Straight to the point (estimate)

SAMPLING IN R

Richie Cotton
Data Evangelist at DataCamp

Sample is number of rows

```
coffee_ratings %>%
  slice_sample(n = 300) %>%
  nrow()
```

```
300
```

```
coffee_ratings %>%
  slice_sample(prop = 0.25) %>%
  nrow()
```

```
334
```

Various sample sizes

```
coffee_ratings %>%
  summarize(mean_points = mean(total_cup_points)) %>%
  pull(mean_points)
```

```
82.15
```

```
coffee_ratings %>%
  slice_sample(n = 10) %>%
  summarize(mean_points = mean(total_cup_points)) %>%
  pull(mean_points)
```

```
82.82
```

```
coffee_ratings %>%
  slice_sample(n = 100) %>%
  summarize(mean_points = mean(total_cup_points)) %>%
  pull(mean_points)
```

```
82.02
```

```
coffee_ratings %>%
  slice_sample(n = 1000) %>%
  summarize(mean_points = mean(total_cup_points)) %>%
  pull(mean_points)
```

```
82.16
```

Relative errors

Population parameter

```
population_mean <- coffee_ratings %>%
  summarize(mean_points = mean(total_cup_points)) %>%
  pull(mean_points)
```

Point estimate

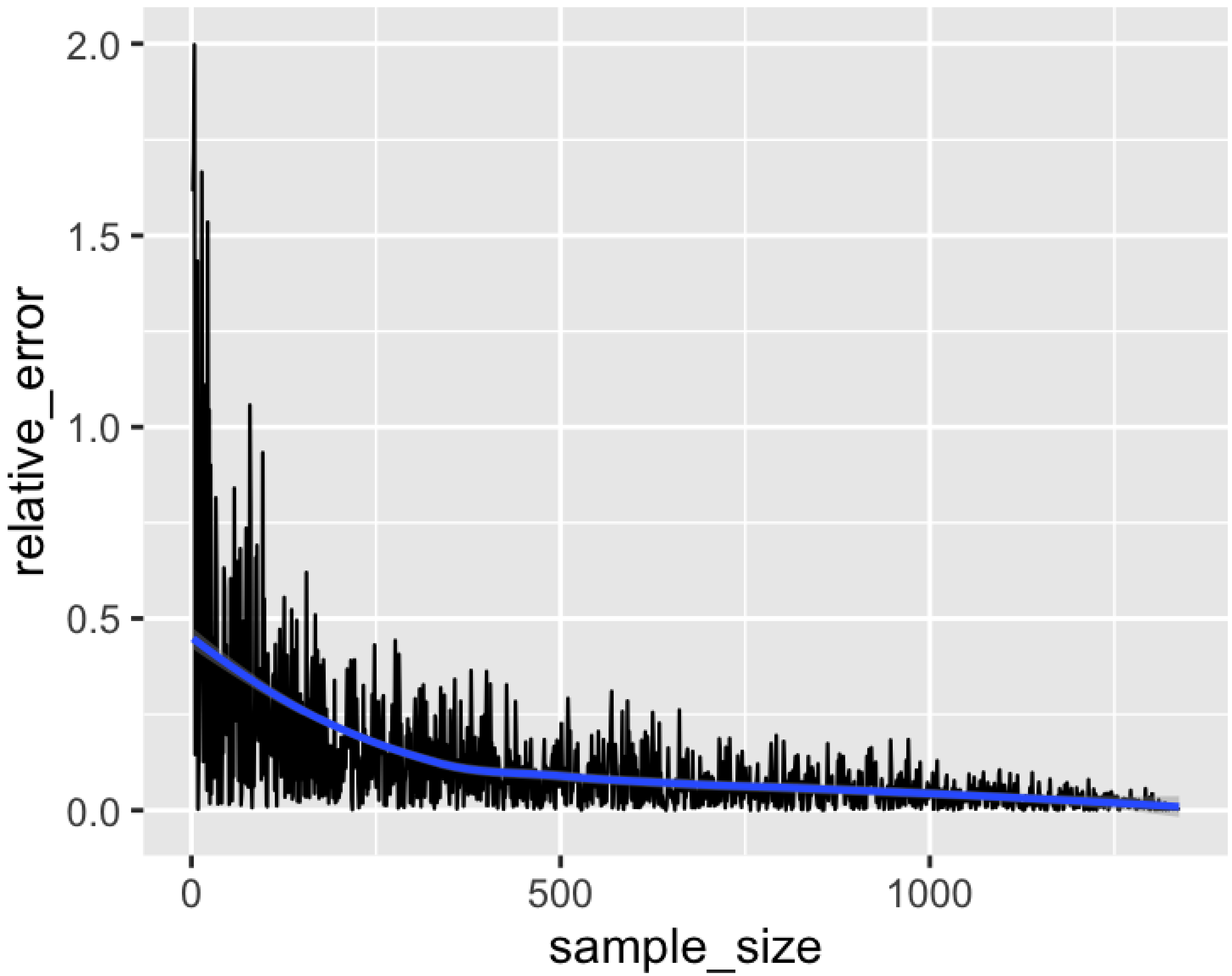
```
sample_mean <- coffee_ratings %>%
  slice_sample(n = sample_size) %>%
  summarize(mean_points = mean(total_cup_points)) %>%
  pull(mean_points)
```

Relative error as a percentage

```
100 * abs(population_mean - sample_mean) / population_mean
```

Relative error vs. sample size

```
ggplot(errors, aes(sample_size, relative_error)) +
  geom_line() +
  geom_smooth(method = "loess")
```



Let's practice!

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Baby back dist-rib-ution

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Richie Cotton
Data Evangelist at DataCamp

Same code, different answer

```r
coffee_ratings %>%
  slice_sample(n = 30) %>%
  summarize(mean_cup_points = mean(total_cup_points)) %>%
  pull(mean_cup_points)
```

```
83.33
```

```r
coffee_ratings %>%
  slice_sample(n = 30) %>%
  summarize(mean_cup_points = mean(total_cup_points)) %>%
  pull(mean_cup_points)
```

```
82.59
```

```r
coffee_ratings %>%
  slice_sample(n = 30) %>%
  summarize(mean_cup_points = mean(total_cup_points)) %>%
  pull(mean_cup_points)
```

```
82.16
```

```r
coffee_ratings %>%
  slice_sample(n = 30) %>%
  summarize(mean_cup_points = mean(total_cup_points)) %>%
  pull(mean_cup_points)
```

```
82.25
```

Same code, 1000 times

```
mean_cup_points_1000 <- replicate(
  n = 1000,
  expr = coffee_ratings %>%
    slice_sample(n = 30) %>%
    summarize(
      mean_cup_points = mean(total_cup_points)
    ) %>%
    pull(mean_cup_points)
)
```

```
  [1] 81.65 81.57 82.66 82.27 81.76 81.74 82.71
  [8] 82.20 80.43 82.45 82.29 82.63 82.28 82.11
 [15] 82.14 81.72 81.97 82.58 81.78 82.47 81.73
 [22] 82.78 82.14 82.39 81.69 82.36 82.64 82.68
 [29] 82.56 82.14 82.72 82.43 81.68 82.74 82.80
 [36] 82.12 82.31 81.02 82.83 81.71 82.25 82.11
 [43] 82.76 82.26 81.57 82.00 81.75 81.47 81.99
 [50] 82.68 82.05 82.43 82.40 82.66 80.78 82.43
 ...
[967] 81.84 83.12 81.54 81.83 82.24 82.36 82.49
[974] 82.05 82.08 81.98 82.45 82.04 81.42 83.06
[981] 81.97 82.65 81.12 82.48 81.64 81.92 81.96
[988] 81.71 81.96 81.78 82.30 81.76 82.46 82.43
[995] 81.95 82.60 81.84 82.78 82.23 82.56
```

Preparing for plotting

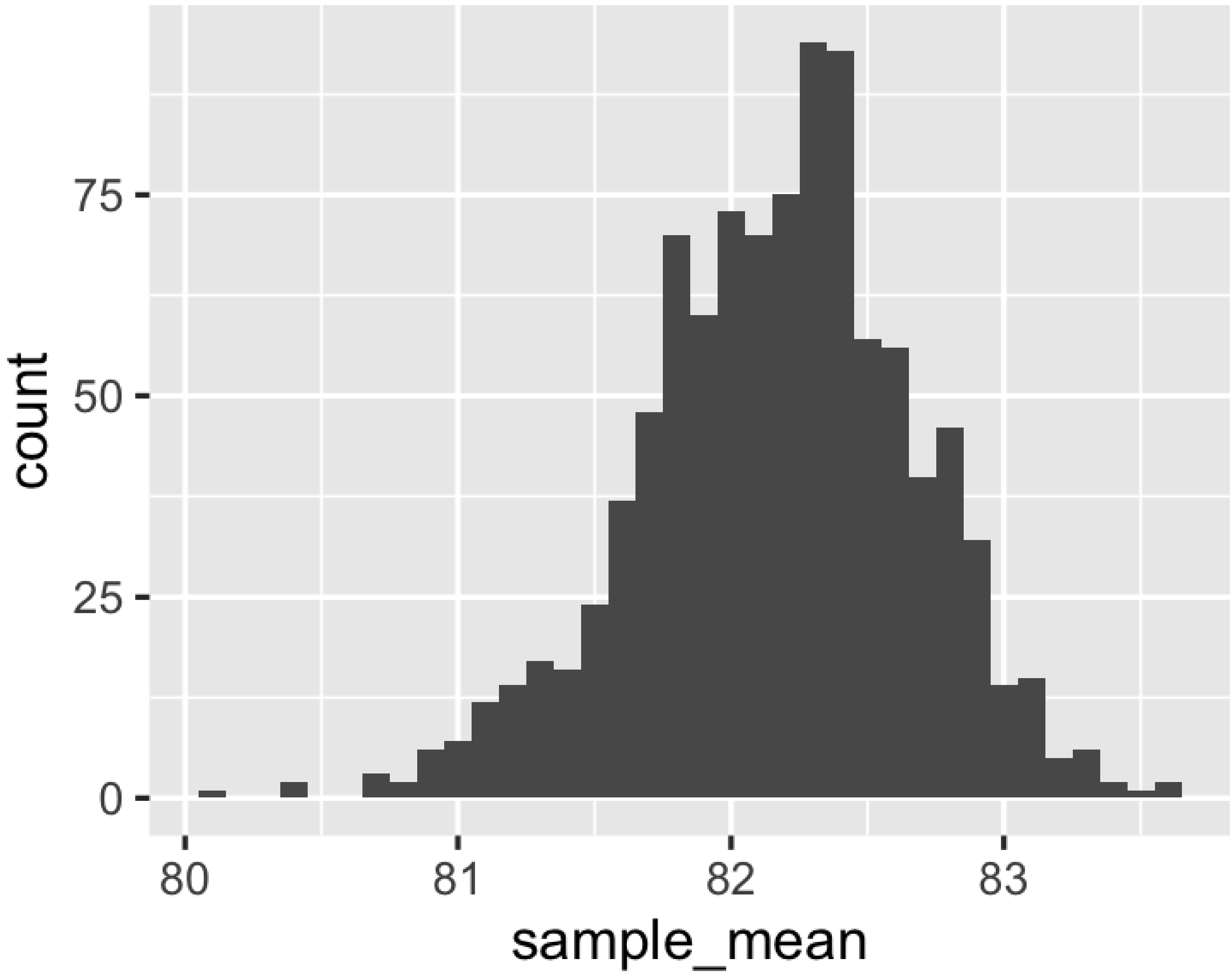
```
library(tibble)
sample_means <- tibble(
  sample_mean = mean_cup_points_1000
)
```

```
# A tibble: 1,000 x 1
   sample_mean
         <dbl>
 1        83.3
 2        82.6
 3        82.2
 4        82.2
 5        81.7
 6        81.6
 7        82.7
 8        82.3
 9        81.8
10        81.7
# ... with 990 more rows
```

Distribution of sample means for size 30

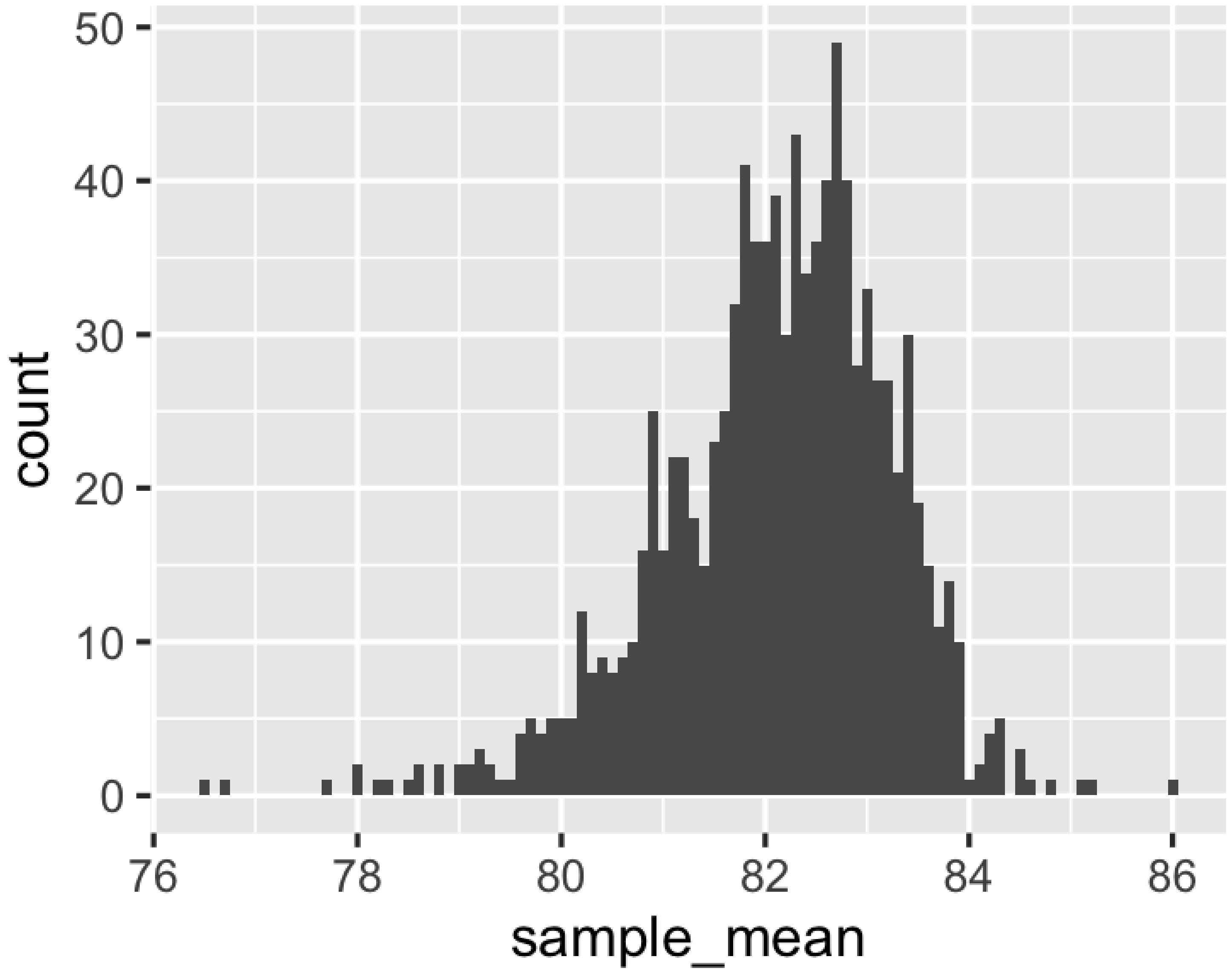
```
ggplot(sample_means, aes(sample_mean)) +
  geom_histogram(binwidth = 0.1)
```

A *sampling distribution* is a distribution of several replicates of point estimates.

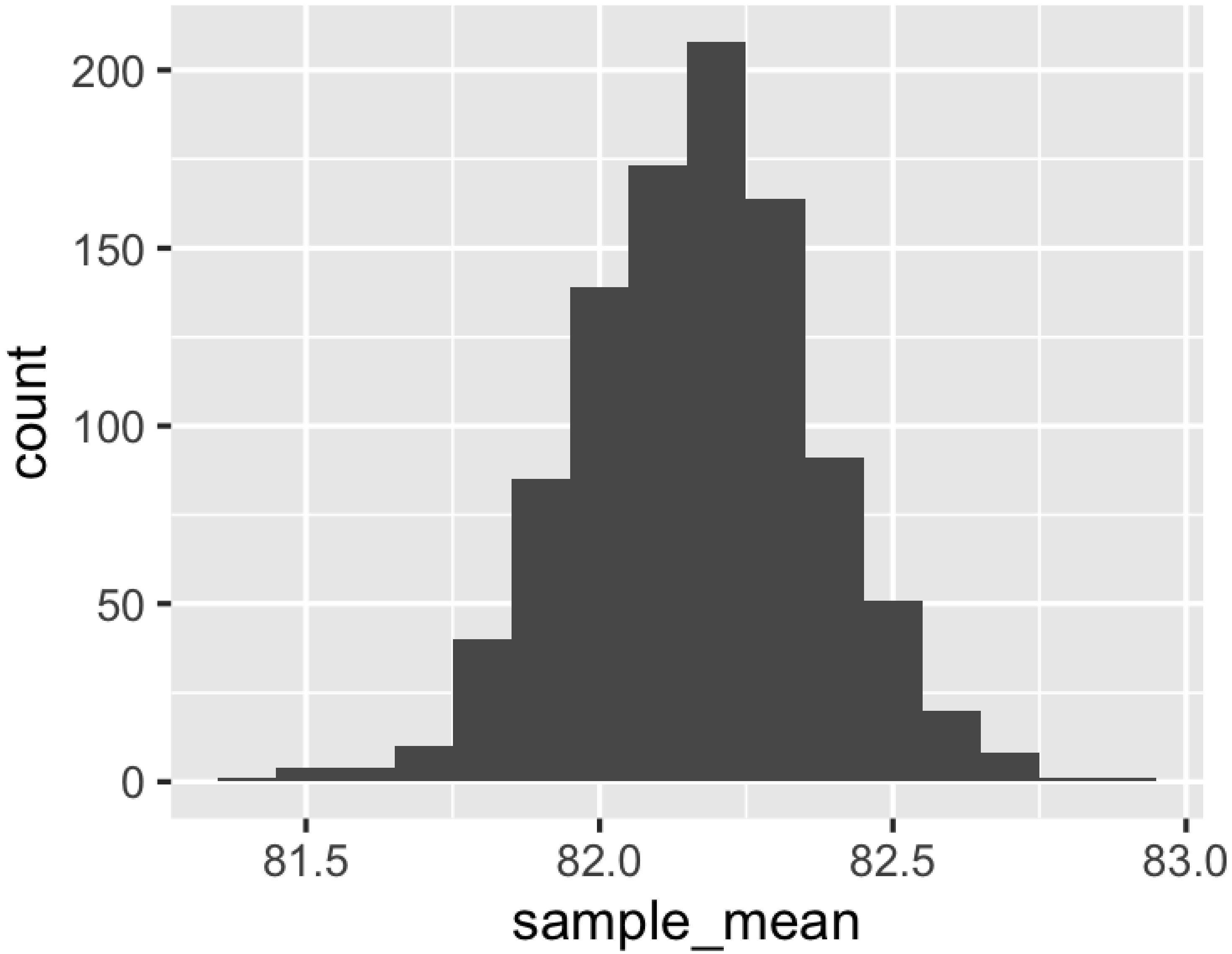


Different sample sizes

Sample size 6



Sample size 150



Let's practice!

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Be our guess, put our samples to the test

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Data Evangelist at DataCamp

4 dice

```
library(tidyr)
dice <- expand_grid(
  die1 = 1:6,
  die2 = 1:6,
  die3 = 1:6,
  die4 = 1:6
)
```

```
# A tibble: 1,296 x 4
    die1  die2  die3  die4
   <int> <int> <int> <int>
 1     1     1     1     1
 2     1     1     1     2
 3     1     1     1     3
 4     1     1     1     4
 5     1     1     1     5
 6     1     1     1     6
 7     1     1     2     1
 8     1     1     2     2
 9     1     1     2     3
10     1     1     2     4
# ... with 1,286 more rows
```

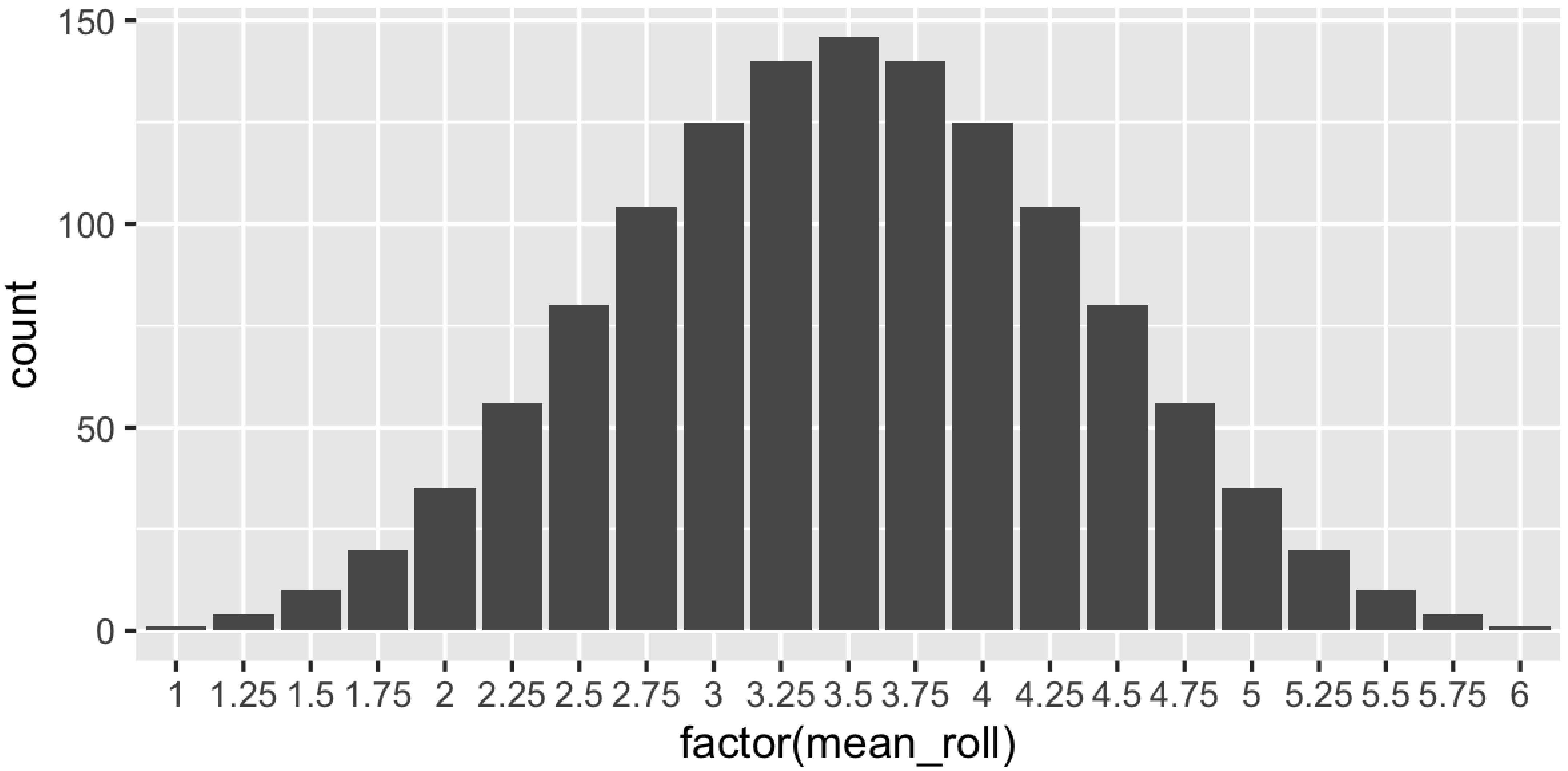
Mean roll

```
dice <- expand_grid(
  die1 = 1:6,
  die2 = 1:6,
  die3 = 1:6,
  die4 = 1:6
) %>%
  mutate(
    mean_roll = (die1 + die2 + die3 + die4) / 4
  )
```

```
# A tibble: 1,296 x 5
    die1  die2  die3  die4 mean_roll
   <int> <int> <int> <int>     <dbl>
 1     1     1     1     1      1
 2     1     1     1     2      1.25
 3     1     1     1     3      1.5
 4     1     1     1     4      1.75
 5     1     1     1     5      2
 6     1     1     1     6      2.25
 7     1     1     2     1      1.25
 8     1     1     2     2      1.5
 9     1     1     2     3      1.75
10     1     1     2     4      2
# ... with 1,286 more rows
```

Exact sampling distribution

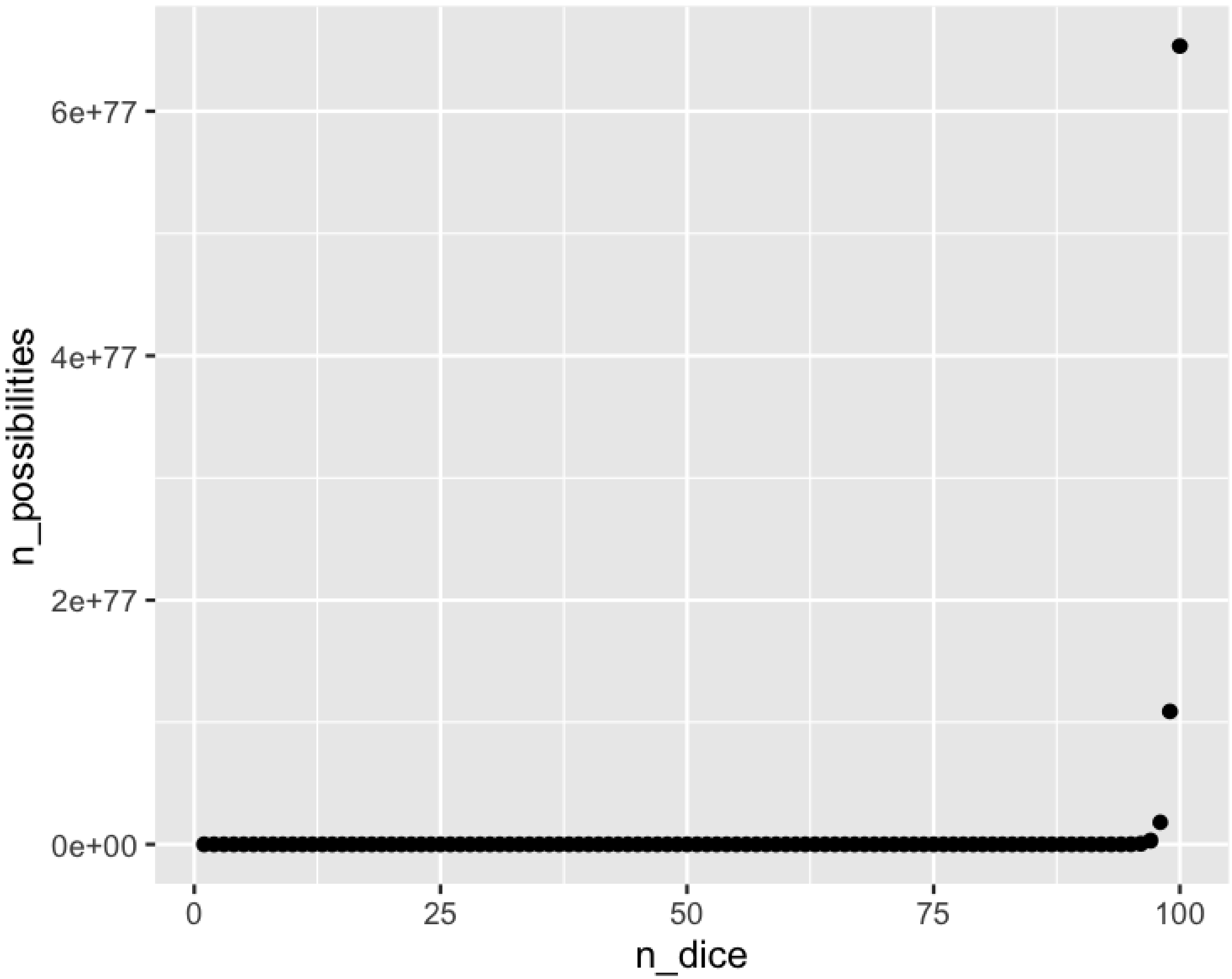
```
ggplot(dice, aes(factor(mean_roll))) +
  geom_bar()
```



The number of outcomes increases fast

```
outcomes <- tibble(
  n_dice = 1:100,
  n_outcomes = 6 ^ n_dice
)
```

```
ggplot(outcomes, aes(n_dice, n_outcomes)) +
  geom_point()
```



Simulating the mean of four dice rolls

```
four_rolls <- sample(
  1:6, size = 4, replace = TRUE
)
mean(four_rolls)
```

Simulating the mean of four dice rolls

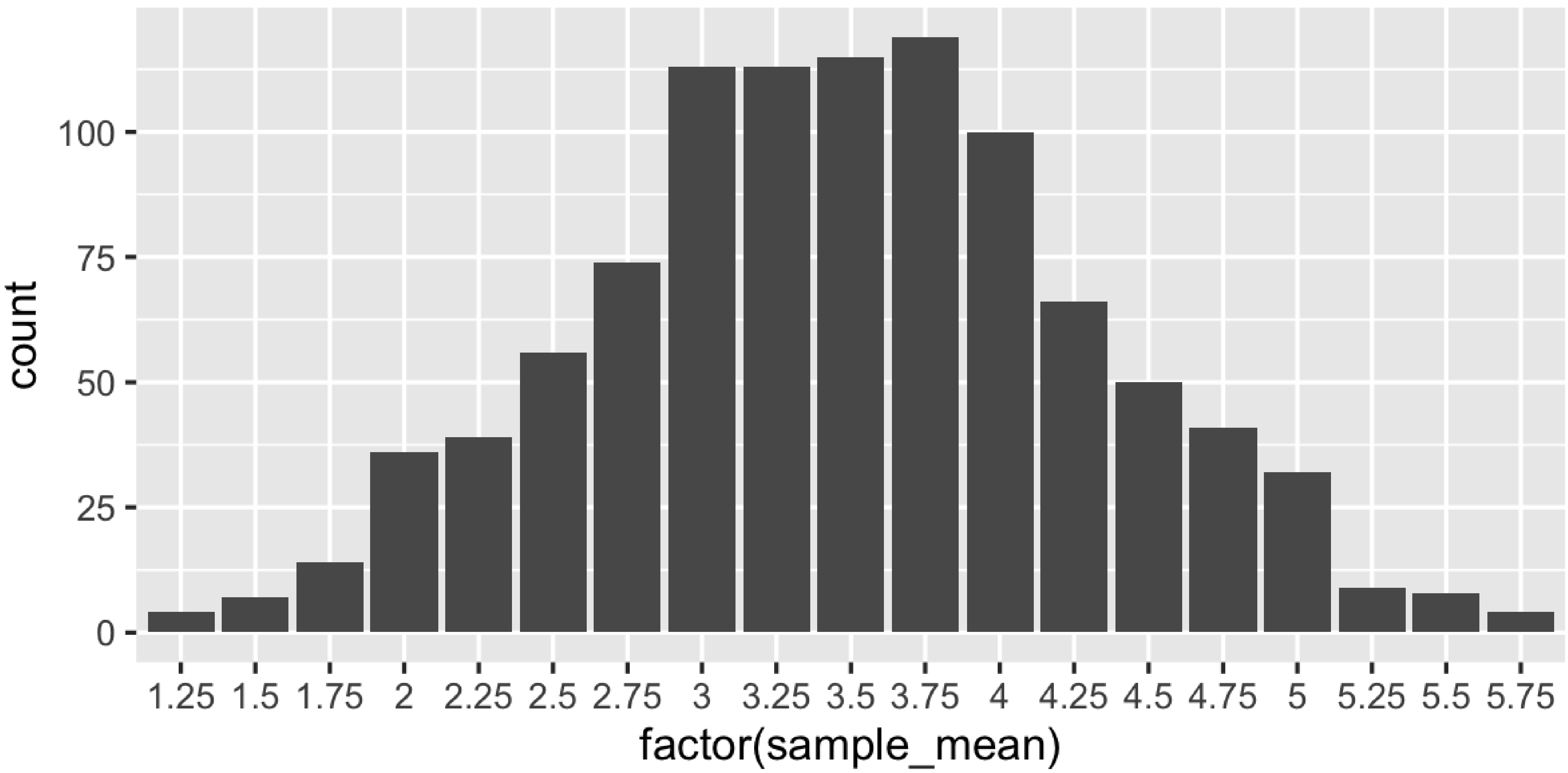
```
sample_means_1000 <- replicate(
  n = 1000,
  expr = {
    four_rolls <- sample(
      1:6, size = 4, replace = TRUE
    )
    mean(four_rolls)
  }
)
```

```
sample_means <- tibble(
  sample_mean = sample_means_1000
)
```

```
# A tibble: 1,000 x 1
   sample_mean
         <dbl>
 1           4
 2         4.5
 3         2.5
 4        3.75
 5        3.75
 6           4
 7           3
 8        4.75
 9        3.75
10        4.25
# ... with 990 more rows
```

Approximate sampling distribution

```
ggplot(sample_means, aes(factor(sample_mean))) +
  geom_bar()
```



Let's practice!

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Err on the side of Gaussian

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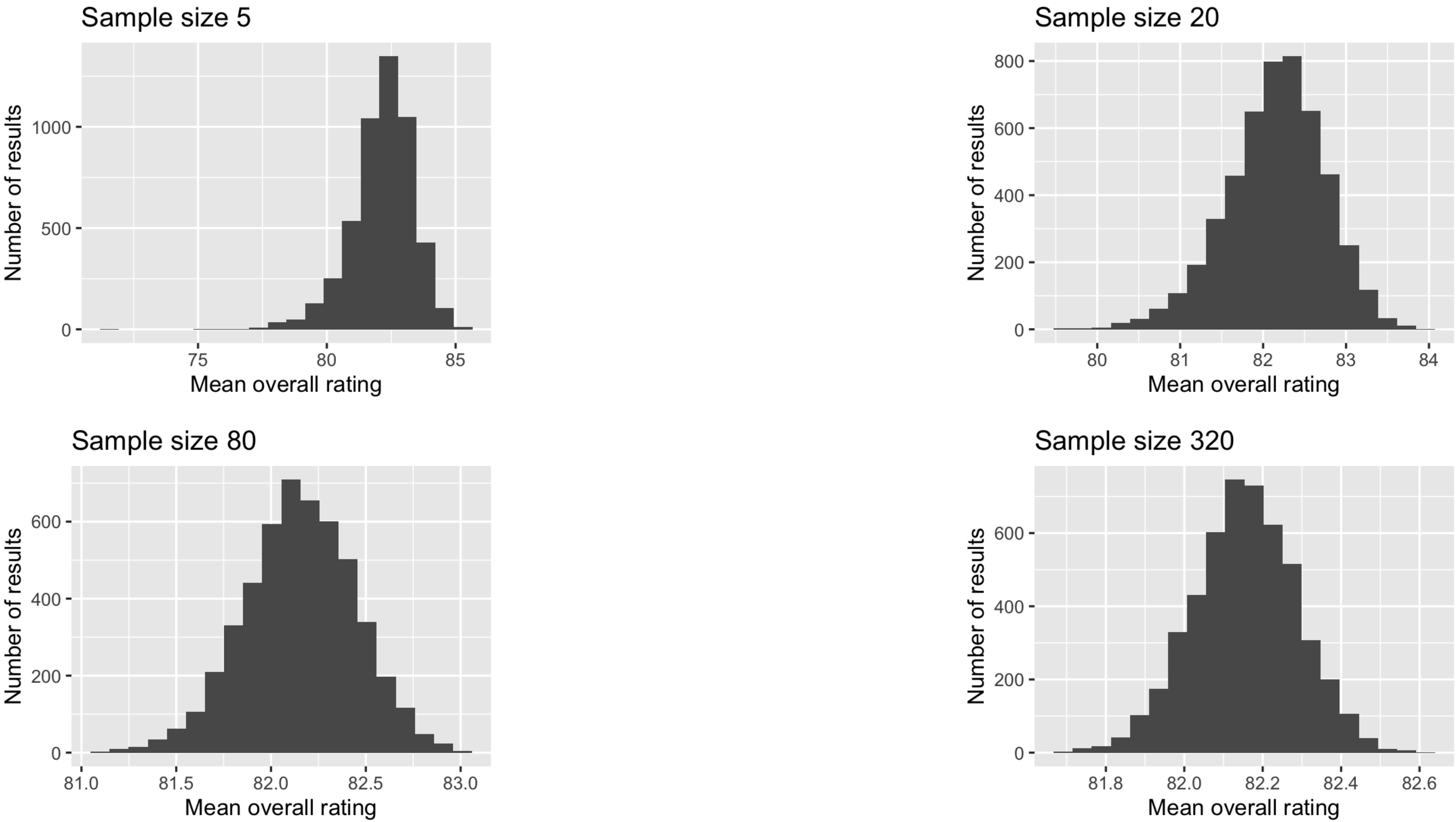
Richie Cotton
Data Evangelist at DataCamp

Sampling distribution of mean cup points



Consequences of the central limit theorem

- Averages of independent samples have approximately normal distributions.

As the sample size increases,

- the distribution of the averages gets closer to being normally distributed, and
- the width of the sampling distribution gets narrower.

Population & sampling distribution means

```
coffee_ratings %>%
  summarize(
    mean_cup_points = mean(total_cup_points)
  ) %>%
  pull(mean_cup_points)
```

```
82.1512
```

Sample size	Mean sample mean
5	82.1496
20	82.1610
80	82.1496
320	82.1521

Population & sampling distribution standard deviations

```
coffee_ratings %>%
  summarize(
    sd_cup_points = sd(total_cup_points)
  ) %>%
  pull(sd_cup_points)
```

```
2.68686
```

Sample size	Std dev sample mean
5	1.1929
20	0.6028
80	0.2865
320	0.1304

Population mean over square root sample size

Sample size	Std dev sample mean	Calculation	Result
5	`1.1929`	`2.68686 / sqrt(5)`	`1.2016`
20	`0.6028`	`2.68686 / sqrt(20)`	`0.6008`
80	`0.2865`	`2.68686 / sqrt(80)`	`0.3004`
320	`0.1304`	`2.68686 / sqrt(320)`	`0.1502`

Let's practice!

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