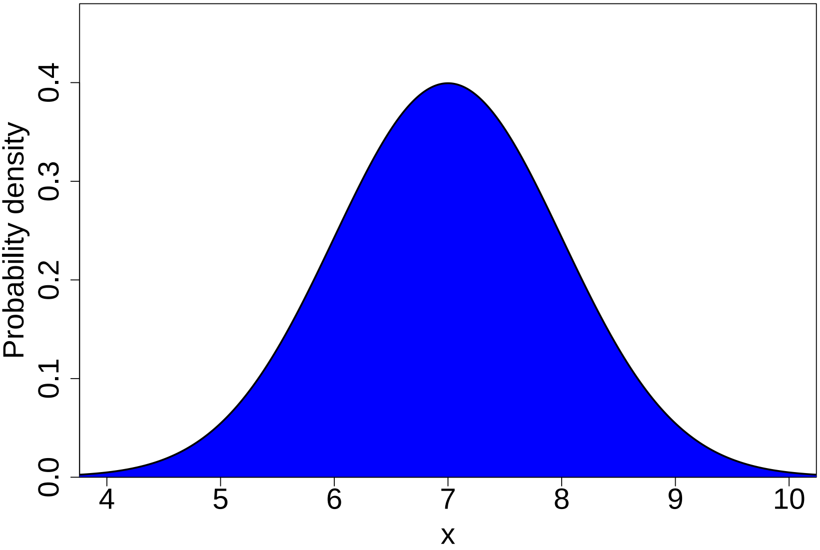
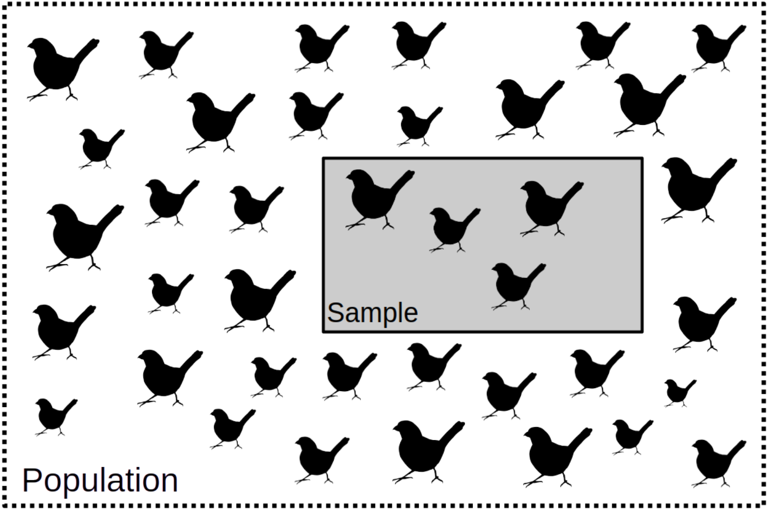
The Central Limit Theorem (CLT)

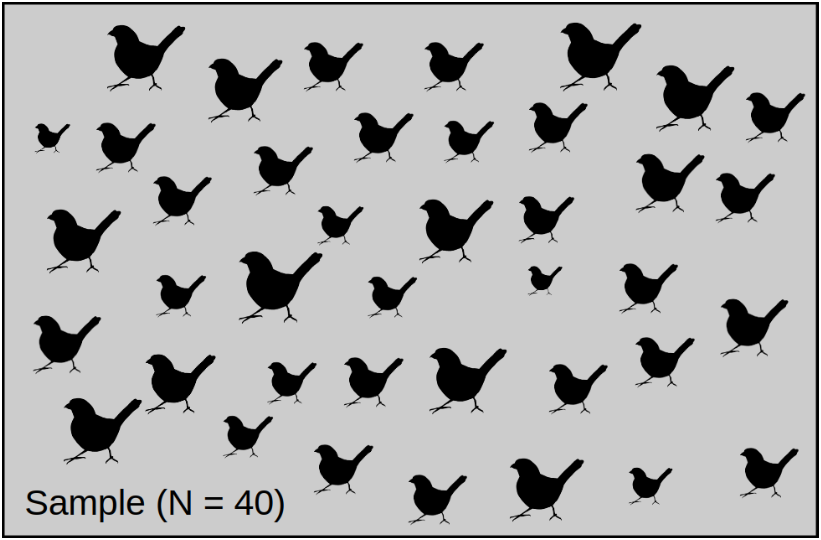
Normal distribution



Sampling from a population (distribution)



Consider the distribution of a sample of N = 40



Consider the distribution of a sample of N = 40

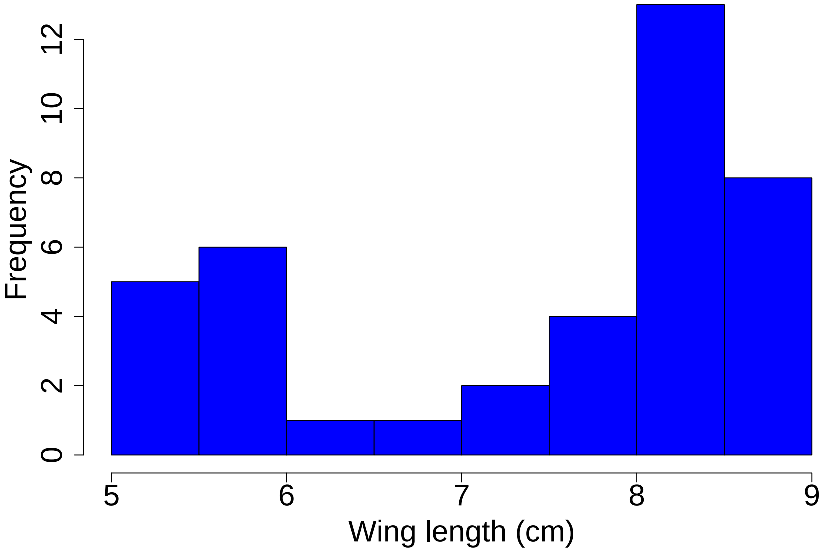
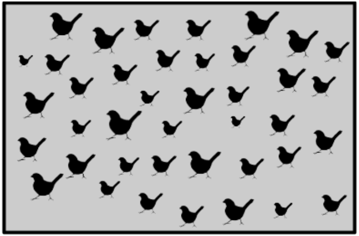
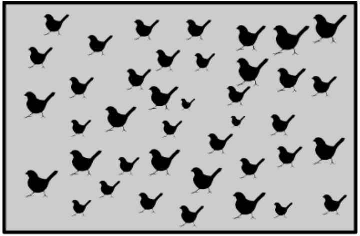


Figure 1: Distribution of a sample of bird wing length (cm)

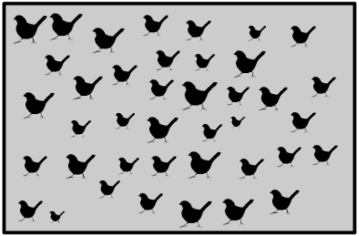
Sample means always distributed normally around true mean



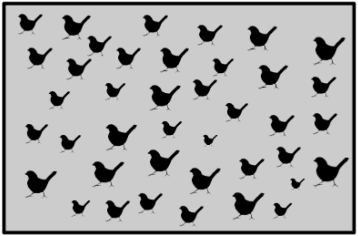
Sample mean = 6.59 cm



Sample mean = 7.45 cm

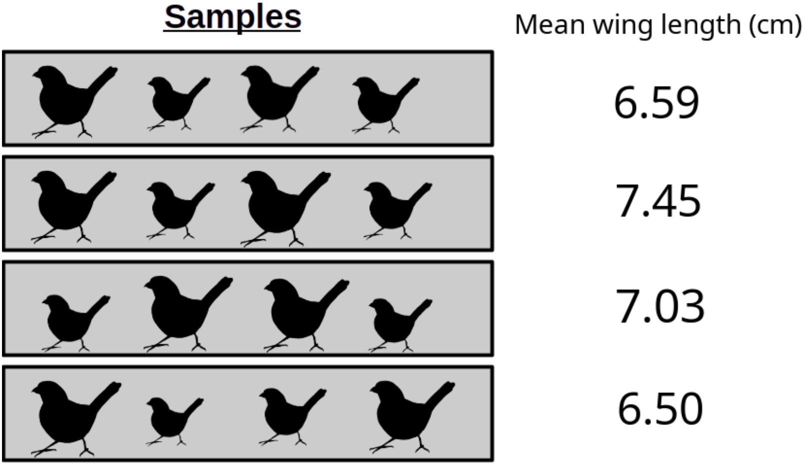


Sample mean = 7.03 cm



Sample mean = 6.50 cm

Sample means always distributed normally around true mean



What if we had 1000 sample means?

Sample means always distributed normally around true mean

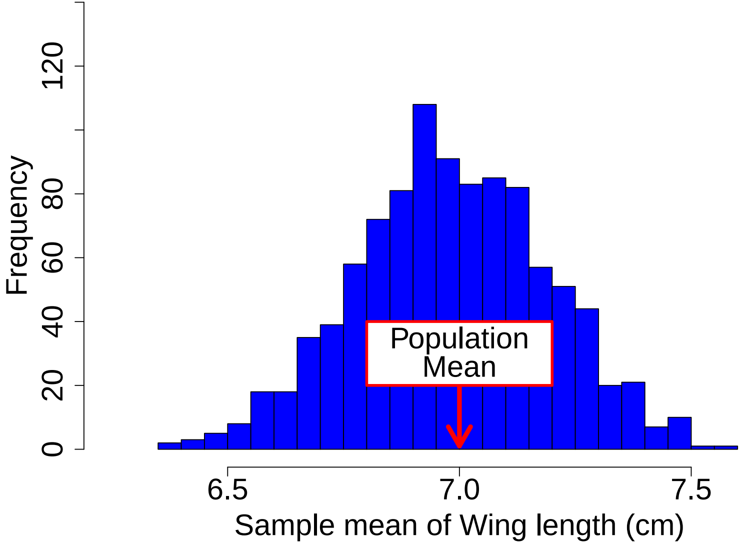


Figure 2: Distribution of the mean of bird wing length (cm) samples (N = 40), with sampling repeated 1000 times.

Sample means always distributed normally around true mean

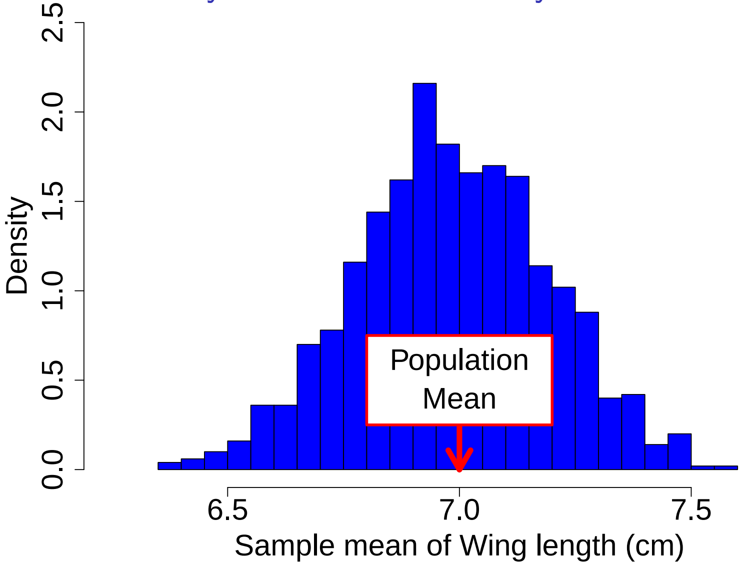


Figure 3: Distribution of the mean of bird wing length (cm) samples (N = 40), with sampling repeated 1000 times.

Sample means always distributed normally around true mean

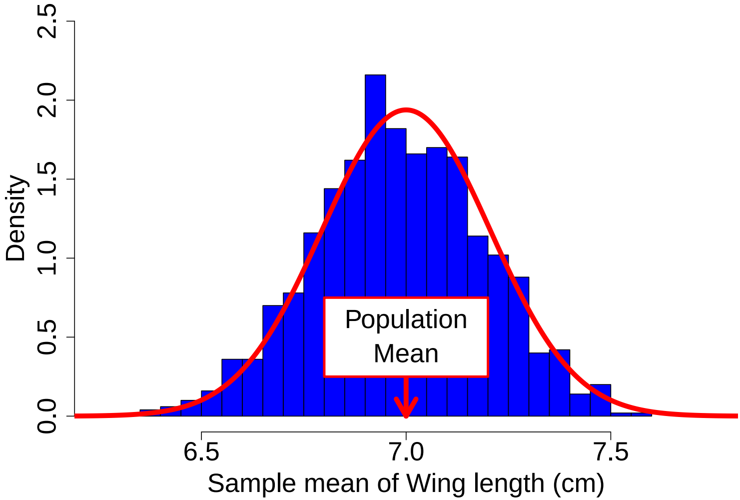
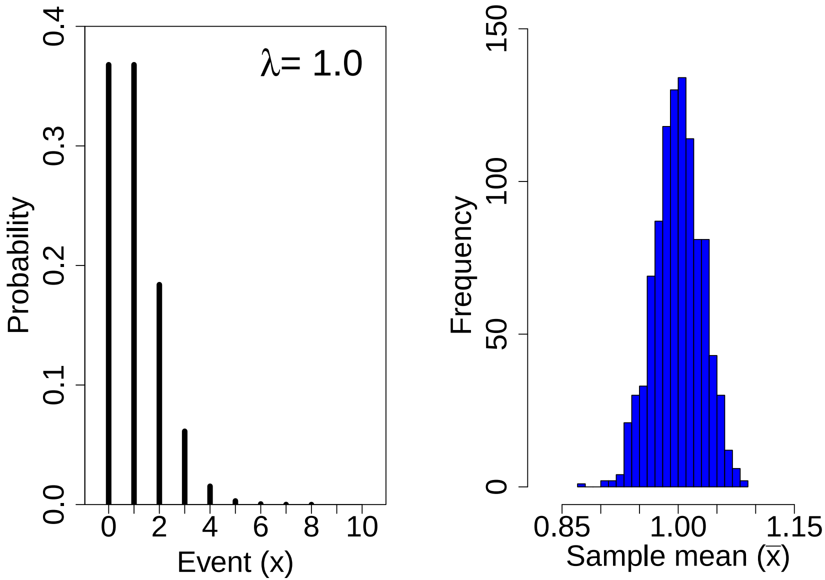


Figure 4: Distribution of the mean of bird wing length (cm) samples (N = 40), with sampling repeated 1000 times.

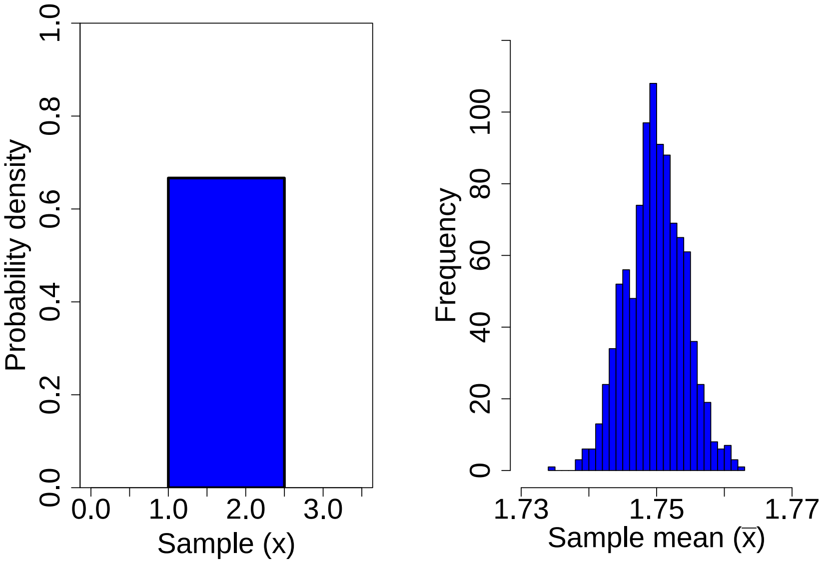
Sample means always distributed normally around true mean

- Distribution of sample means gets closer to the population mean with increasing N
- Can demonstrate this ourselves with simulated data

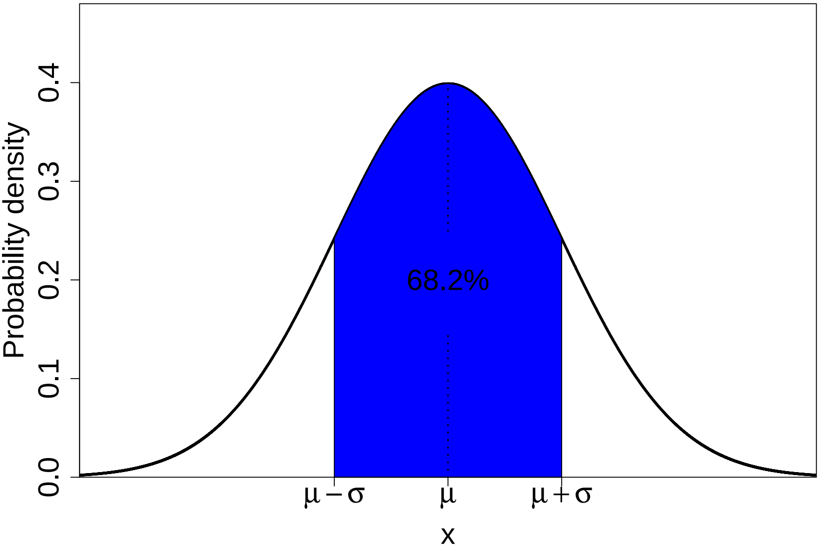
Sample means always distributed normally around true mean



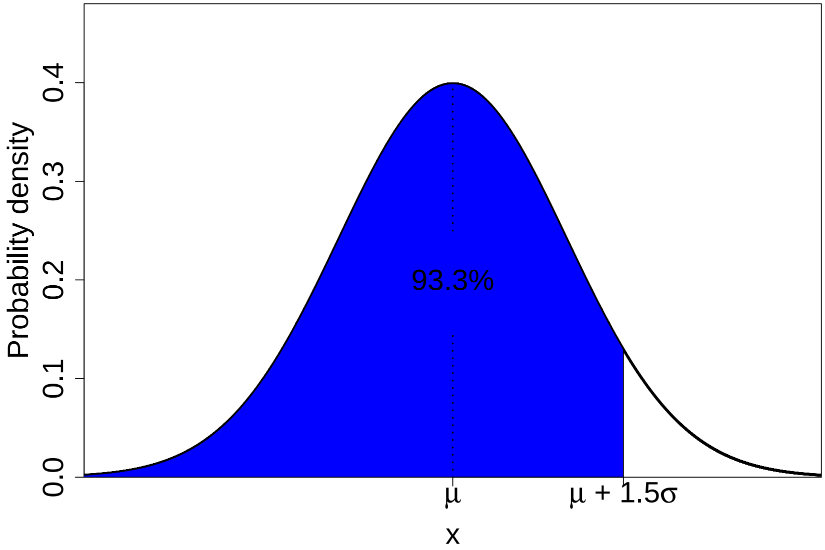
Sample means always distributed normally around true mean



Probability density and the normal distribution



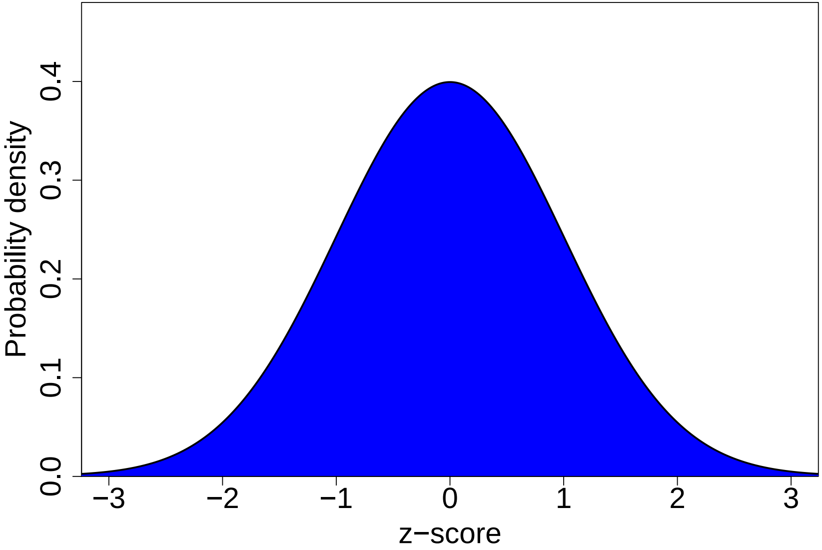
Probability density and the normal distribution



Standard normal distribution

- Need some standard values of x to work out probability
- Standard normal distribution
  - Mean $(\bar{x}) = 0$
  - Standard deviation $(s) = 1$
- Baseline for comparison

Standard normal distribution



[1] https://bradduthie.github.io/stats/app/zandp/

Standard normal distribution

- **z-score**: deviation from 0
- Work out probability density
- Basis for confidence intervals
- Critical for hypothesis testing

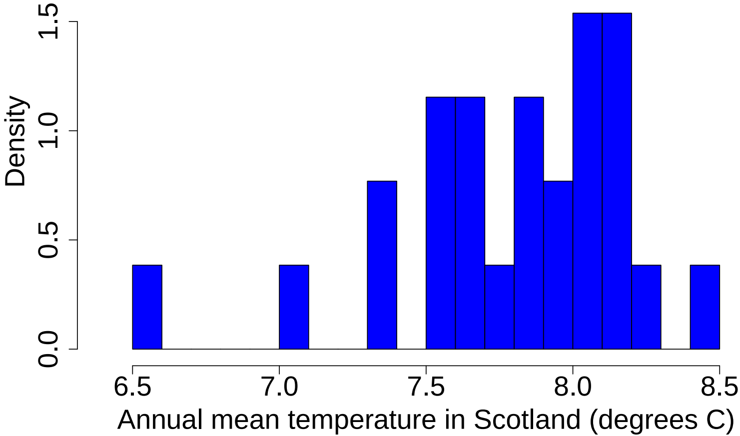
Translating a variable into a standard normal distribution

- Subtract mean
- Divide by standard deviation

$$z = \frac{x - \bar{x}}{s}$$

Can turn x-values into z-scores

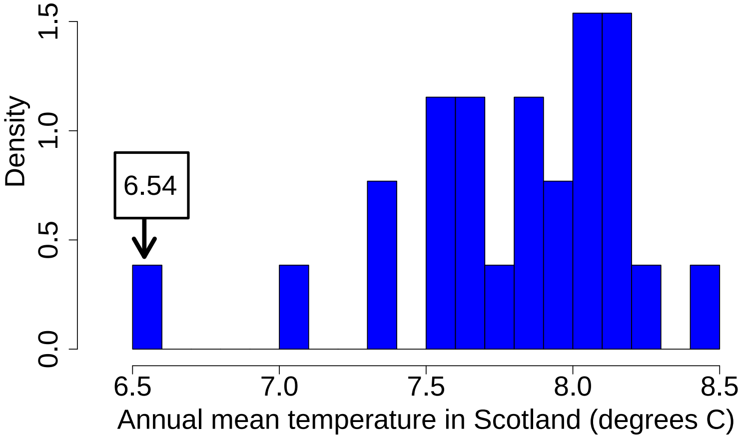
Turning a value into z-score



$N = 26 \qquad \bar{x} = 7.789 \qquad s = 0.4124844$

[1] Met Office. (July 1, 2021). Annual mean temperature in Scotland from 1995 to 2020. In Statista. Retrieved February 10, 2026, from https://www.statista.com/statistics/367853/scotland-average-temperature/

Turning a value into z-score



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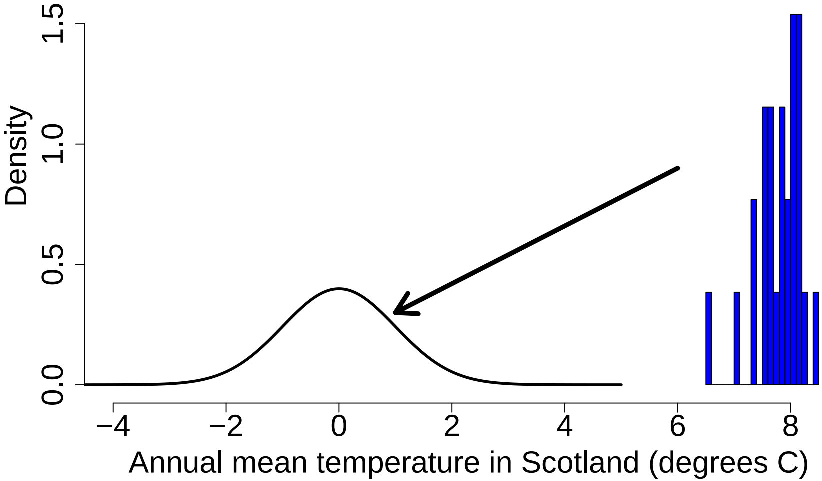
Turning a value into z-score

- Subtract mean
- Divide by standard deviation

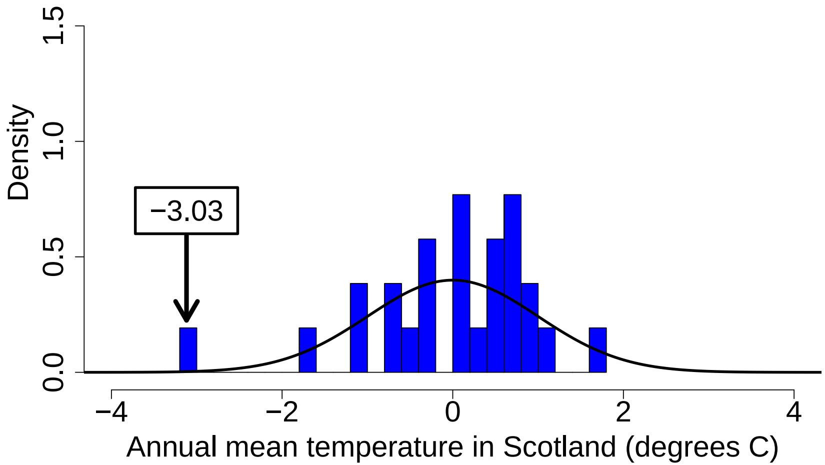
$$z = \frac{6.54 - 7.789}{0.4124844} = -3.03$$

Over 3 standard deviations below the mean

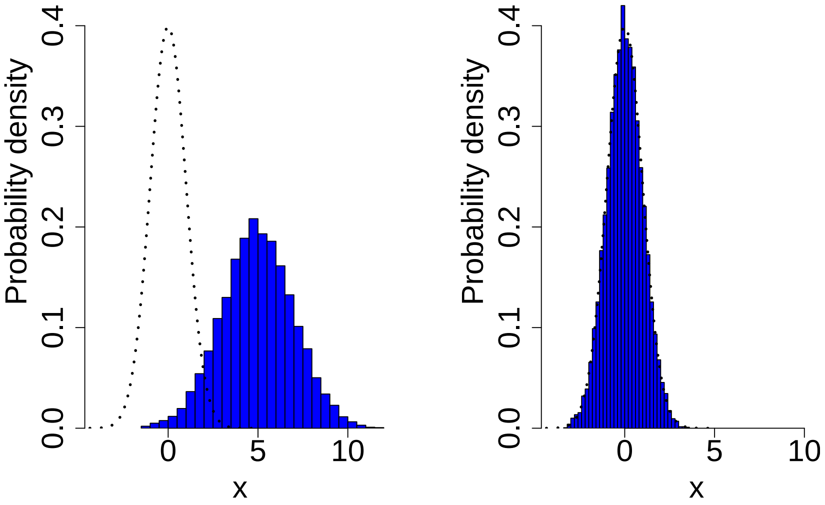
Turning a value into z-score



Turning a value into z-score



Turning a value into z-score



Exploring distributions in jamovi with distrACTION module