12.1    11.9    50
2 Owl monkey          omni      17      7      0.48
3 Mountain beaver     herbi     14.4     9.6    1.35
4 Greater short-tailed shrew omni     14.9     9.1    0.019
5 Cow                 herbi       4     20    600
6 Three-toed sloth    herbi     14.4     9.6    3.85
...
```

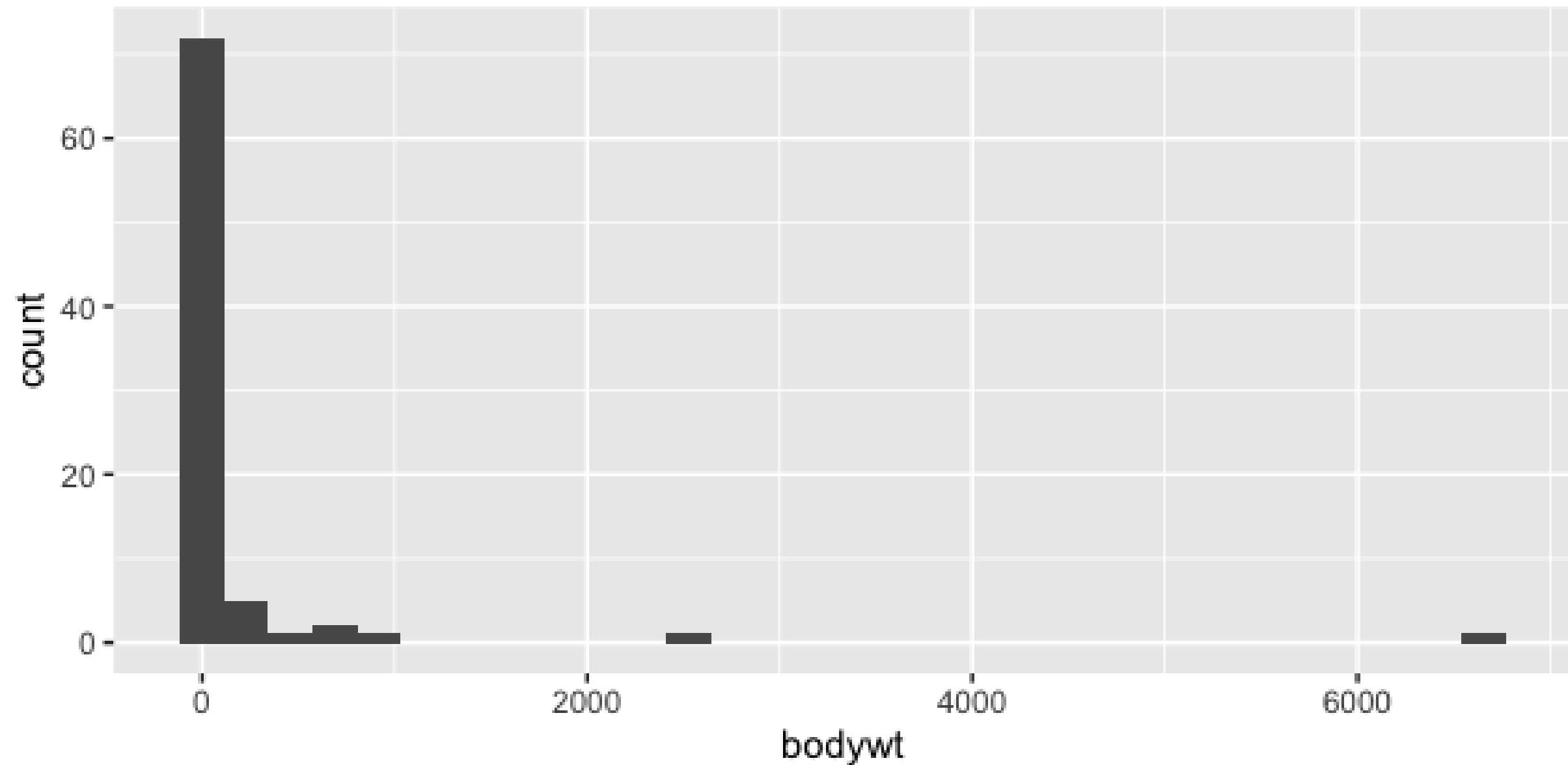
# Body weight vs. awake time



```
cor(msleep$bodywt, msleep$awake)
```

```
0.3119801
```

# Distribution of body weight

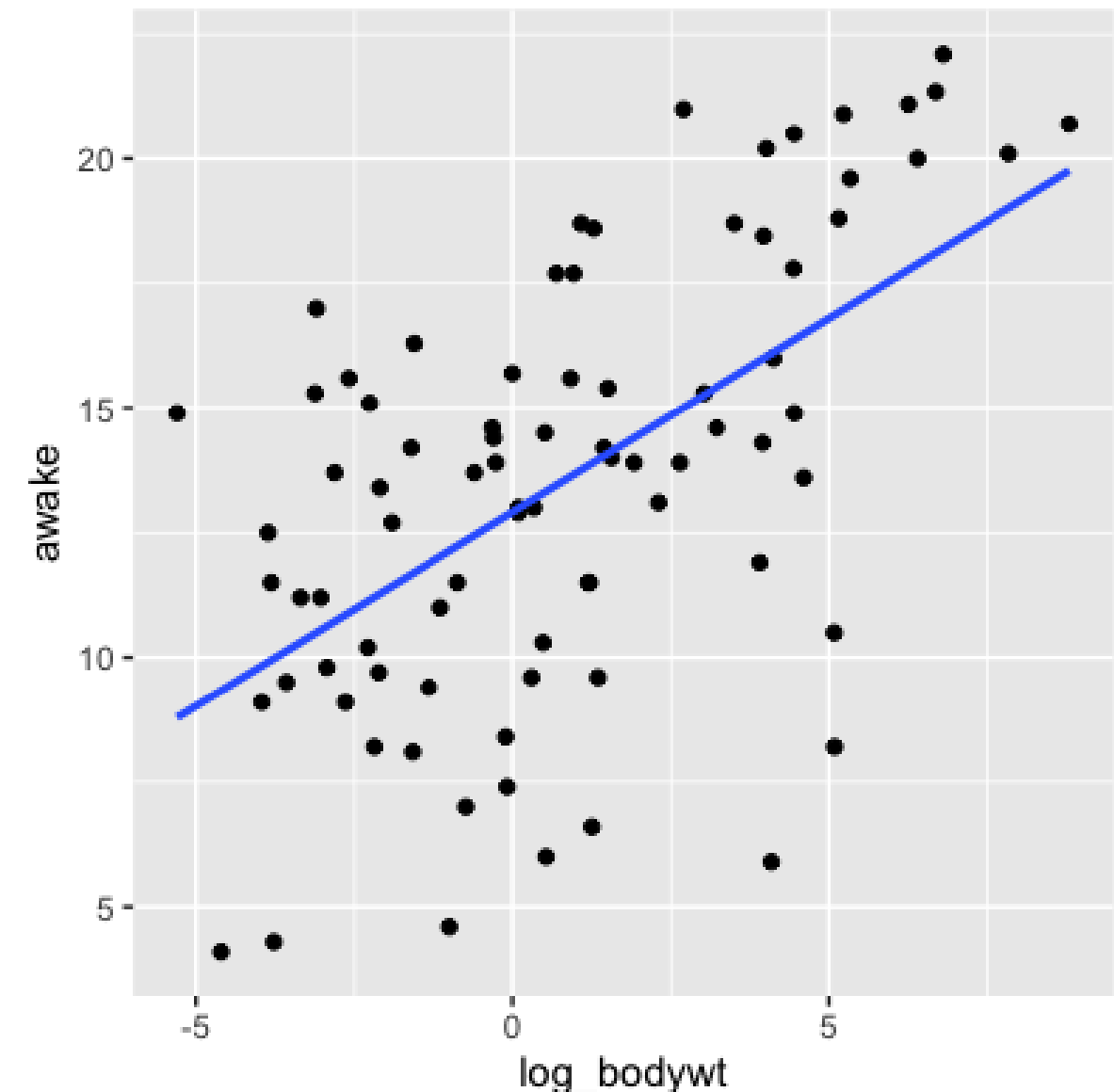


# Log transformation

```
msleep %>%  
  mutate(log_bodywt = log(bodywt)) %>%  
  ggplot(aes(log_bodywt, awake)) +  
  geom_point() +  
  geom_smooth(method = "lm", se = FALSE)
```

```
cor(msleep$log_bodywt, msleep$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`

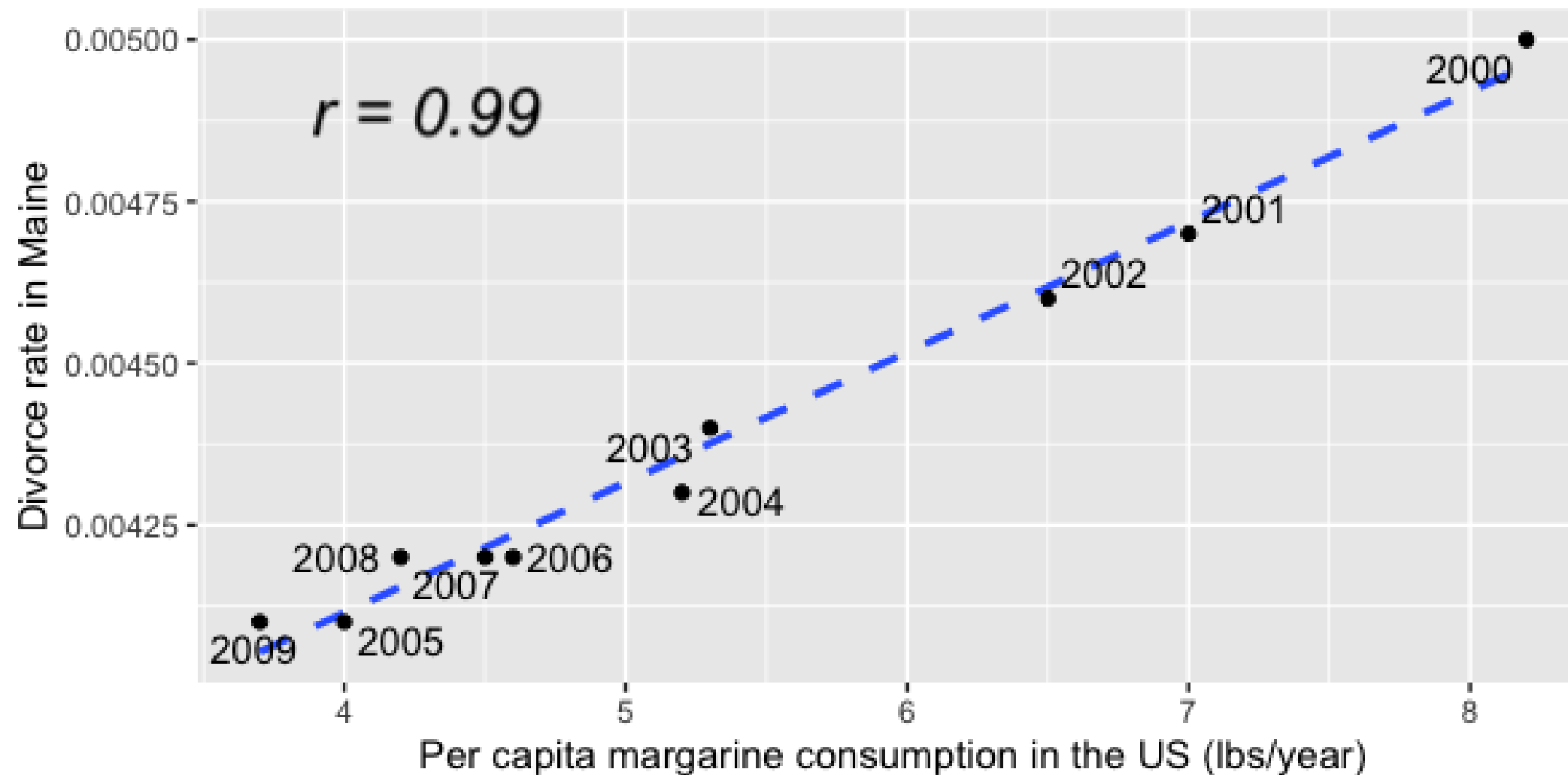


# Why use a transformation?

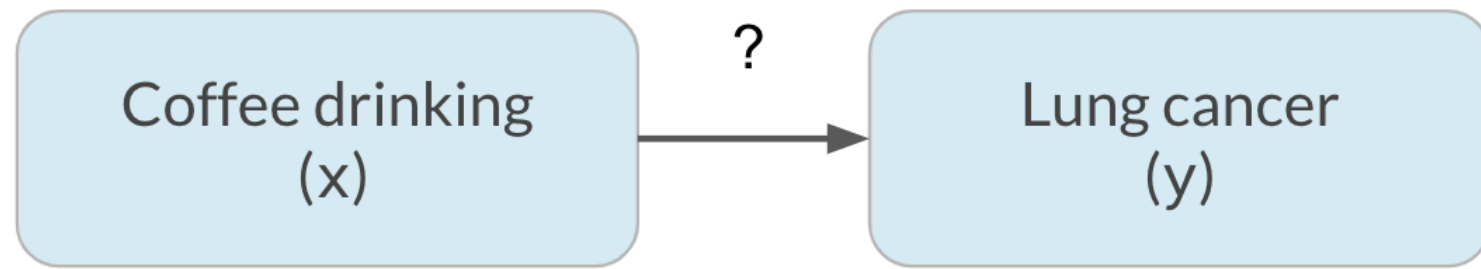
- Certain statistical methods rely on variables having a linear relationship
  - Correlation coefficient
  - Linear regression
- **Introduction to Regression in R**

# Correlation does not imply causation

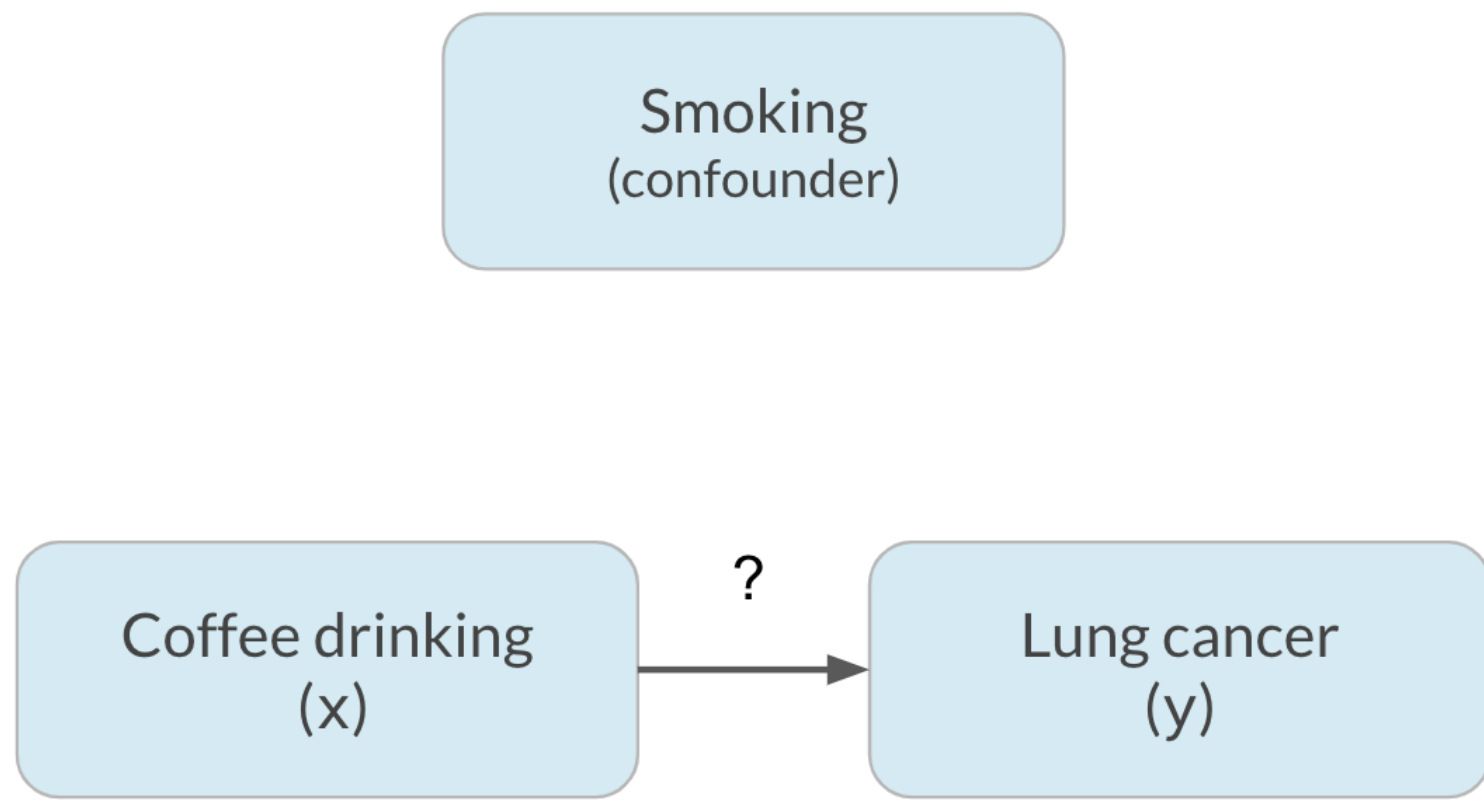
$x$  is correlated with  $y$  does not mean  $x$  causes  $y$



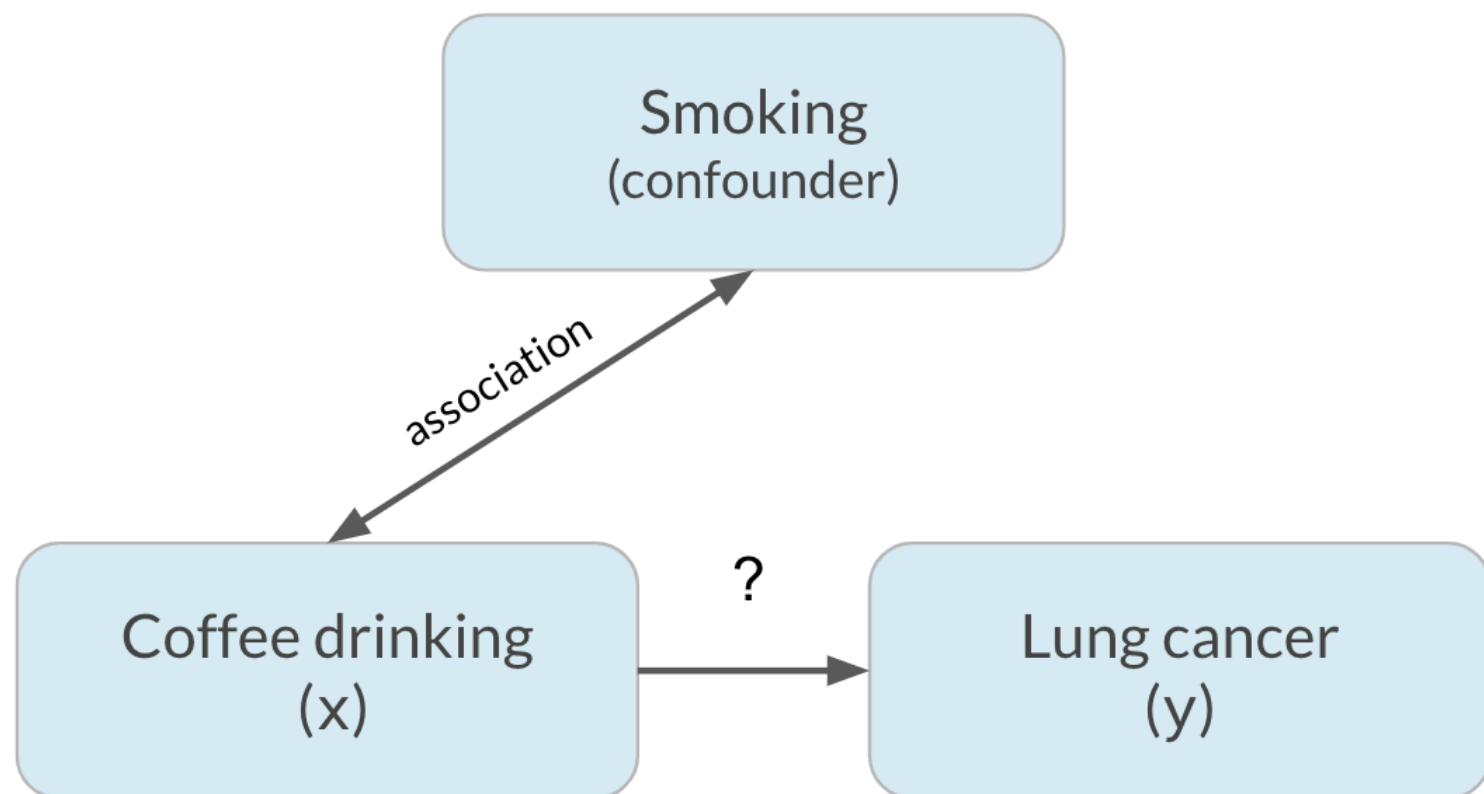
# Confounding



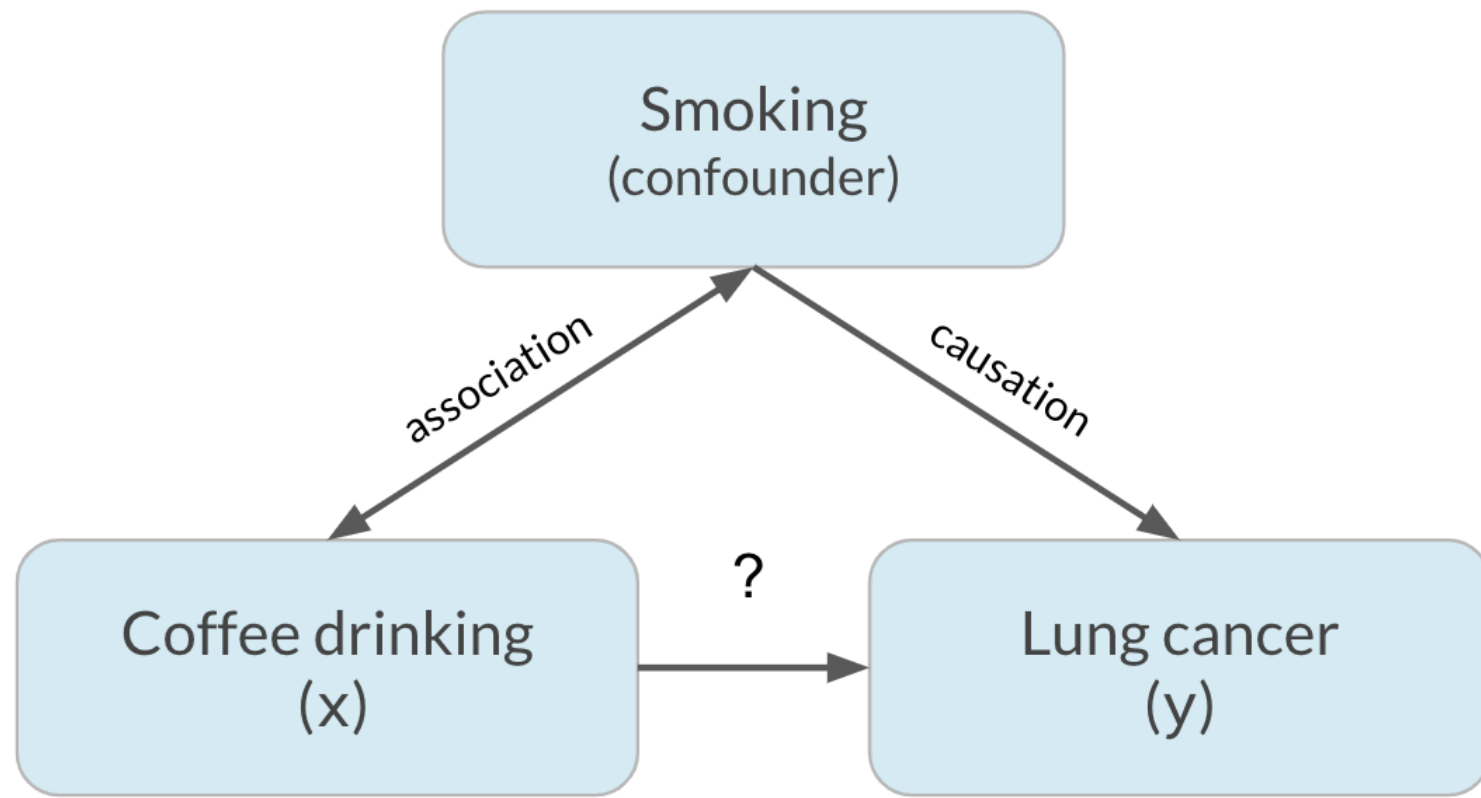
# Confounding



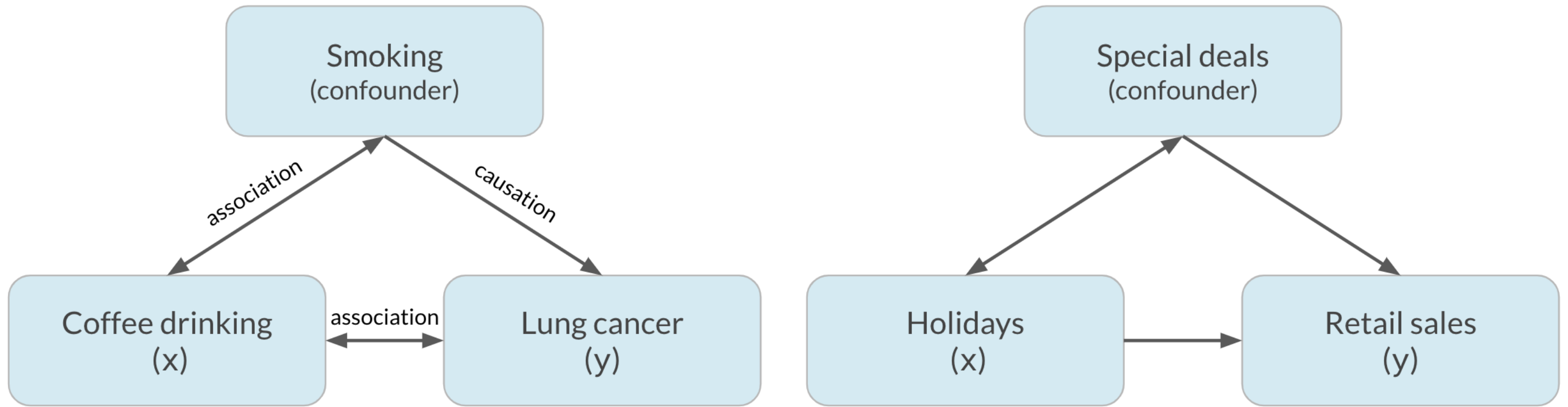
# Confounding



# 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

*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 Regression in R](#)

# Congratulations!

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