

UG2 Semester 1 survey

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BURNS NIGHT CEILIDH

THURSDAY

29 January 2026

19.00 – 21.30

Informatics Forum

Join us for a toe-tapping Burns Night
Ceilidh packed with great music,
lively dancing, and brilliant company!
— no experience needed

Book now! – tickets £5



Inf2 - Foundations of Data Science: Randomness, sampling and simulation - Sampling, statistics, simulations



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So far...

1. Intro to inferential stats

- Estimation
- Hypothesis testing
- Comparing two samples (A/B testing)

2. Two examples of inference on coins

- Estimate the average year of a coin
 - we have an estimate, but we don't know how precise it is
- Test the hypothesis that the coins are unbiased
 - we think the coins are unbiased, but we can't prove it

Today

- Big idea: method to determine if the coin is biased:
Statistical simulation of what we expect to happen if the coin isn't biased
- Steps:
 1. sampling, both random and non-random
 2. definition of a "statistic"
 3. statistical simulation
- Then get intuition about what happens as sample size changes
 1. distribution of statistics from small samples
 2. distribution of statistics from large samples
 - The Central Limit Theorem & Law of Large Numbers

Statistical simulation overview

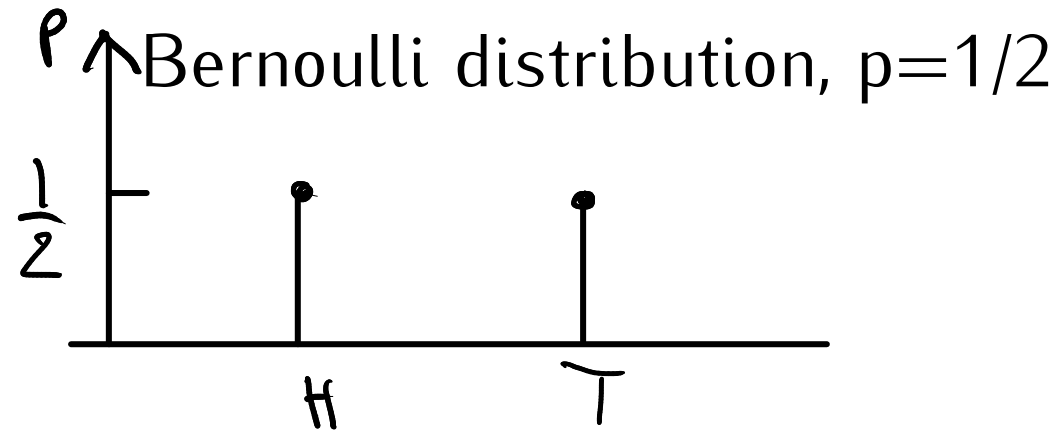
Reality



Experiment

67 students made
536 tosses, of which
264 Heads and 272 Tails

Model of unbiased coin



Computational simulation

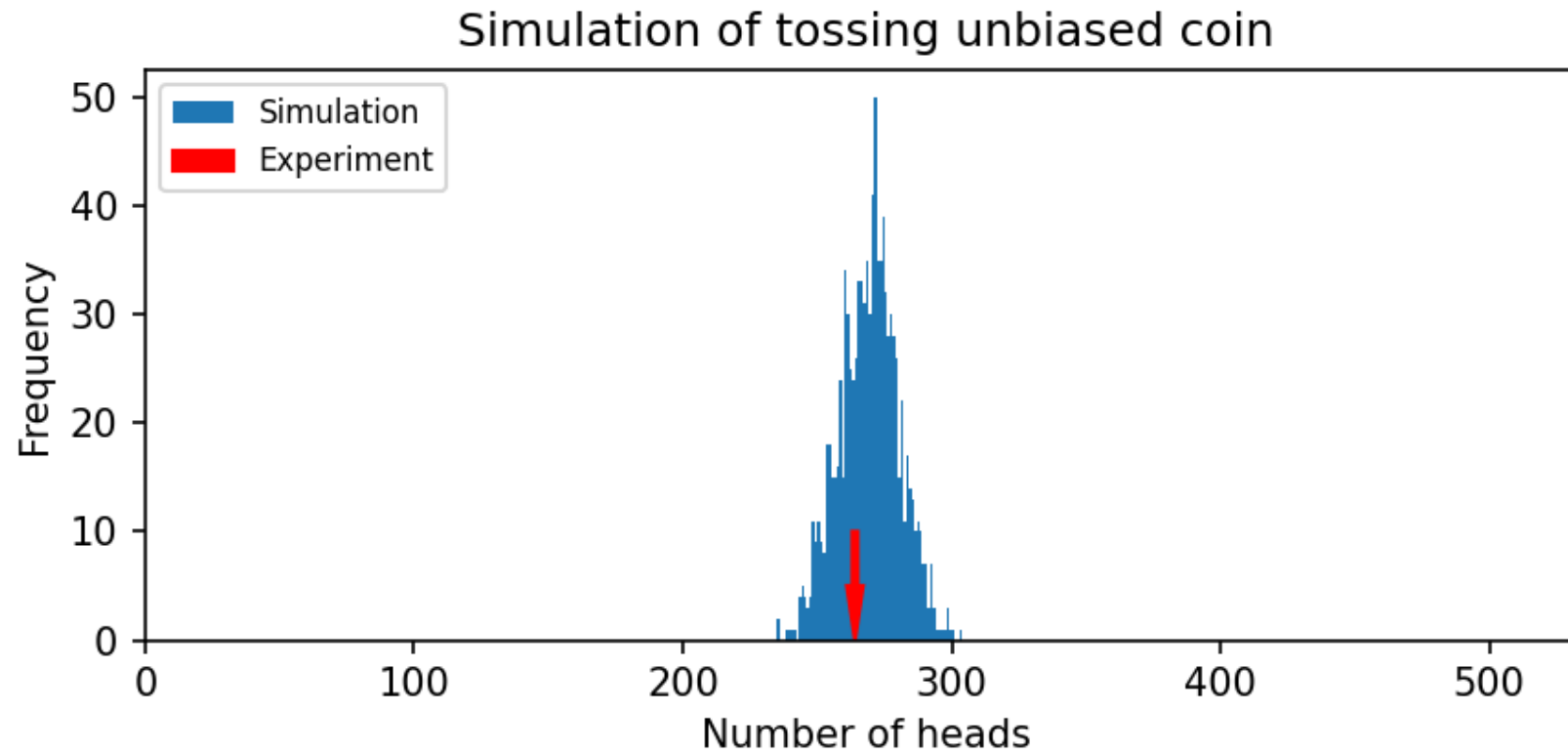
536 samples, of which
Heads and Tails

...

...

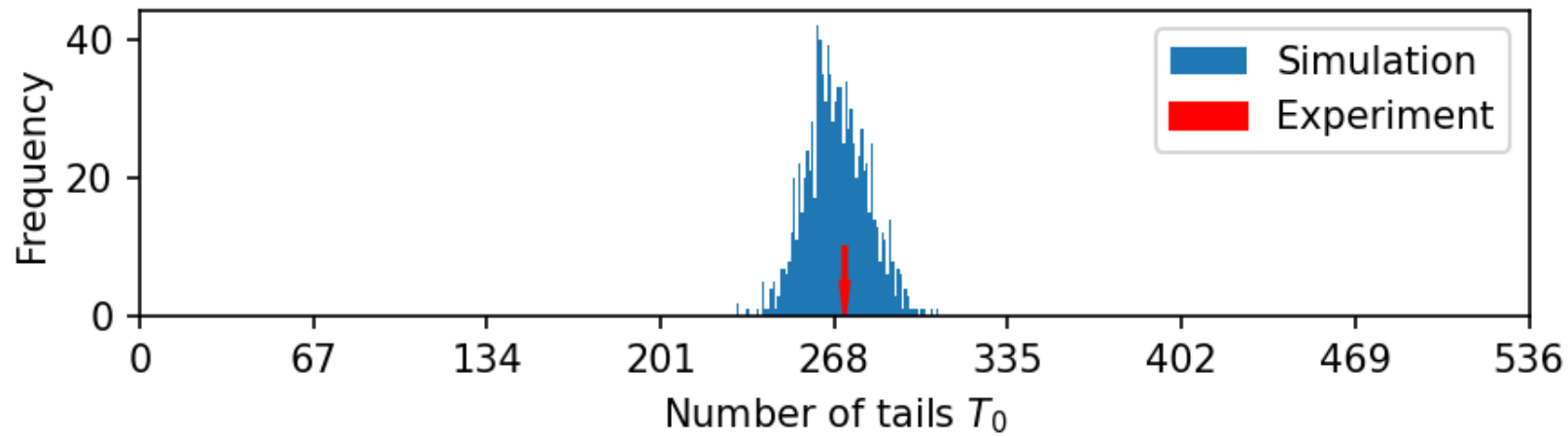
Statistical simulation results

1000 repetitions later... consistent with experiment?

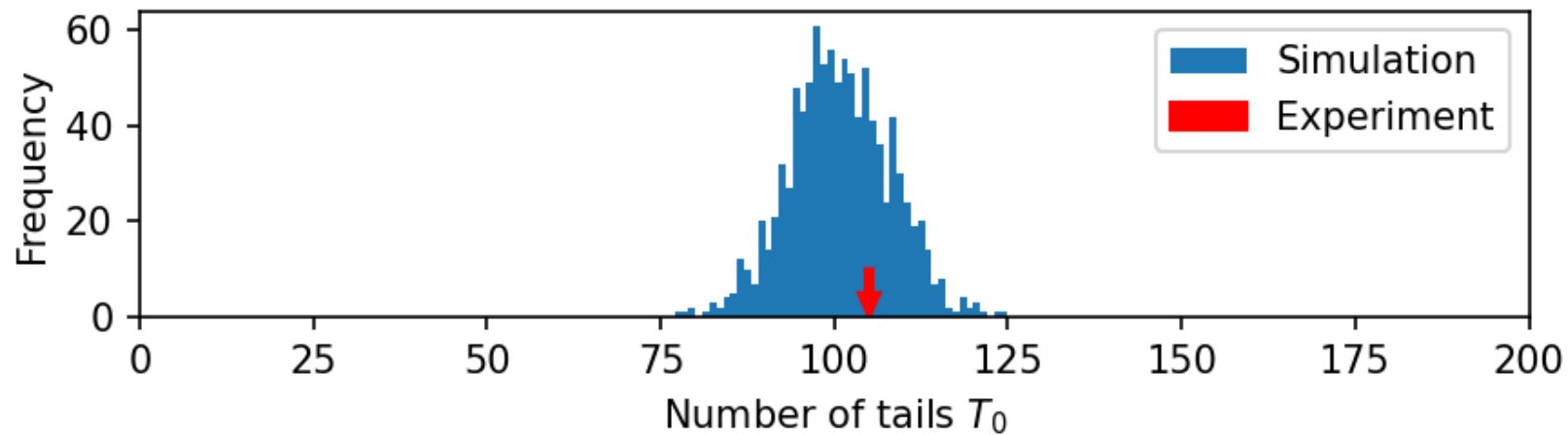


Statistical simulation results - for the 10p coins too

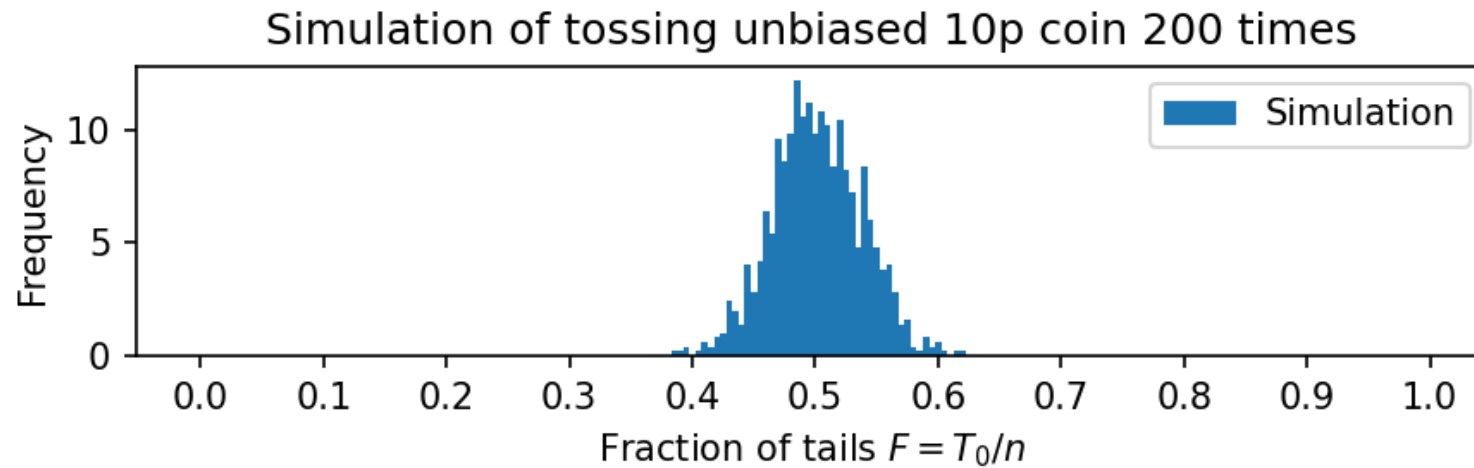
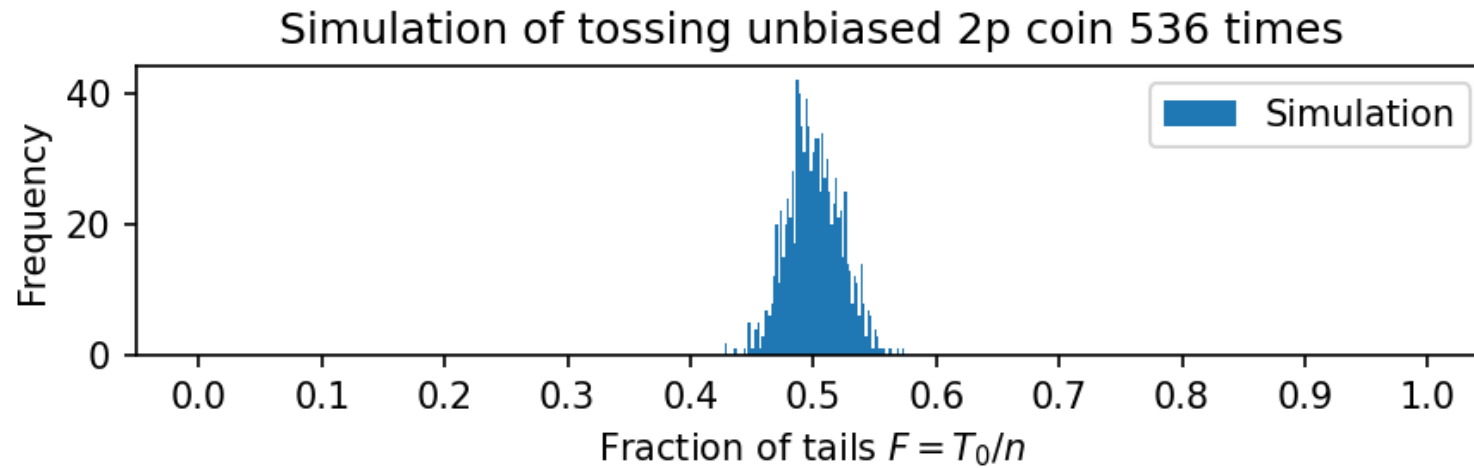
Simulation of tossing unbiased 2p coin 536 times



Simulation of tossing unbiased 10p coin 200 times



Plot fractions of tosses that are tails to help comparison

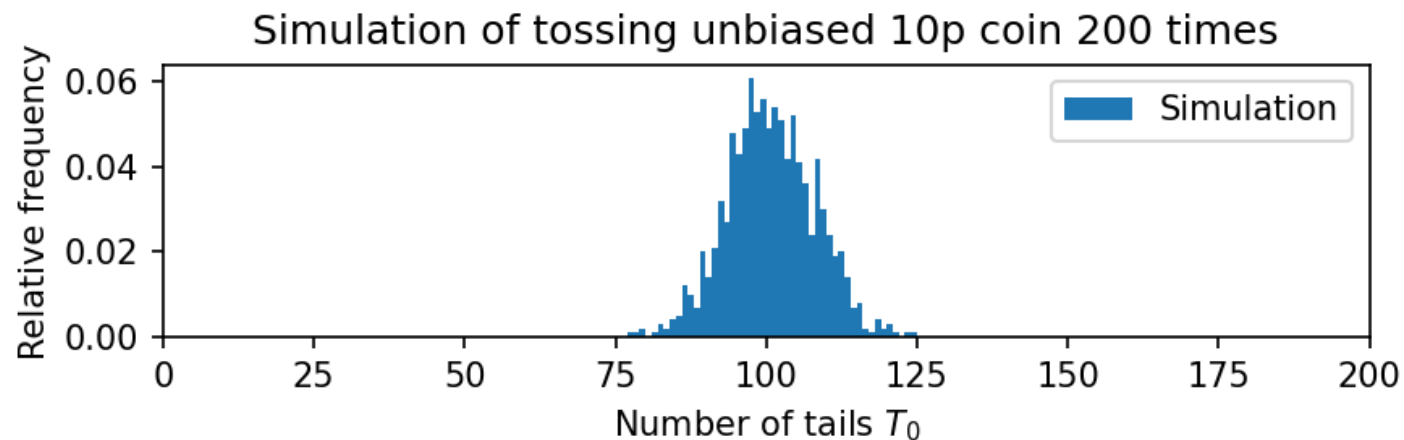
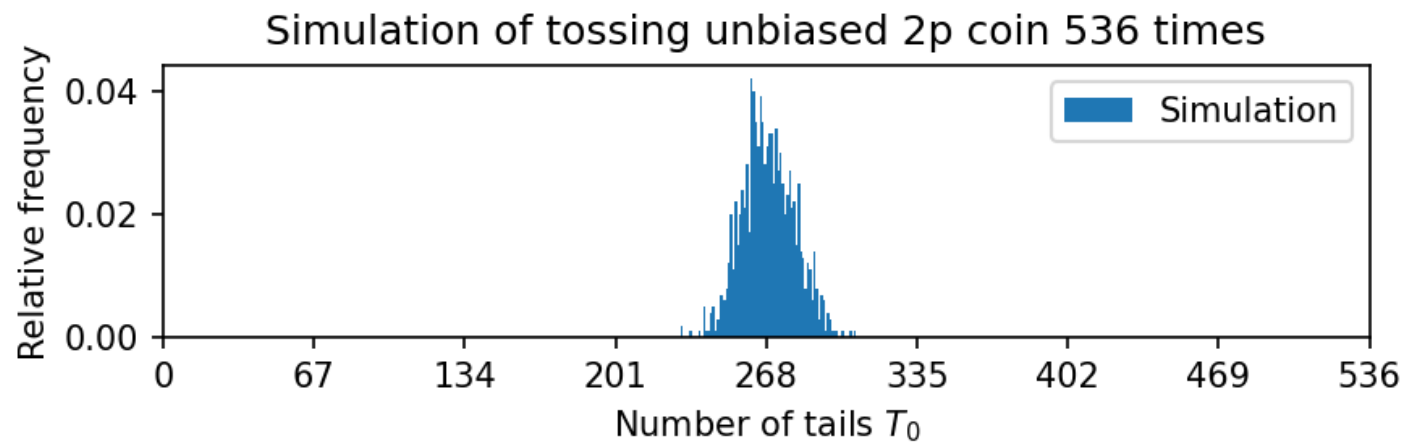


Are the sample means of the fraction of the number of tails in each simulation similar or different?

Are the sample variances of the fraction of the number of tails in each simulation similar or different?

Note on relative frequency

Relative frequency of event A = $\frac{\text{number of outcomes in which } A \text{ occurs}}{\text{total of number of outcomes in experiment}}$



e.g. $A = \text{"275 Tails"}$

$$\Rightarrow f_A = \frac{n_A}{n} = \frac{25}{1000} = 0.025$$

Also called empirical probability

Inf2 - Foundations of Data Science: Randomness, sampling and simulation - Sampling



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Definition of a random sample (Strictly, an "independent and identically distributed" (iid) random sample)

In a random sample of size n from either

- a probability distribution
- or a finite population of N items

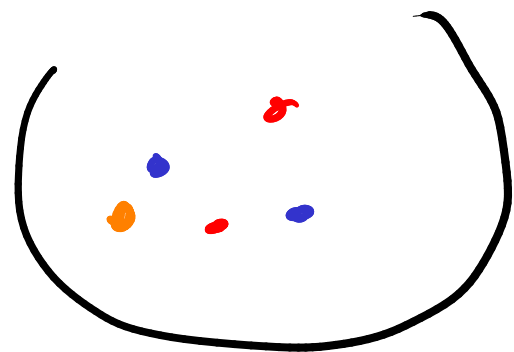
the random variables

comprising the sample are all

1. independent and
2. have the same probability distribution

Sampling from a finite population of discrete items without replacement

Discrete items

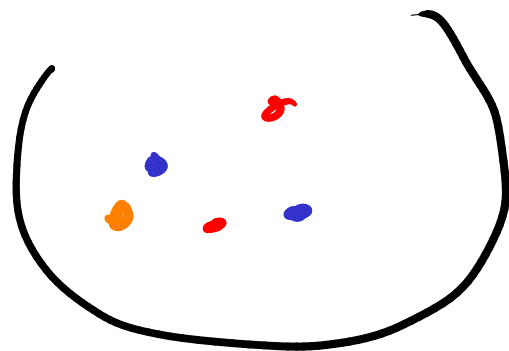


$N = 5$

n	Samples	Counts		
		R	B	Y
3				
3				
5				
5				

Sampling from a finite population of discrete items with replacement

Discrete items



$N = 5$

n	Samples	Counts		
		R	B	Y
3				
3				
5				
5				

Practical sampling

For each set of S2 comprehension questions:

I am going to enter every consenting student who has done the questions by 12 noon of the day of the next lecture into a prize draw, and announce the winner in that day's lecture (unless they elect to remain anonymous).

Your probability of winning will be in proportion to the number of points you get on your last attempt of the questions (you can take the questions as many times as you want).

Prizes to be determined! (Though they won't be big.)

Questions

1. Is sampling with replacement an iid random sample?
2. Is sampling without replacement an iid random sample?

Why are random samples good?

Consider non-random samples

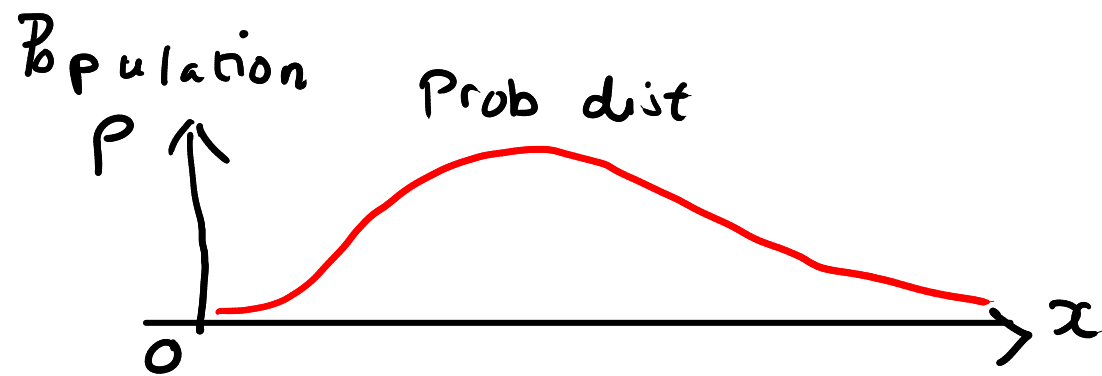
Day	£
Mon	100
Tue	120
Wed	130
Thu	140
Fri	150
Sat	130
Sun	120
Mon	100
⋮	⋮



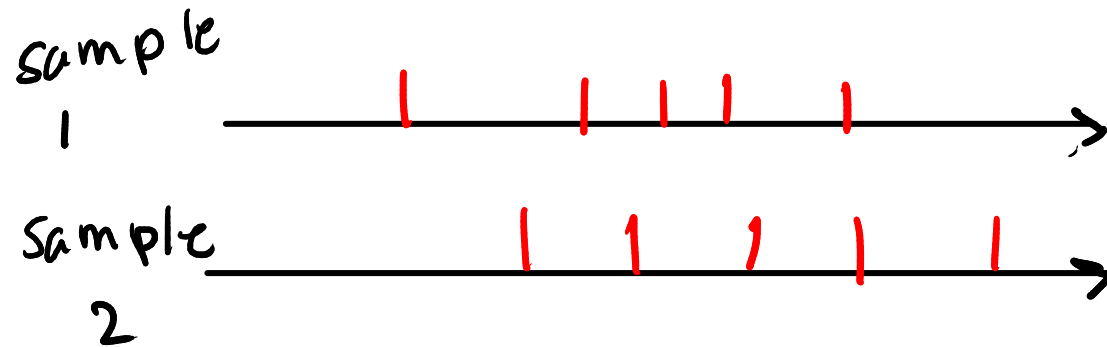
Mstyslav Chernov, Wikimedia Commons, CC BY SA 3.0

Sampling from a probability distribution

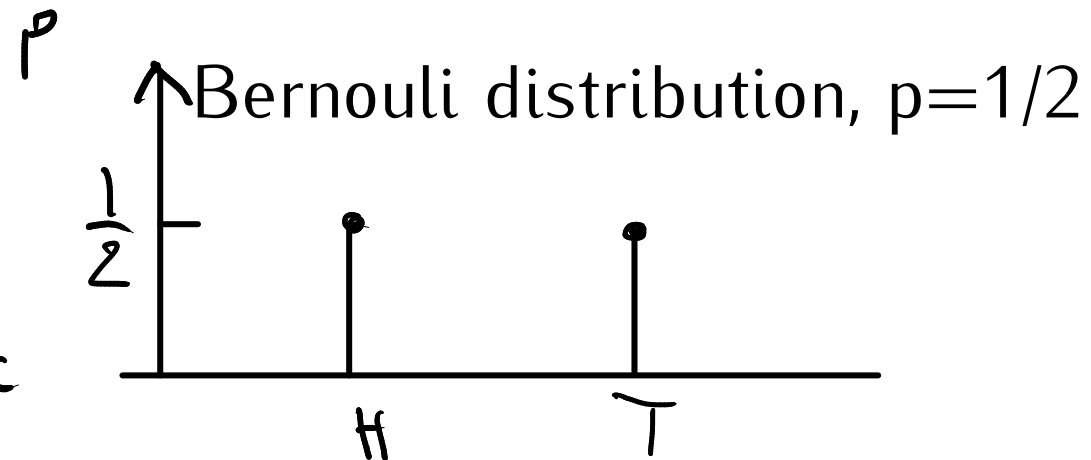
Continuous



sample size $n=5$



Discrete

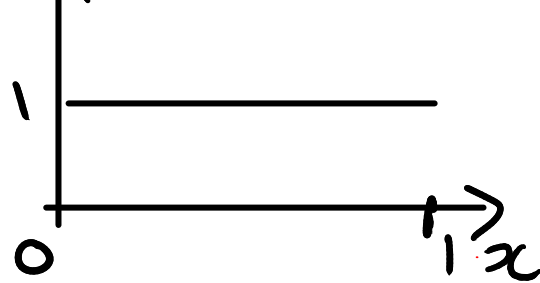


HT TH TT HH

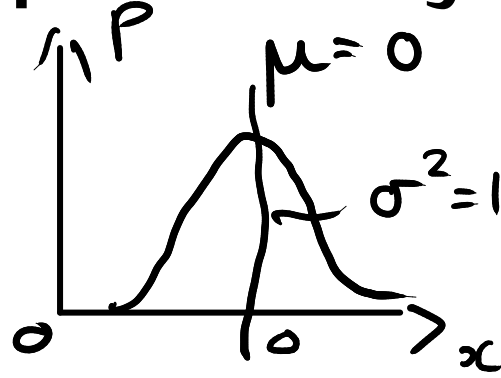
TH TT TH

Sampling from continuous probability distributions

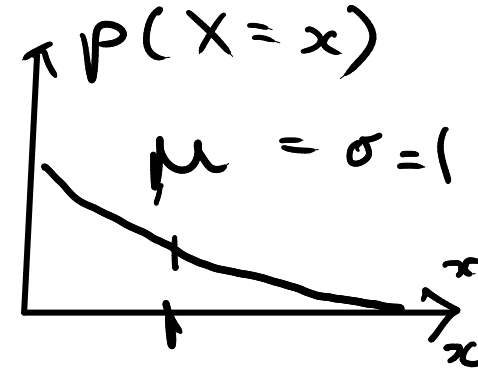
$$P(X=x)$$



Uniform

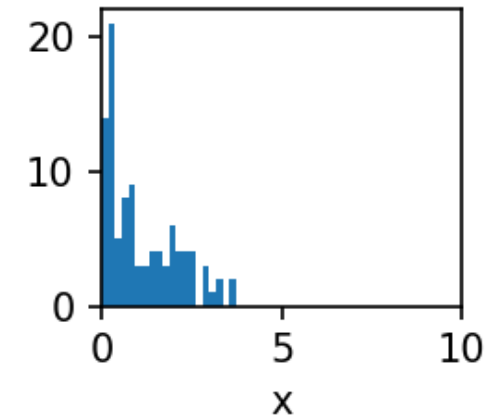
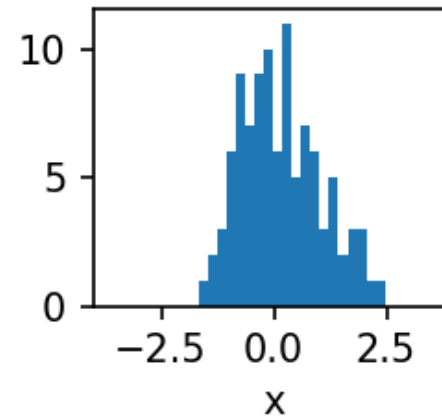
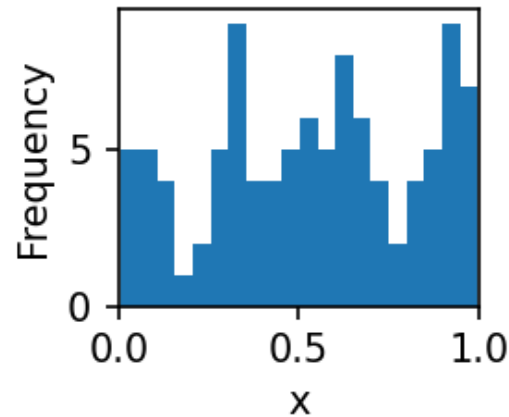


Normal

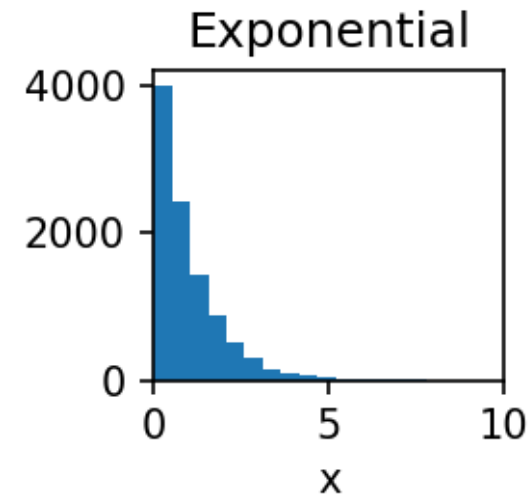
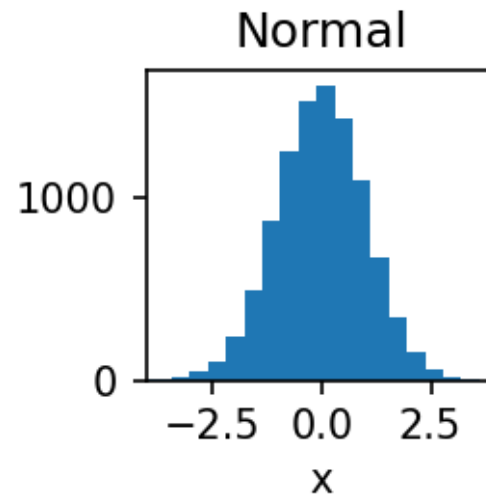
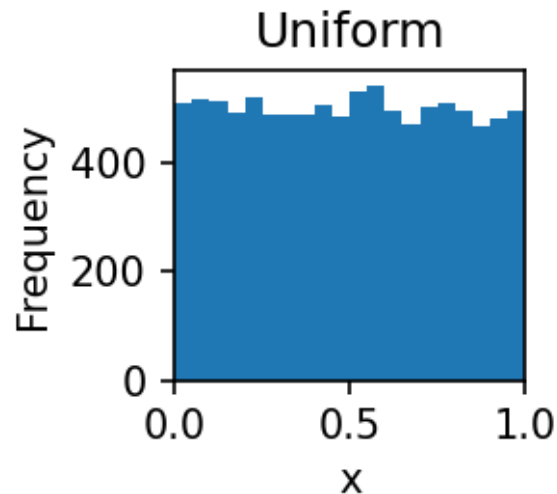


Exponential

100
samples



10000
samples



RNGs

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Definition of a statistic

A statistic is any quantity whose value can be calculated from sample data

Example: Number of heads from sequence of coin tosses

Treat statistics from simulations as random variables and denote with upper case:

Denote observed sample statistic with lower case:

Recipe for a statistical simulation

A. Decide on

- Statistic of interest
- Population distribution or set of items
- Sample size
- Number of repetitions

B. Simulation procedure

1. For in

- a. Sample items from the population distribution or set
- b. Compute and store statistic of interest

2. Generate histogram of the stored sample statistics

Statistical simulation applied to Swain versus Alabama

8 out of 100 people selected for a jury panel were black

26% of population of Alabama were black

How do we simulate unbiased jury selection?

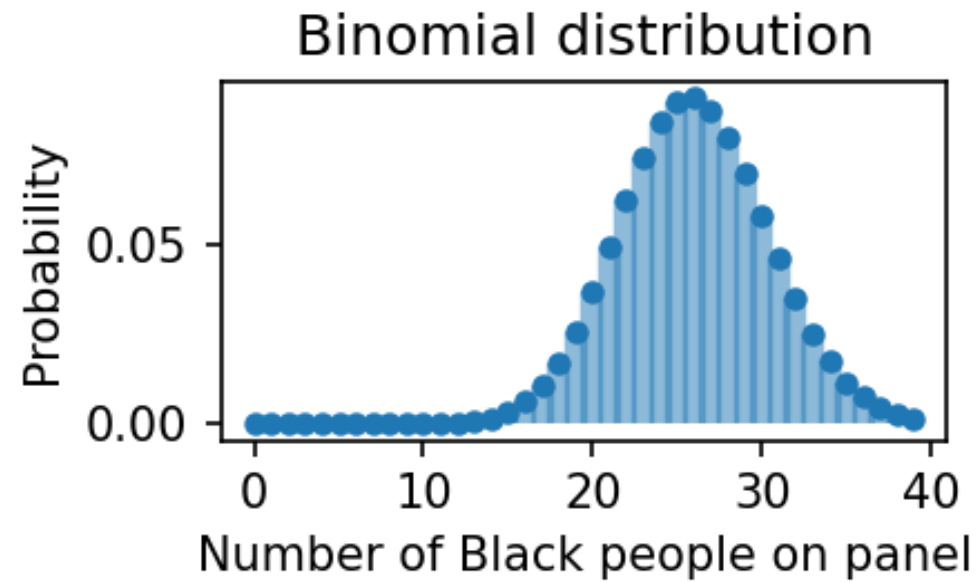
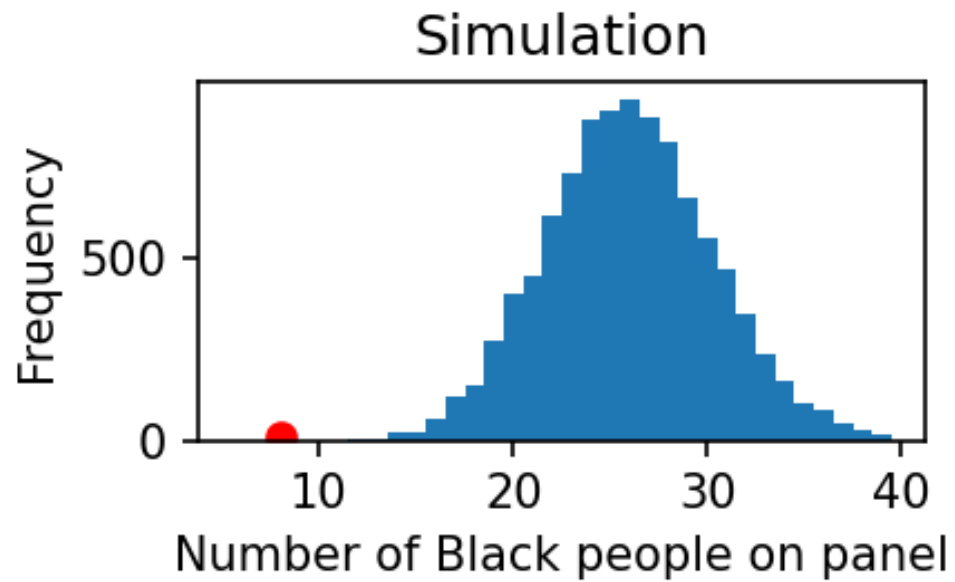
Statistic:

Population:

Sample size:

Num. repetitions:

Swain versus Alabama simulation results



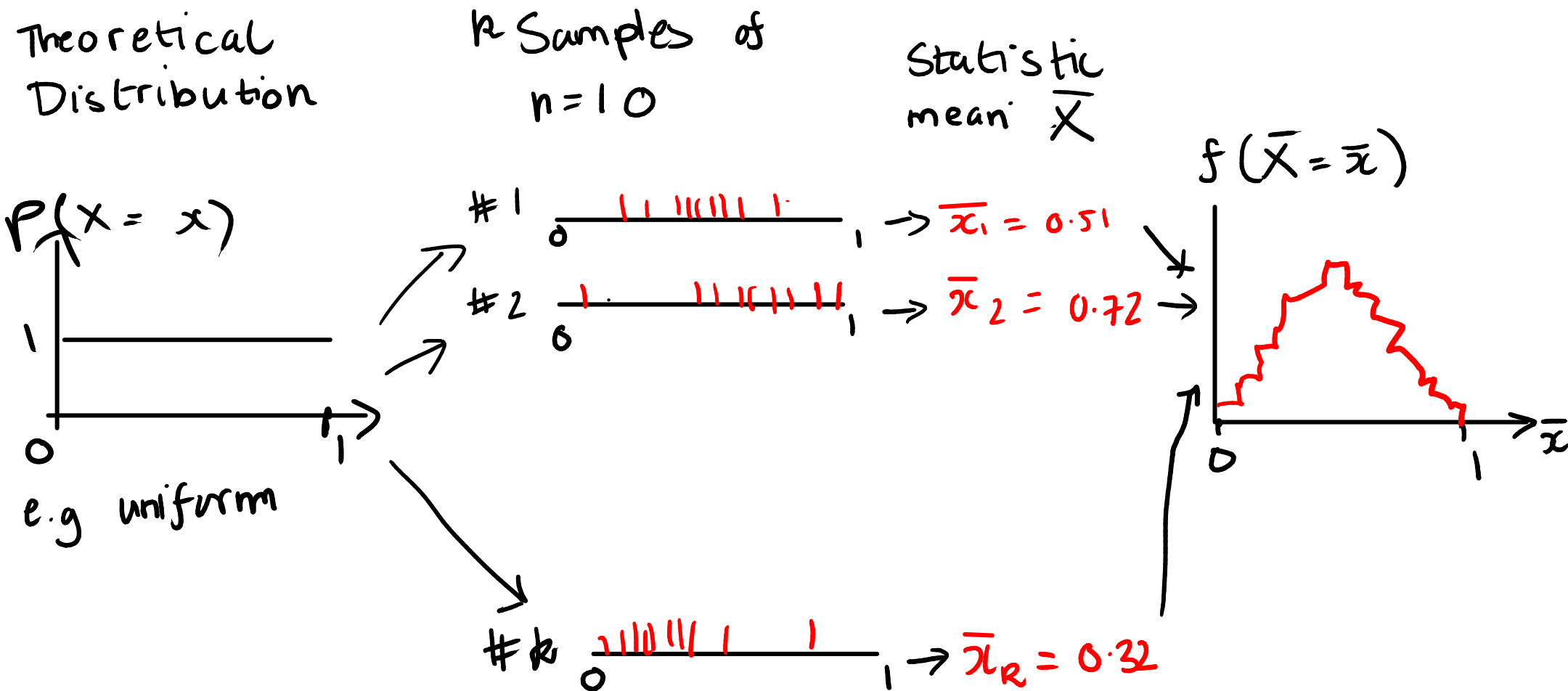
Inf2 - Foundations of Data Science: Randomness, sampling and simulation - Distributions of sample statistics from small samples



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Example: Sampling statistics from continuous distributions



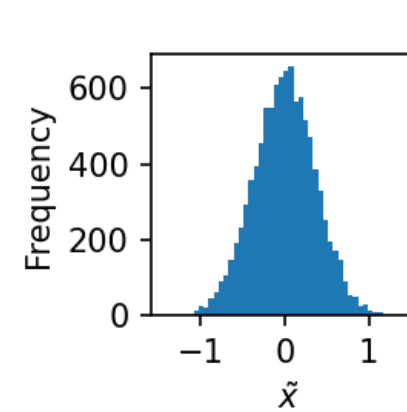
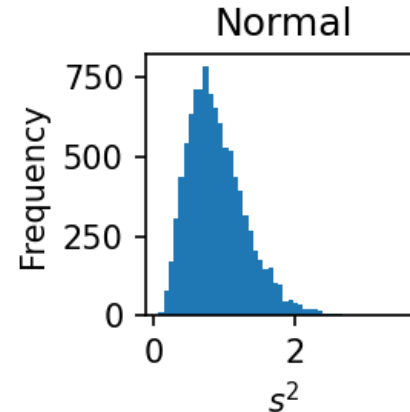
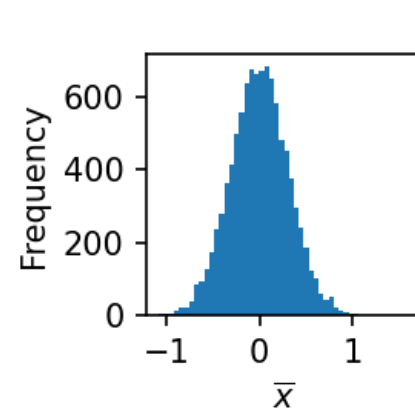
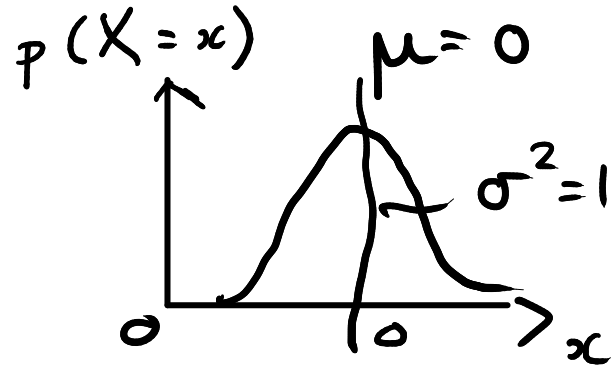
Distribution

Mean

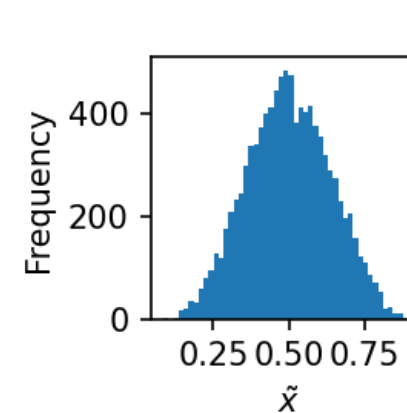
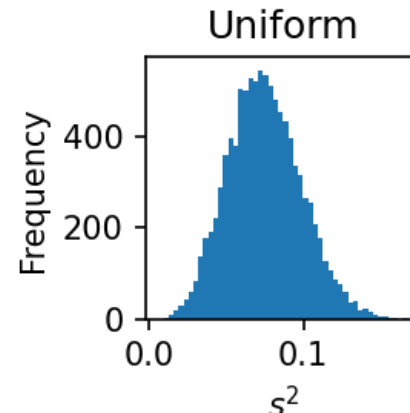
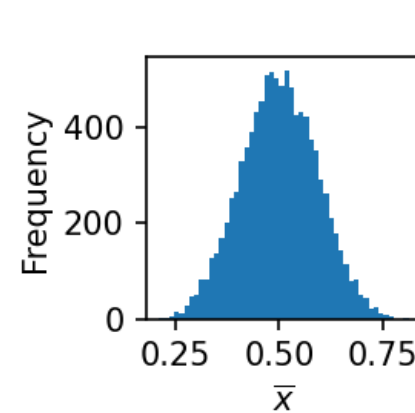
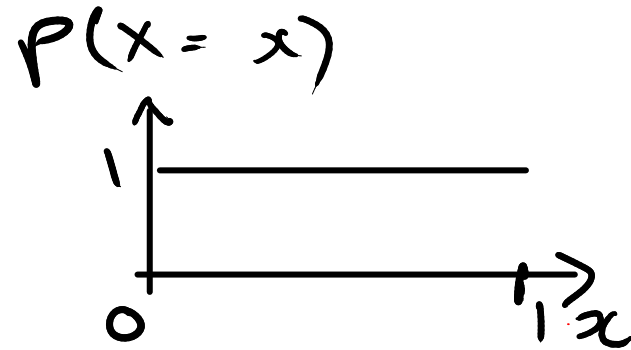
Variance

Median

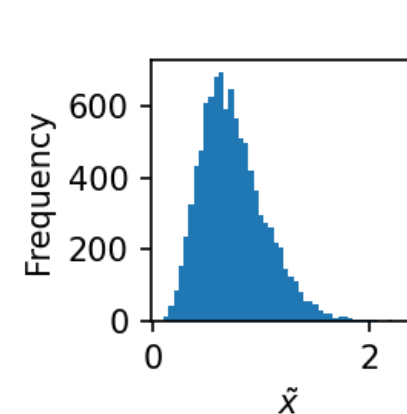
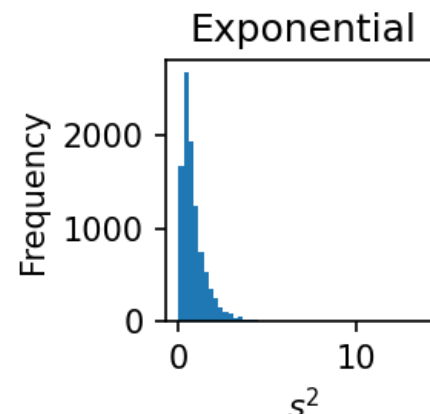
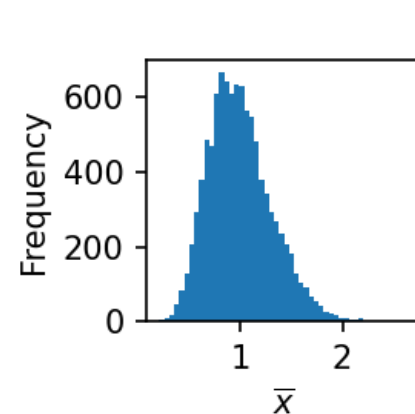
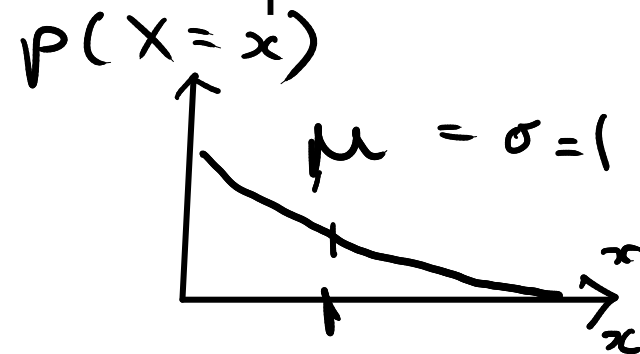
Normal



Uniform



Exponential



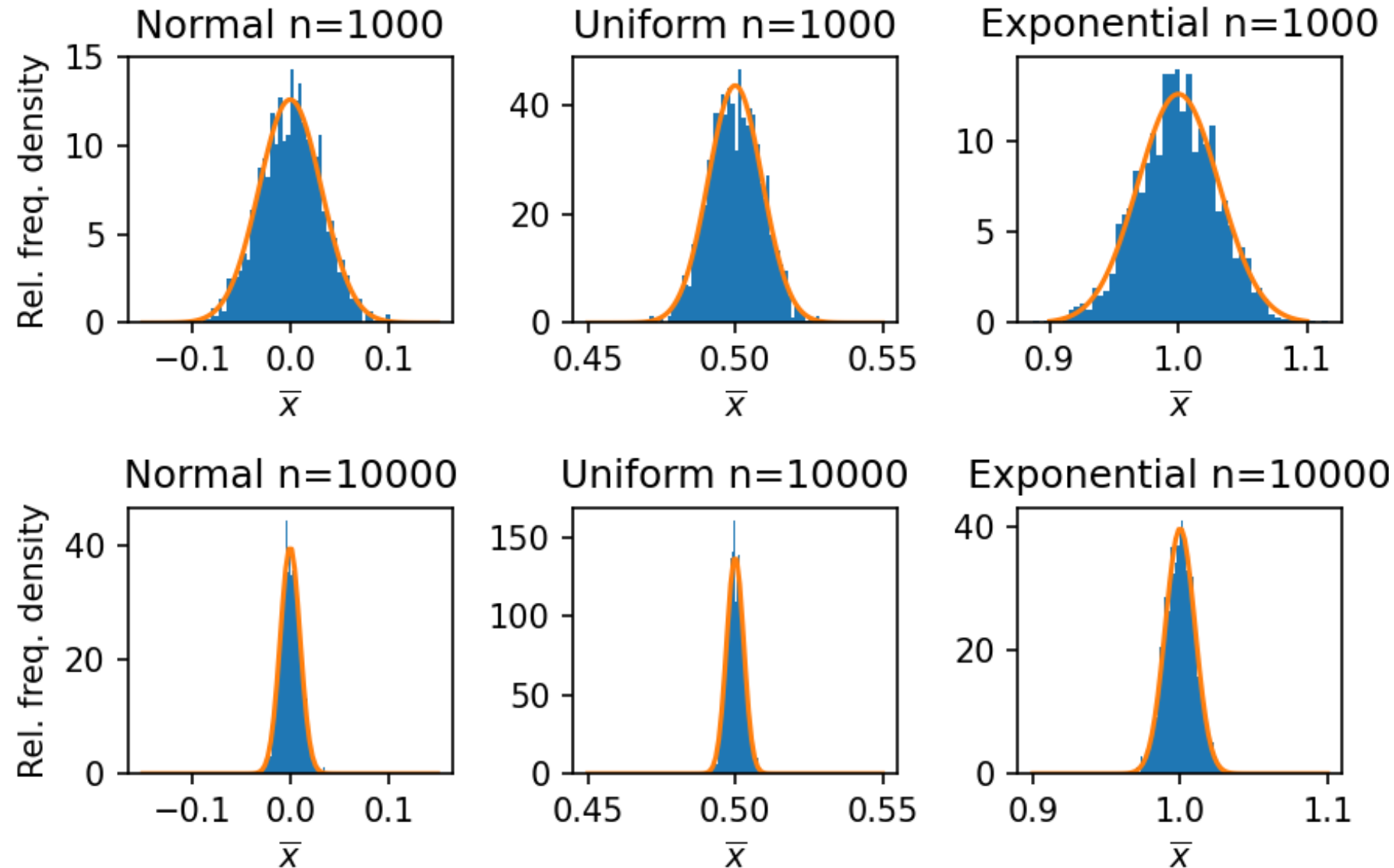
Inf2 - Foundations of Data Science: Randomness, sampling and simulation - Distributions of sample statistics from large samples



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Distribution of sample mean from large samples



Central Limit Theorem

Distribution of the mean (or the sum) of a random sample drawn from any distribution will converge on a normal distribution

If the population distribution mean is μ and variance is σ^2 and sample size is n then:

Expected value of sample mean is the same as the mean of the population distribution

Expected variance of the mean

Standard error of the mean (SEM)

- **Central Limit Theorem applied to tossing an unbiased coin**

Law of large numbers

In the limit of infinite sample size $n \rightarrow \infty$, the expected value of the sample mean \bar{x} tends to the population mean μ and the expected value of the sample variance s^2 tends to 0.

Summary

- Statistical simulations
 - Sampling
 - Statistics
- Distributions of common statistics for small sample sizes
- Sampling distribution of the mean is normal for large samples from any distribution (Central Limit Theorem)

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