

# Relative error of point estimates

SAMPLING IN PYTHON



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# Sample size is number of rows

```
len(coffee_ratings.sample(n=300))
```

300

```
len(coffee_ratings.sample(frac=0.25))
```

334

# Various sample sizes

```
coffee_ratings['total_cup_points'].mean()
```

```
82.15120328849028
```

```
coffee_ratings.sample(n=10)['total_cup_points'].mean()
```

```
83.027
```

```
coffee_ratings.sample(n=100)['total_cup_points'].mean()
```

```
82.4897
```

```
coffee_ratings.sample(n=1000)['total_cup_points'].mean()
```

```
82.1186
```

# Relative errors

Population parameter:

```
population_mean = coffee_ratings['total_cup_points'].mean()
```

Point estimate:

```
sample_mean = coffee_ratings.sample(n=sample_size)['total_cup_points'].mean()
```

Relative error as a percentage:

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

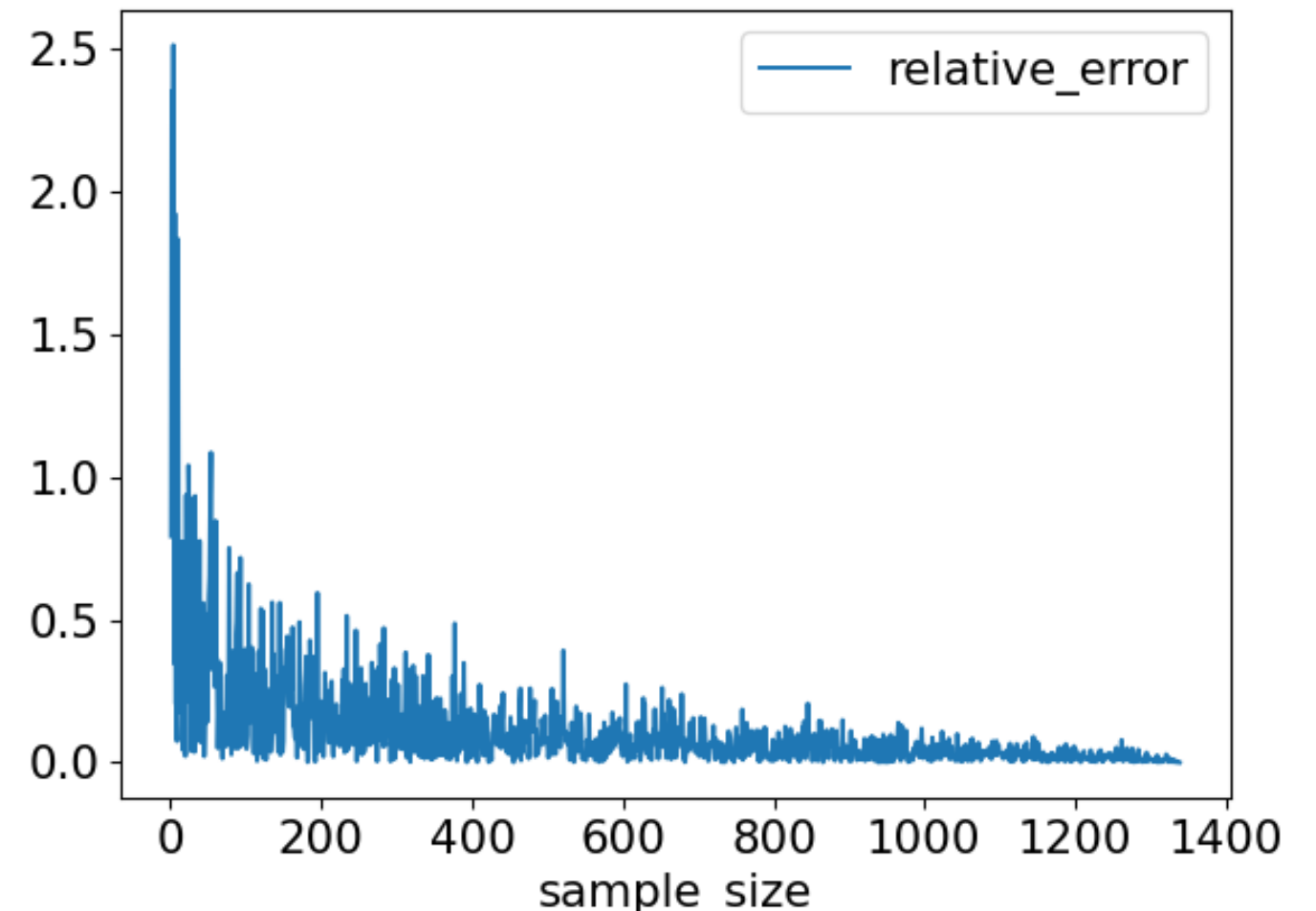
# Relative error vs. sample size

```
import matplotlib.pyplot as plt
errors.plot(x="sample_size",
            y="relative_error",
            kind="line")

plt.show()
```

## Properties:

- Really noisy, particularly for small samples
- Amplitude is initially steep, then flattens
- Relative error decreases to zero (when the sample size = population)



# Let's practice!

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# Creating a sampling distribution

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# Same code, different answer

```
coffee_ratings.sample(n=30)['total_cup_points'].mean()
```

```
82.53066666666668
```

```
coffee_ratings.sample(n=30)['total_cup_points'].mean()
```

```
81.97566666666667
```

```
coffee_ratings.sample(n=30)['total_cup_points'].mean()
```

```
82.68
```

```
coffee_ratings.sample(n=30)['total_cup_points'].mean()
```

```
81.675
```



# Same code, 1000 times

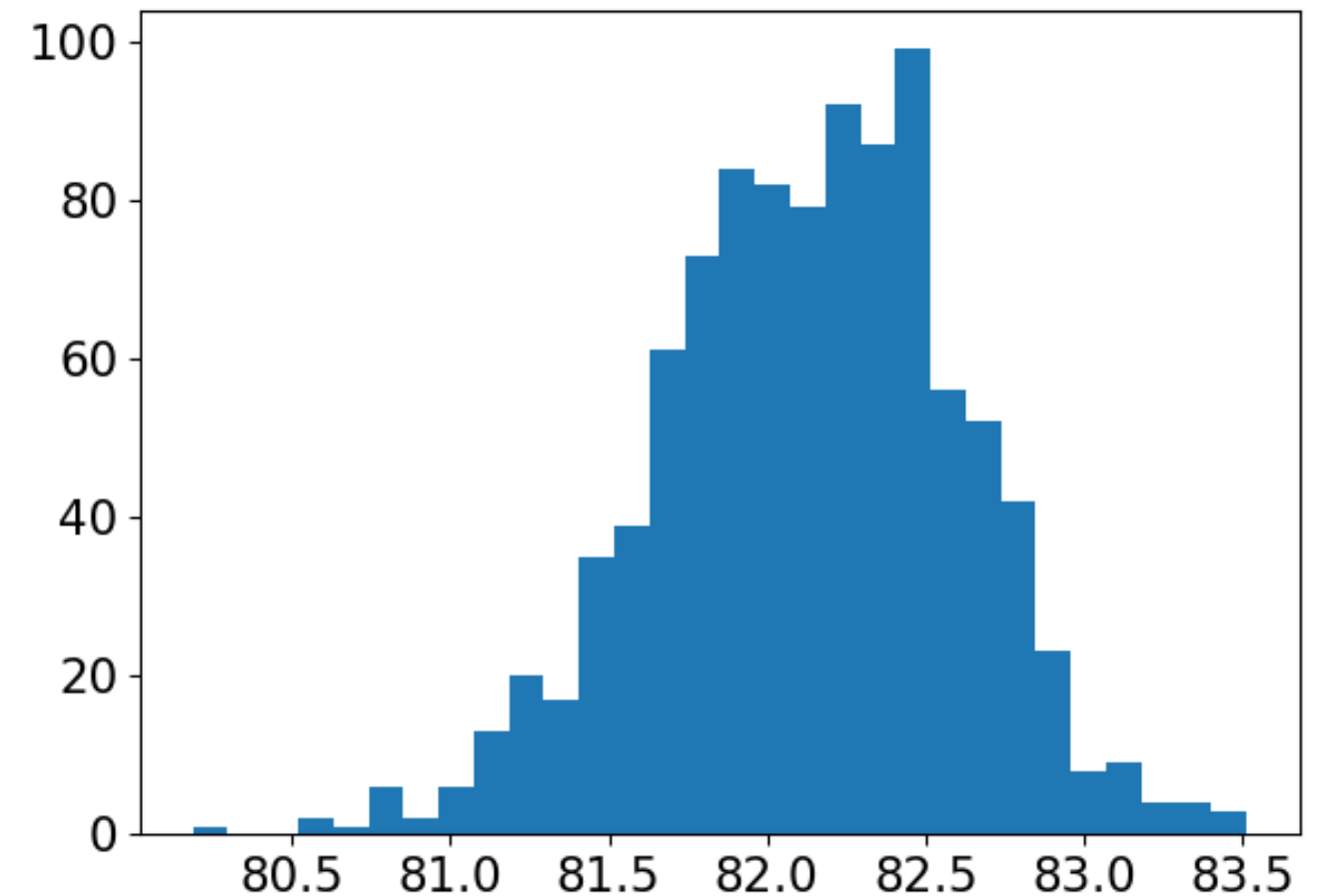
```
mean_cup_points_1000 = []  
for i in range(1000):  
    mean_cup_points_1000.append(  
        coffee_ratings.sample(n=30)['total_cup_points'].mean()  
    )  
print(mean_cup_points_1000)
```

```
[82.11933333333333, 82.55300000000001, 82.07266666666668, 81.76966666666667,  
...  
82.74166666666666, 82.45033333333335, 81.77199999999999, 82.81633333333333]
```

# Distribution of sample means for size 30

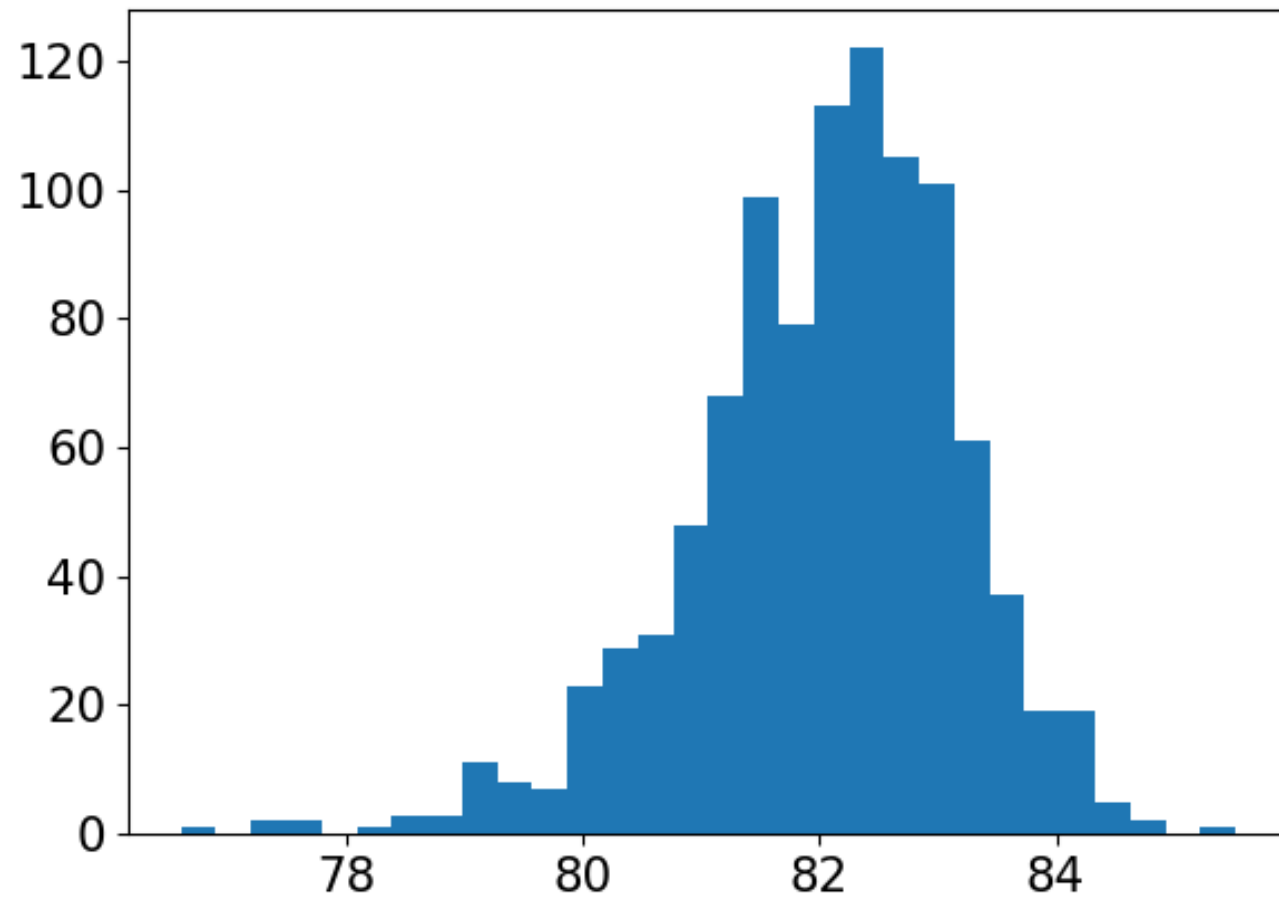
```
import matplotlib.pyplot as plt
plt.hist(mean_cup_points_1000, bins=30)
plt.show()
```

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

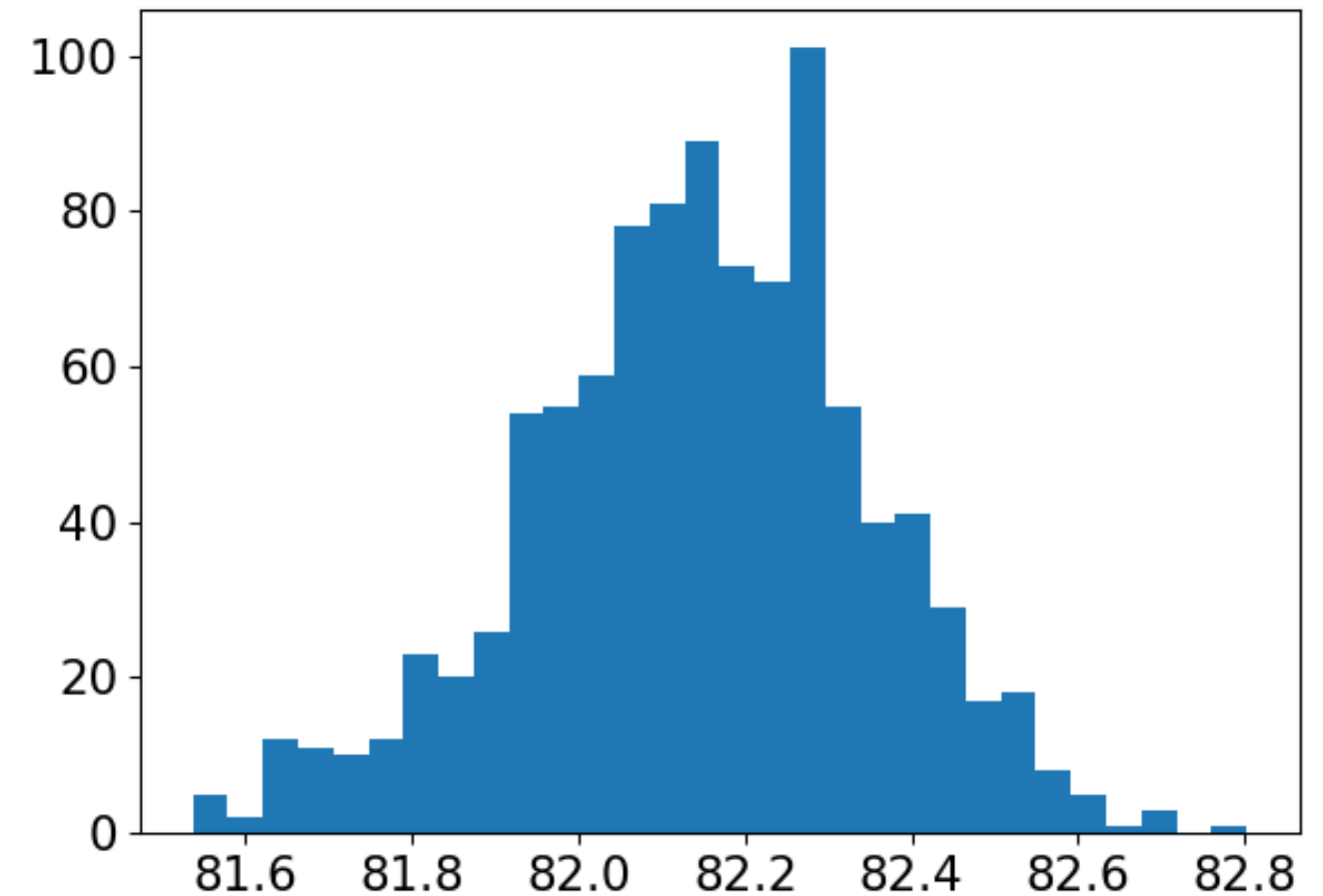


# Different sample sizes

Sample size: 6



Sample size: 150



# Let's practice!

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# Approximate sampling distributions

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# 4 dice



```
dice = expand_grid(  
  'die1': [1, 2, 3, 4, 5, 6],  
  'die2': [1, 2, 3, 4, 5, 6],  
  'die3': [1, 2, 3, 4, 5, 6],  
  'die4': [1, 2, 3, 4, 5, 6]  
)
```

	die1	die2	die3	die4
0	1	1	1	1
1	1	1	1	2
2	1	1	1	3
3	1	1	1	4
4	1	1	1	5
...	...	...	...	...
1291	6	6	6	2
1292	6	6	6	3
1293	6	6	6	4
1294	6	6	6	5
1295	6	6	6	6

[1296 rows x 4 columns]

# Mean roll

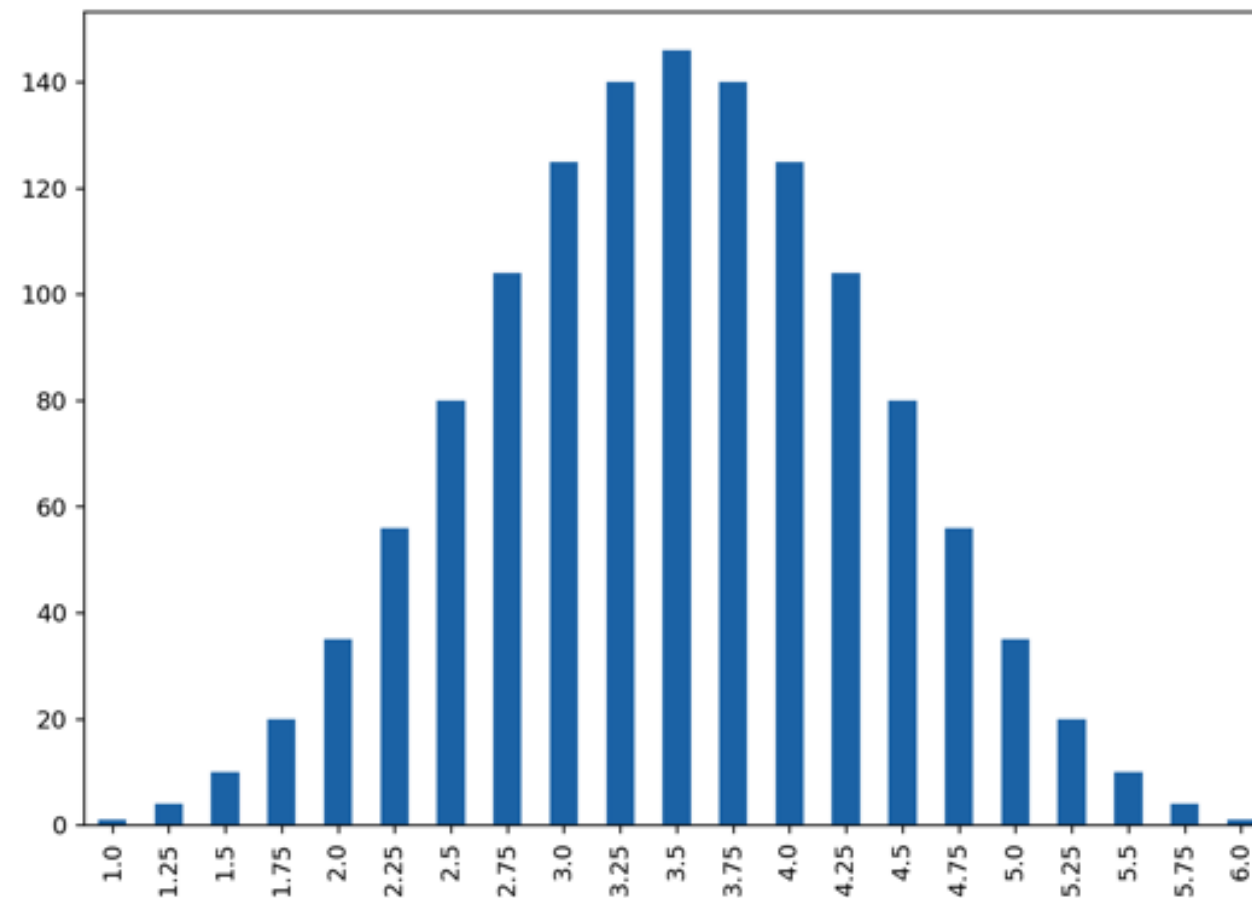
```
dice['mean_roll'] = (dice['die1'] +  
                    dice['die2'] +  
                    dice['die3'] +  
                    dice['die4']) / 4  
  
print(dice)
```

	die1	die2	die3	die4	mean_roll
0	1	1	1	1	1.00
1	1	1	1	2	1.25
2	1	1	1	3	1.50
3	1	1	1	4	1.75
4	1	1	1	5	2.00
...	...	...	...	...	...
1291	6	6	6	2	5.00
1292	6	6	6	3	5.25
1293	6	6	6	4	5.50
1294	6	6	6	5	5.75
1295	6	6	6	6	6.00

[1296 rows x 5 columns]

# Exact sampling distribution

```
dice['mean_roll'] = dice['mean_roll'].astype('category')  
dice['mean_roll'].value_counts(sort=False).plot(kind="bar")
```





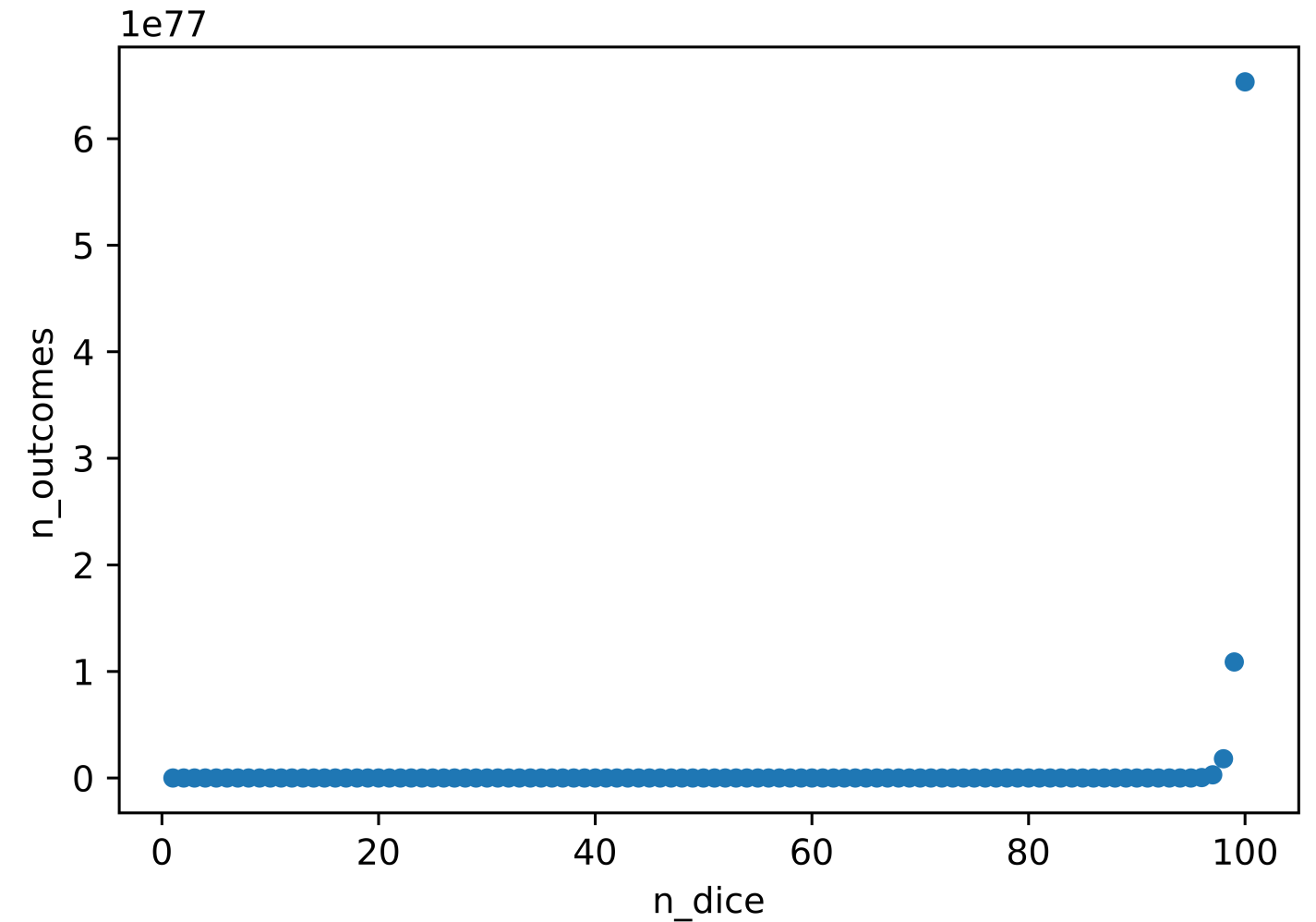
# The number of outcomes increases fast

```
n_dice = list(range(1, 101))
n_outcomes = []
for n in n_dice:
    n_outcomes.append(6**n)
```

```
outcomes = pd.DataFrame(
    {"n_dice": n_dice,
     "n_outcomes": n_outcomes})
```

```
outcomes.plot(x="n_dice",
               y="n_outcomes",
               kind="scatter")

plt.show()
```



# Simulating the mean of four dice rolls

```
import numpy as np
```

```
np.random.choice(list(range(1, 7)), size=4, replace=True).mean()
```

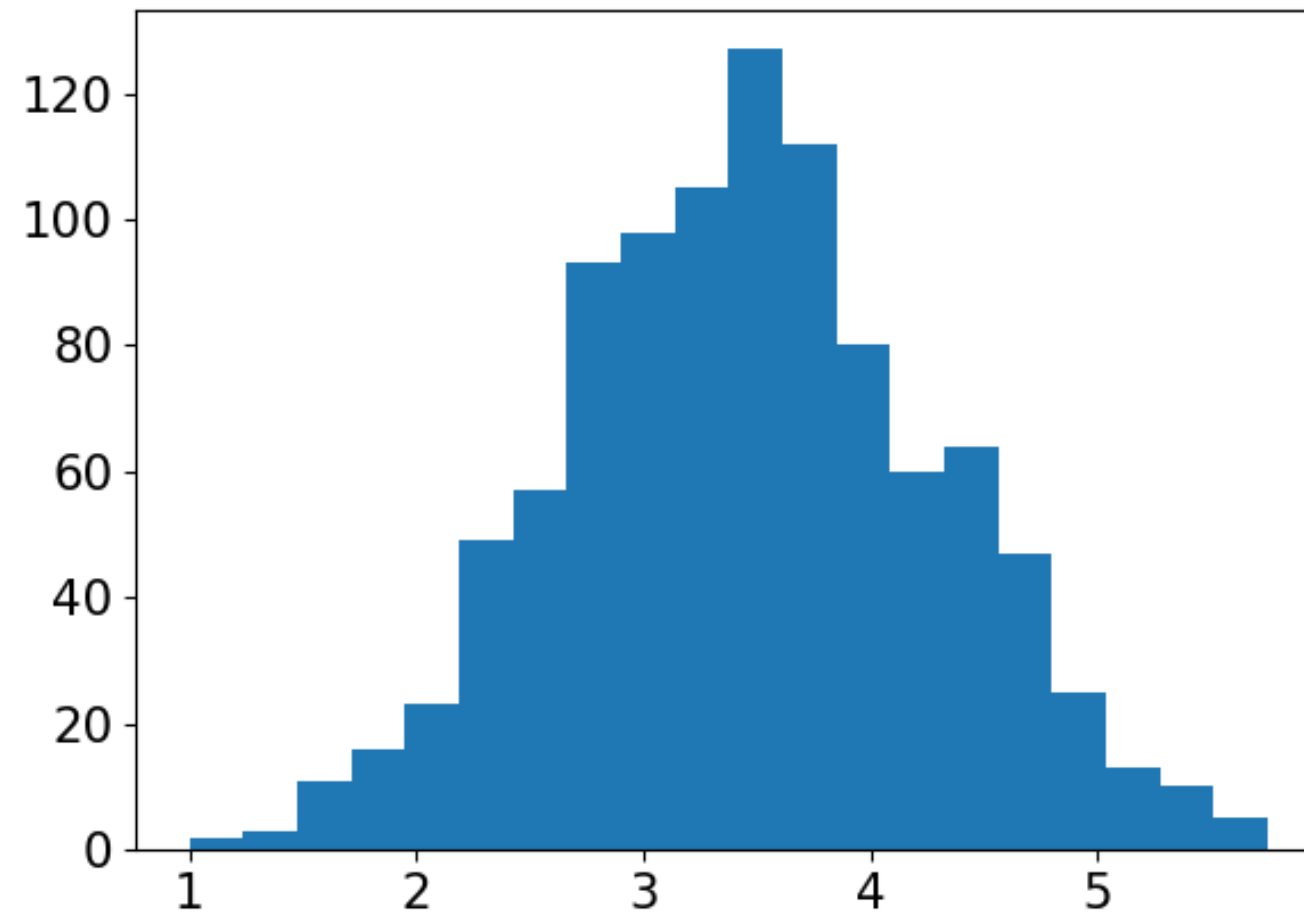
# Simulating the mean of four dice rolls

```
import numpy as np
sample_means_1000 = []
for i in range(1000):
    sample_means_1000.append(
        np.random.choice(list(range(1, 7)), size=4, replace=True).mean()
    )
print(sample_means_1000)
```

```
[3.25, 3.25, 1.75, 2.0, 2.0, 1.0, 1.0, 2.75, 2.75, 2.5, 3.0, 2.0, 2.75,
...
1.25, 2.0, 2.5, 2.5, 3.75, 1.5, 1.75, 2.25, 2.0, 1.5, 3.25, 3.0, 3.5]
```

# Approximate sampling distribution

```
plt.hist(sample_means_1000, bins=20)
```



# Let's practice!

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# Standard errors and the Central Limit Theorem

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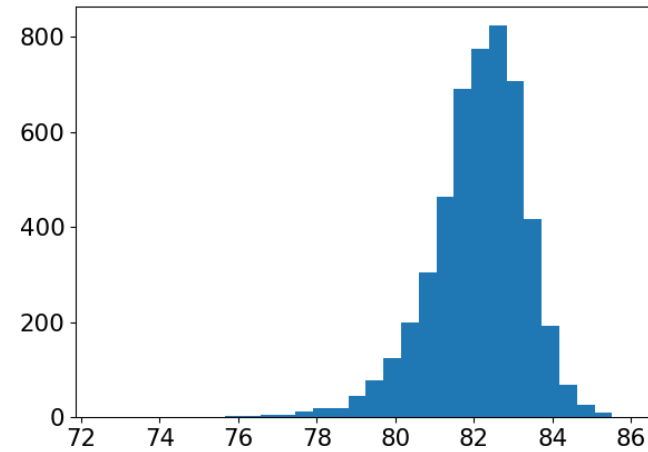


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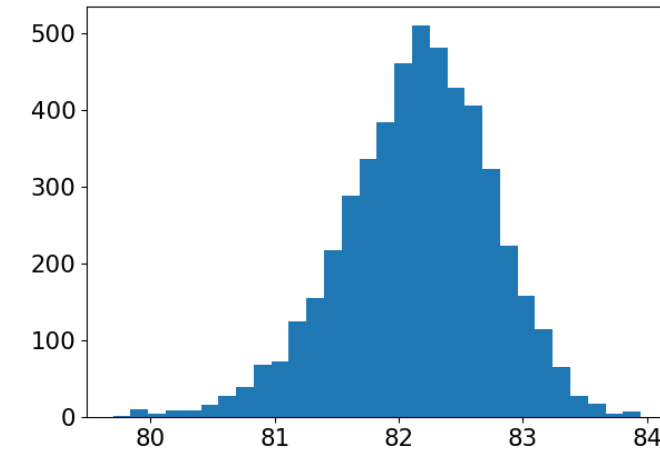
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# Sampling distribution of mean cup points

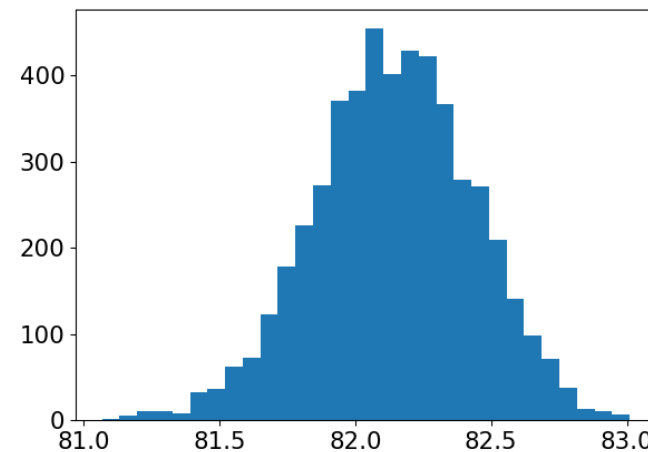
Sample size: 5



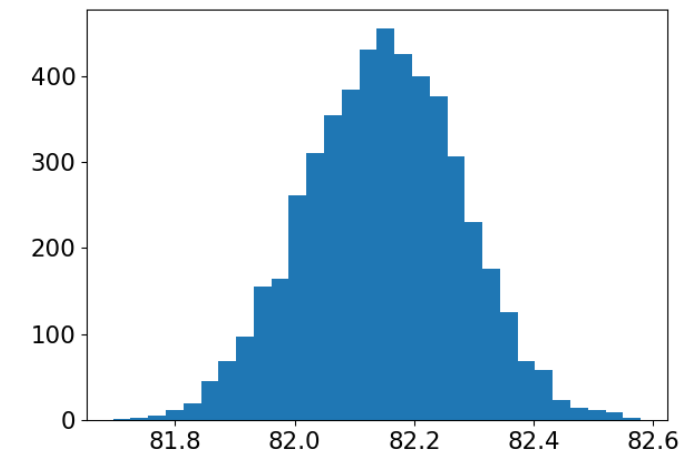
Sample size: 20



Sample size: 80



Sample size: 320



# 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*
- The width of the sampling distribution gets *narrower*



# Population & sampling distribution means

```
coffee_ratings['total_cup_points'].mean()
```

```
82.15120328849028
```

Use `np.mean()` on each approximate sampling distribution:

Sample size	Mean sample mean
5	82.18420719999999
20	82.1558634
80	82.14510154999999
320	82.154017925

# Population & sampling distribution standard deviations

```
coffee_ratings['total_cup_points'].std(ddof=0)
```

```
2.685858187306438
```

- Specify `ddof=0` when calling `.std()` on populations
- Specify `ddof=1` when calling `np.std()` on samples or sampling distributions

Sample size	Std dev sample mean
5	1.1886358227738543
20	0.5940321141669805
80	0.2934024263916487
320	0.13095083089190876

# Population mean over square root sample size

Sample size	Std dev sample mean	Calculation	Result
5	1.1886358227738543	2.685858187306438 / sqrt(5)	1.201
20	0.5940321141669805	2.685858187306438 / sqrt(20)	0.601
80	0.2934024263916487	2.685858187306438 / sqrt(80)	0.300
320	0.13095083089190876	2.685858187306438 / sqrt(320)	0.150

# Standard error

- Standard deviation of the sampling distribution
- Important tool in understanding sampling variability

# Let's practice!

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