

Preparing for the Midterm Exam

- Thursday, November 9, 2pm-3:20pm
- Here in 305 MSE
- Closed book exam; no books, notes, laptops, etc.
- However, calculators can be used.
- You can prepare one cheat sheet (letter size)

This will be provided

Name	Probability Distribution	Mean	Variance	Section in Book
Discrete				
Uniform	$\frac{1}{n}, a \leq b$	$\frac{(b + a)}{2}$	$\frac{(b - a + 1)^2 - 1}{12}$	3-5
Binomial	$\binom{n}{x} p^x (1 - p)^{n-x},$ $x = 0, 1, \dots, n, 0 \leq p \leq 1$	np	$np(1 - p)$	3-6
Geometric	$(1 - p)^{x-1} p,$ $x = 1, 2, \dots, 0 \leq p \leq 1$	$1/p$	$(1 - p)/p^2$	3-7.1
Negative binomial	$\binom{x-1}{r-1} (1 - p)^{x-r} p^r$ $x = r, r + 1, r + 2, \dots, 0 \leq p \leq 1$	r/p	$r(1 - p)/p^2$	3-7.2
Hypergeometric	$\frac{\binom{K}{x} \binom{N-K}{n-x}}{\binom{N}{n}}$ $x = \max(0, n - N + K), 1$ $\min(K, n), K \leq N, n \leq N$	$np,$ where $p = \frac{K}{N}$	$np(1 - p) \frac{\binom{N-n}{N-1}}{\binom{N-1}{N-1}}$	3-8
Poisson	$\frac{e^{-\lambda} \lambda^x}{x!}, x = 0, 1, 2, \dots, 0 < \lambda$	λ	λ	3-9
Continuous				
Uniform	$\frac{1}{b - a}, a \leq x \leq b$	$\frac{(b + a)}{2}$	$\frac{(b - a)^2}{12}$	4-5
Normal	$\frac{1}{\sigma \sqrt{2\pi}} e^{-1/2 (\frac{x-\mu}{\sigma})^2}$ $-\infty < x < \infty, -\infty < \mu < \infty, 0 < \sigma$	μ	σ^2	4-6
Exponential	$\lambda e^{-\lambda x}, 0 \leq x, 0 < \lambda$	$1/\lambda$	$1/\lambda^2$	4-8
Erlang	$\frac{\lambda^r x^{r-1} e^{-\lambda x}}{(r - 1)!}, 0 < x, r = 1, 2, \dots$	r/λ	r/λ^2	4-9.1
Gamma	$\frac{\lambda^r x^{r-1} e^{-\lambda x}}{\Gamma(r)}, 0 < x, 0 < r, 0 < \lambda$	r/λ	r/λ^2	4-9.2

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.500000	0.503989	0.507978	0.511967	0.515953	0.519939	0.523922	0.527903	0.531881	0.535856
0.1	0.539828	0.543795	0.547758	0.551717	0.555670	0.559618	0.563559	0.567495	0.571424	0.575345
0.2	0.579260	0.583166	0.587064	0.590954	0.594835	0.598706	0.602568	0.606420	0.610261	0.614092
0.3	0.617911	0.621719	0.625516	0.629300	0.633072	0.636831	0.640576	0.644309	0.648027	0.651732
0.4	0.655422	0.659097	0.662757	0.666402	0.670031	0.673645	0.677242	0.680822	0.684386	0.687933
0.5	0.691462	0.694974	0.698468	0.701944	0.705401	0.708840	0.712260	0.715661	0.719043	0.722405
0.6	0.725747	0.729069	0.732371	0.735653	0.738914	0.742154	0.745373	0.748571	0.751748	0.754903
0.7	0.758036	0.761148	0.764238	0.767305	0.770350	0.773373	0.776373	0.779350	0.782305	0.785236
0.8	0.788145	0.791030	0.793892	0.796731	0.799546	0.802338	0.805106	0.807850	0.810570	0.813267
0.9	0.815940	0.818589	0.821214	0.823815	0.826391	0.828944	0.831472	0.833977	0.836457	0.838913
1.0	0.841345	0.843752	0.846136	0.848495	0.850830	0.853141	0.855428	0.857690	0.859929	0.862143
1.1	0.864334	0.866500	0.868643	0.870762	0.872857	0.874928	0.876976	0.878999	0.881000	0.882977
1.2	0.884930	0.886860	0.888767	0.890651	0.892512	0.894350	0.896165	0.897958	0.899727	0.901475
1.3	0.903199	0.904902	0.906582	0.908241	0.909877	0.911492	0.913085	0.914657	0.916207	0.917736
1.4	0.919243	0.920730	0.922196	0.923641	0.925066	0.926471	0.927855	0.929219	0.930563	0.931888
1.5	0.933193	0.934478	0.935744	0.936992	0.938220	0.939429	0.940620	0.941792	0.942947	0.944083
1.6	0.945201	0.946301	0.947384	0.948449	0.949497	0.950529	0.951543	0.952540	0.953521	0.954486
1.7	0.955435	0.956367	0.957284	0.958185	0.959071	0.959941	0.960796	0.961636	0.962462	0.963273
1.8	0.964070	0.964852	0.965621	0.966375	0.967116	0.967843	0.968557	0.969258	0.969946	0.970621
1.9	0.971283	0.971933	0.972571	0.973197	0.973810	0.974412	0.975002	0.975581	0.976148	0.976705
2.0	0.977250	0.977784	0.978308	0.978822	0.979325	0.979818	0.980301	0.980774	0.981237	0.981691
2.1	0.982136	0.982571	0.982997	0.983414	0.983823	0.984222	0.984614	0.984997	0.985371	0.985738
2.2	0.986097	0.986447	0.986791	0.987126	0.987455	0.987776	0.988089	0.988396	0.988696	0.988989
2.3	0.989276	0.989556	0.989830	0.990097	0.990358	0.990613	0.990863	0.991106	0.991344	0.991576
2.4	0.991802	0.992024	0.992240	0.992451	0.992656	0.992857	0.993053	0.993244	0.993431	0.993613
2.5	0.993790	0.993963	0.994132	0.994297	0.994457	0.994614	0.994766	0.994915	0.995060	0.995201
2.6	0.995339	0.995473	0.995604	0.995731	0.995855	0.995975	0.996093	0.996207	0.996319	0.996427
2.7	0.996533	0.996636	0.996736	0.996833	0.996928	0.997020	0.997110	0.997197	0.997282	0.997365
2.8	0.997445	0.997523	0.997599	0.997673	0.997744	0.997814	0.997882	0.997948	0.998012	0.998074
2.9	0.998134	0.998193	0.998250	0.998305	0.998359	0.998411	0.998462	0.998511	0.998559	0.998605
3.0	0.998650	0.998694	0.998736	0.998777	0.998817	0.998856	0.998893	0.998930	0.998965	0.998999
3.1	0.999032	0.999065	0.999096	0.999126	0.999155	0.999184	0.999211	0.999238	0.999264	0.999289
3.2	0.999313	0.999336	0.999359	0.999381	0.999402	0.999423	0.999443	0.999462	0.999481	0.999499
3.3	0.999517	0.999533	0.999550	0.999566	0.999581	0.999596	0.999610	0.999624	0.999638	0.999650
3.4	0.999663	0.999675	0.999687	0.999698	0.999709	0.999720	0.999730	0.999740	0.999749	0.999758
3.5	0.999767	0.999776	0.999784	0.999792	0.999800	0.999807	0.999815	0.999821	0.999828	0.999835
3.6	0.999841	0.999847	0.999853	0.999858	0.999864	0.999869	0.999874	0.999879	0.999883	0.999888
3.7	0.999892	0.999896	0.999900	0.999904	0.999908	0.999912	0.999915	0.999918	0.999922	0.999925
3.8	0.999928	0.999931	0.999933	0.999936	0.999938	0.999941	0.999943	0.999946	0.999948	0.999950
3.9	0.999952	0.999954	0.999956	0.999958	0.999959	0.999961	0.999963	0.999964	0.999966	0.999967

What may be on the exam?

- Bayes Theorem
- Discrete & Continuous Random Variables
- Joint Probability Distributions, Covariance/Correlations
- Confidence Intervals
- Hypothesis testing
- Other topics
- Look at Homeworks 1-4 for examples of problems

Hypothesis testing

3. (8 points) The college bookstore tells prospective students that the average cost of its textbooks is \$52 with a standard deviation of \$4.50. A group of statistics students think that the average cost is actually higher. In order to test bookstore's claim against this alternative hypothesis, the students bought a random sample of 100 books. The mean price of this sample was \$52.80. Perform the hypothesis test at the 5% level of significance and state your decision.

What type of hypothesis should I apply?

- A. Two-sided: $\mu_1 \neq \mu_0$
- B. One-sided: $\mu_1 > \mu_0$
- C. One-sided: $\mu_1 < \mu_0$
- D. Three-sided
- E. I have no idea

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The standard deviation of \bar{x} in this sample is:

A. \$4.50

B. \$45

C. \$0.45

D. I have no idea

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3. (8 points) The college bookstore tells prospective students that the average cost of its textbooks is \$52 with a standard deviation of \$4.50. A group of statistics students think that the average cost is actually higher. In order to test bookstore's claim against this alternative hypothesis, the students bought a random sample of 100 books. The mean price of this sample was \$52.80. Perform the hypothesis test at the 5% level of significance and state your decision.

3. (8 points) The college bookstore tells prospective students that the average cost of its textbooks is \$52 with a standard deviation of \$4.50. A group of statistics students think that the average cost is actually higher. In order to test bookstore's claim against this alternative hypothesis, the students bought a random sample of 100 books. The mean price of this sample was \$52.80. Perform the hypothesis test at the 5% level of significance and state your decision.

Answer: Hypothesis: $\begin{cases} H_0 : \mu = 52 \\ H_1 : \mu > 52 \end{cases}$. The critical z-value can be obtained from $z^* = \frac{52.8 - 52}{4.5 / 10} = 1.78$. Since $z^* > z_\alpha = 1.65$, this test statistic lies in the rejection region for H_0 . Thus null hypothesis H_0 will be rejected and alternative hypothesis H_1 is accepted.

Confidence intervals

1. A sample of size 100 which has the sample mean $\bar{X} = 500$ was drawn from a population with an unknown mean μ and the standard deviation $\sigma = 80$.

a) Give the 95% confidence interval for the population mean.

1. A sample of size 100 which has the sample mean $\bar{X} = 500$ was drawn from a population with an unknown mean μ and the standard deviation $\sigma = 80$.

a) Give the 95% confidence interval for the population mean.

Answer: $P(500 - z_{0.025} \frac{80}{\sqrt{100}} < Z < 500 + z_{0.025} \frac{80}{\sqrt{100}}) = 0.95$ where $z_{0.025} = 1.96$.

Therefore, the interval is [484.32, 515.68].

Bayes rule

In answering a question on a multiple-choice test, a student either knows the answer or he guesses. Let $\frac{1}{3}$ be the probability that he knows the answer. If he does not know the answer, he randomly guesses one out of 4 multiple choice questions. What is the conditional probability that a student knew the answer to a question given that he answered it correctly?

A. $\frac{1}{4}$

B. $\frac{1}{3}$

C. $\frac{2}{3}$

D. $\frac{1}{5}$

E. I don't know

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In answering a question on a multiple-choice test, a student either knows the answer or he guesses. Let $1/3$ be the probability that he knows the answer. If he does not know the answer, he randomly guesses one out of 4 multiple choice questions. What is the conditional probability that a student knew the answer to a question given that he answered it correctly?

Answer: $P(K)=1/3$, $P(K')=2/3$, $P(C|K)=1$, $P(C|K')=1/4$.

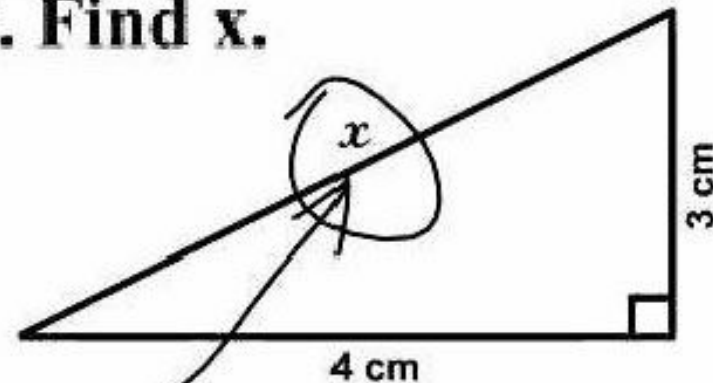
$P(K|C)=P(C|K)*P(K)/P(C)=1*(1/3)/(1*1/3+(1/4)*(2/3))=2/3=0.666\dots$

Discrete Probability Distributions

What is X in this problem?

- What is the random variable: Look for keywords:
 - Find the probability that....
 - What is the mean (or variance) of...
- What are parameters? Look for keywords:
 - Given that...
 - Assuming that...

3. Find x.



Here it is

Guide to probability distributions

- Binomial: # of samples, n , is fixed, # of successes, x , is variable

$$P(X=x) = \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x}$$

- Geometric: # of samples, x is variable. # of successes 1 is fixed. Success comes in the end

$$P(X=x) = (1-p)^{x-1} \cdot p$$

- Negative binomial: # of samples, x is variable. # of successes, r , is fixed r th success in the end

$$P(X=x) = \frac{(x-1)!}{(r-1)!(x-r)!} p^r (1-p)^{x-r}$$

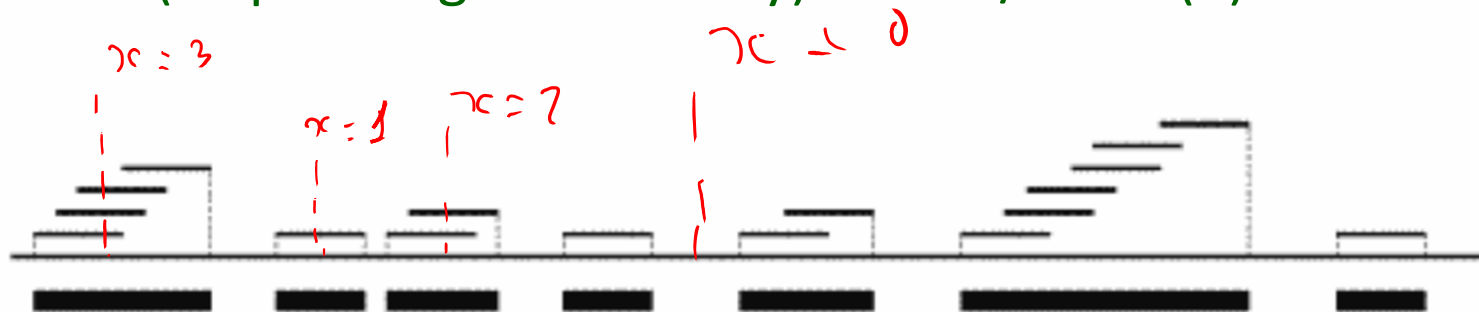
Poisson distribution in genomics

- G - genome length (in bp)
- L - short read average length
- N - number of short read sequenced
- λ - sequencing redundancy = LN/G
- x - number of short reads covering a given site on the genome

$$P(x) = \frac{\lambda^x e^{-\lambda}}{x!}$$

Ewens, Grant, Chapter 5.1

Poisson as a limit of Binomial. For a given site on the genome for each short read Prob(site covered): $p=L/G$ is very small. Number of attempts (short reads): N is very large. Their product (sequencing redundancy): $\lambda = NL/G$ is $O(1)$.



Probability that a base pair in the genome is not covered by any short reads is 0.1

One randomly selects base pairs until exactly 5 uncovered base pairs are found.

Which discrete probability distribution describes the number of attempts?

- A. Poisson
- B. Binomial
- C. Geometric
- D. Negative Binomial**
- E. I have no idea

Poisson	$\frac{e^{-\lambda} \lambda^x}{x!}, x = 0, 1, 2, \dots, 0 < \lambda$
Binomial	$\binom{n}{x} p^x (1-p)^{n-x}$ $x = 0, 1, \dots, n, 0 \leq p \leq 1$
Geometric	$(1-p)^{x-1} p$ $x = 1, 2, \dots, 0 \leq p \leq 1$
Negative binomial	$\binom{x-1}{r-1} (1-p)^{x-r} p^r$ $x = r, r+1, r+2, \dots, 0 \leq p \leq 1$

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Probability that a base pair in the genome is not covered by any short reads is 0.1

One randomly selects base pairs until exactly 5 uncovered base pairs are found.

What are the values of p , r ?

- A. $p=0.5, r=5$
- B. $p=0.1, r=0.5$
- C. $p=0.1, r=5$
- D. $p=0.5, r=0.1$
- E. I have no idea

Poisson	$\frac{e^{-\lambda} \lambda^x}{x!}, x = 0, 1, 2, \dots, 0 < \lambda$
Binomial	$\binom{n}{x} p^x (1-p)^{n-x}$ $x = 0, 1, \dots, n, 0 \leq p \leq 1$
Geometric	$(1-p)^{x-1} p$ $x = 1, 2, \dots, 0 \leq p \leq 1$
Negative binomial	$\binom{x-1}{r-1} (1-p)^{x-r} p^r$ $x = r, r+1, r+2, \dots, 0 \leq p \leq 1$

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Cancer happens when the gene p53 mutates.

Probability of p53 to mutate per year is 5%.

How many years before a patient gets disease?

Which discrete probability distribution
would you use to answer?

A. Poisson

B. Binomial

C. Geometric

D. Negative Binomial

E. I have no idea

Poisson	$\frac{e^{-\lambda} \lambda^x}{x!}, x = 0, 1, 2, \dots, 0 < \lambda$
Binomial	$\binom{n}{x} p^x (1-p)^{n-x}$ $x = 0, 1, \dots, n, 0 \leq p \leq 1$
Geometric	$(1-p)^{x-1} p$ $x = 1, 2, \dots, 0 \leq p \leq 1$
Negative binomial	$\binom{x-1}{r-1} (1-p)^{x-r} p^r$ $x = r, r+1, r+2, \dots, 0 \leq p \leq 1$

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Continuous Probability Distributions

2. (8 points) The length of stay at a specific emergency department in Phoenix, Arizona, in 2009 had a mean of 4.6 hours with a standard deviation of 2.9. Assume that the length of stay is normally distributed.

(A) (4 points) What is the probability of a length of stay greater than 10 hours?

(B) (4 points) How long does one have to stay in this emergency room to know that approximately 25% of all visits last even longer?

2. (8 points) The length of stay at a specific emergency department in Phoenix, Arizona, in 2009 had a mean of 4.6 hours with a standard deviation of 2.9. Assume that the length of stay is normally distributed.

(A) (4 points) What is the probability of a length of stay greater than 10 hours?

Answer: $(10-4.6)/2.9=1.86$ Using table one finds $\text{Prob}=1-0.9687=0.0313$

(B) (4 points) How long does one have to stay in this emergency room to know that approximately 25% of all visits last even longer?

Answer: Using table one finds $P(Z<0.67)=0.75$ meaning it is $4.6+2.9*0.67=6.543$

WHY ARE THERE SLAVES IN THE BIBLE

WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT

Credit: XKCD
comics

QUESTIONS FOUND IN GOOGLE AUTOCOMPLETE



WHY ARE THERE WEEKS IN MAY DO I FEEL DIZZY

WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY ARE THERE MALE AND FEMALE BIKES

WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE VARIOUS PRIETIES
WHY ARE OLD KLINGONS DIFFERENT



WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO AMERICANS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO SOUND ON CNN
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL

WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS

WHY ARE THERE ANTS IN MY LAPTOP

WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN



WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOCKS

WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY

WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD



WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA

WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE



WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG

WHY ARE DOGS AFRAID OF FIREWORKS
WHY IS THERE NO KING IN ENGLAND

Two-sample hypothesis

Mating Calls. In a study of mating calls in the gray treefrogs *Hyla chrysoscelis* and *Hyla versicolor*, Gerhart (1994) reports that in a location in Louisiana the following data on the length of male advertisement calls have been collected:

	Sample size	Average duration	SD of duration	Duration range
<i>Hyla chrysoscelis</i>	43	0.65	0.18	0.36–1.27
<i>Hyla versicolor</i>	12	0.54	0.14	0.36–0.75

The two species cannot be distinguished by external morphology, but *H. chrysoscelis* are diploids while *H. versicolor* are tetraploids. The triploid crosses exhibit high mortality in larval stages, and if they attain sexual maturity, they are sterile. Females responding to the mating calls try to avoid mismatches.

Based on the data summaries provided, test whether the length of call is a discriminatory characteristic? Use $\alpha = 0.05$.

	Sample size	Average duration	SD of duration
<i>Hyla chrysoscelis</i>	43	0.65	0.18
<i>Hyla versicolor</i>	12	0.54	0.14

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<i>Hyla versicolor</i>	12	0.54	0.14

Based on the data summaries provided, test whether the length of call is a discriminatory characteristic? Use $\alpha = 0.05$.

1. Use two-sided hypothesis
2. $z_{\alpha/2}=1.96$
3. $Z=(0.65-0.54)/\sqrt{0.18.^2/43+0.14.^2/12}=2.2516$
4. Since $Z > z_{\alpha/2}$ null hypothesis can be rejected

Continuous probability distributions

Equipment Aging. Suppose that the lifetime T of a particular piece of laboratory equipment (in 1000 hour units) is an exponentially distributed random variable such that $\mathbb{P}(T > 10) = 0.8$.

- (a) Find the “rate” parameter, λ .
- (b) What are the mean and standard deviation of the random variable T ?

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$$\text{PDF: } P(t) = \lambda \exp(-\lambda t)$$

$$\text{Inverse CDF: } P(T > t) = \exp(-\lambda t)$$

$$-\lambda \cdot 10 = \ln(0.8)$$

$$\lambda = 0.0223$$