

**Welcome to Week #8!**

**Foundations for Inference - How well can we really know anything?**

**Last week: Set the Hypothesis**

# Summary: Set the hypothesis

The general outline of the process:

## 1. Set the hypotheses.

For a single mean this will look like:

$$H_0: \mu = \text{null value}$$

$$H_A: \mu < \text{or } > \text{ or } \neq \text{ null value}$$

How do we frame our question into the “null” and “alternative” hypothesis framework? What are these different hypotheses?

## 2. Check assumptions and conditions

## 3. Calculate a test statistic and a p-value

## 4. Make a decision, and interpret it in context

- If  $p\text{-value} < \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If  $p\text{-value} > \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

# Summary: Set the hypothesis

The general outline of the process:

1. Set the hypotheses.

For a single mean this will look like:

$H_0: \mu = \text{null value}$

$H_A: \mu < \text{or} > \text{or} \neq \text{null value}$

**tell us something about  
what tests we will perform  
(more in examples)**

2. Check assumptions and conditions

3. Calculate a test statistic and a p-value

4. Make a decision, and interpret it in context

- If p-value  $< \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If p-value  $> \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

# Summary: Set the hypothesis

The general outline of the process:

1. Set the hypotheses.

For a single mean this will look like:

$H_0: \mu = \text{null value}$

$H_A: \mu < \text{or } > \text{ or } \neq \text{ null value}$

2. Check assumptions and conditions

3. Calculate a test statistic and a p-value

4. Make a decision, and interpret it in context

- If p-value  $< \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If p-value  $> \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

Are we interested in a hypothesis about the population mean ( $\mu$ )?

Proportion (p)? (Ch. 5)

Difference of 2 means and/or paired data  
( $\mu_1 - \mu_2$ )? (Ch. 7)

Difference between observations and theorized results? (Ch. 6)  
(more in examples)

# Hypothesis Testing: Where we are going

The general outline of the process:

1. Set the hypotheses.

For a single mean this will look like:

$H_0: \mu = \text{null value}$

$H_A: \mu < \text{or } > \text{ or } \neq \text{null value}$

2. Check assumptions and conditions

3. Calculate a test statistic and a p-value

4. Make a decision, and interpret it in context

- If p-value  $< \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If p-value  $> \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

**Picking appropriate distributions and applying - Rest of Ch 5, and 6 & 7**

# Hypothesis Testing: Where we are going

The general outline of the process:

1. Set the hypotheses.

For a single mean this will look like:

$H_0: \mu = \text{null value}$

$H_A: \mu < \text{or } > \text{ or } \neq \text{ null value}$

2. Check assumptions and conditions

3. Calculate a test statistic and a p-value

4. Make a decision, and interpret it in context

- If p-value  $< \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If p-value  $> \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

(a) normal, large sample

(b) normal?, small sample

(c) observations & theory

## Test Statistics

(a) Z-score  $\rightarrow P(Z)$

(b) T-Score  $\rightarrow P(T)$

(c)  $\chi^2 \rightarrow P(\chi^2)$



# Hypothesis Testing: Where we are going

The general outline of the process:

1. Set the hypotheses.

For a single mean this will look like:

$H_0: \mu = \text{null value}$

$H_A: \mu < \text{or } > \text{ or } \neq \text{ null value}$

2. Check assumptions and conditions

3. Calculate a test statistic and a p-value

4. Make a decision, and interpret it in context

- If  $p\text{-value} < \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If  $p\text{-value} > \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

## Test Statistics

(a) Z-score  $\rightarrow P(Z)$

(b) T-Score  $\rightarrow P(T)$

(c)  $\chi^2 \rightarrow P(\chi^2)$

Compare Z-score, T-score or  $\chi^2$  to our level of significance -  $\alpha$  - to see if we can reject the null hypothesis (if the p-value of our test statistic  $< \alpha$ )

# Anatomy of a test statistic

The general form of a test statistic is

Only tricks are:  
(1) picking what the point and null values are based on our hypotheses

$$\frac{\text{point estimate} - \text{null value}}{\text{SE of point estimate}}$$

(2) what the form of the standard errors is based on what our underlying distribution looks like (normal, t-distribution,  $\chi^2$ )

This construction is based on

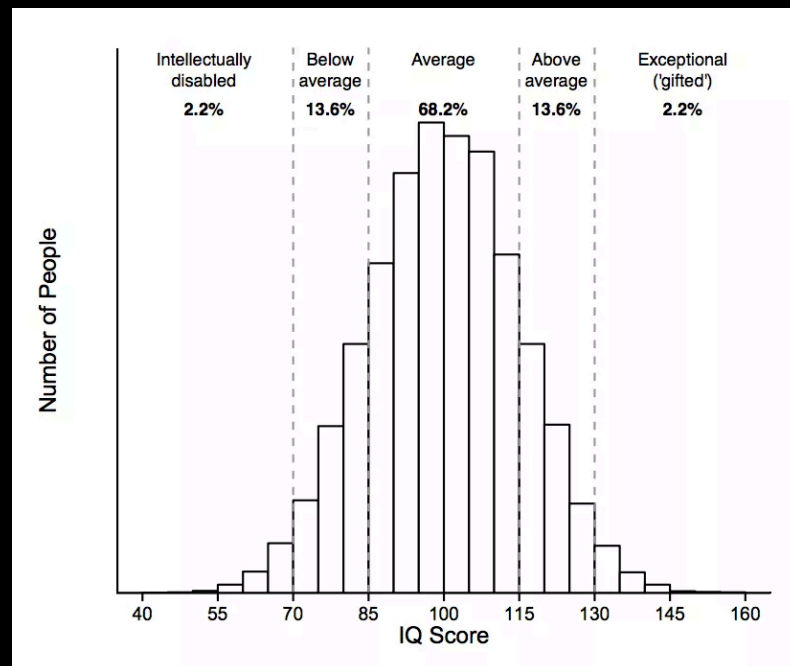
- identifying the difference between a point estimate and an expected value if the null hypothesis was true, and
- standardizing that difference using the standard error of the point estimate.

These two ideas will help in the construction of an appropriate test statistic for count data.

**Examples!**

# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



**Step 1: Write down Null & Alternative Hypotheses**

The “default” or “previously assumed” claim is the null hypothesis

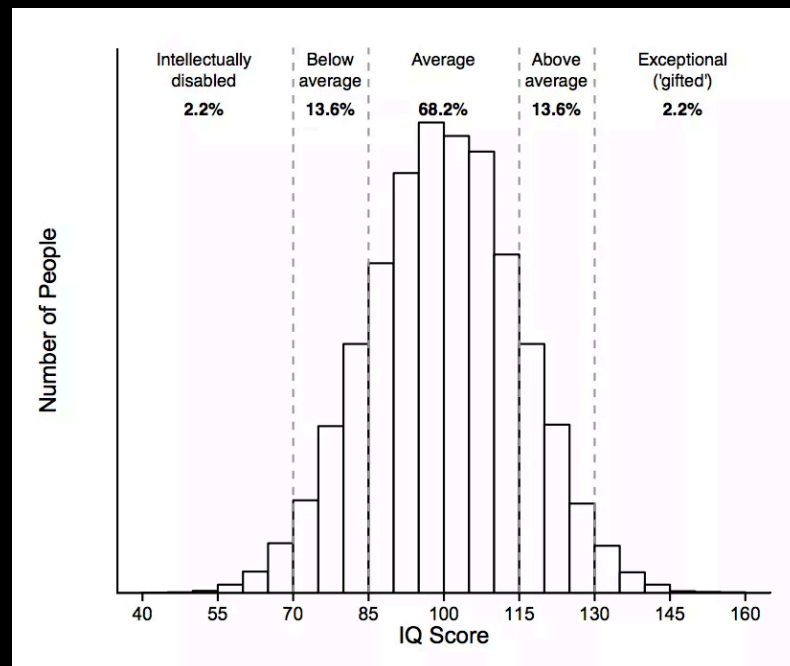
The alternative hypothesis is the claim to be tested

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



**Step 1: Write down Null & Alternative Hypotheses**

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

**Step 2: Write down assumptions & conditions about the underlying population distribution**

# Key Insights about how well we know the “average” number representing a sample:

Lets say we want to know the average observation from a random sample taken from a population (usually the case, very rarely can we sample the entirety of the population):

- \*IF\* the samples are independent (e.g. randomly sampled)
  - \*IF\* the sample size is “large enough” (typically > 30 observations)
  - \*IF\* the underlying population distribution is not strongly skewed
- This is admittedly a bit “hand-wavy” and not rigorous (stay tuned for your future stats classes!)**

THEN

1. The “average” value of this population mean is the sample mean
2. The error on the measurement of the mean is given by the “standard error”:

$SE = s/n^{1/2}$  **If you are curious, this comes from:**

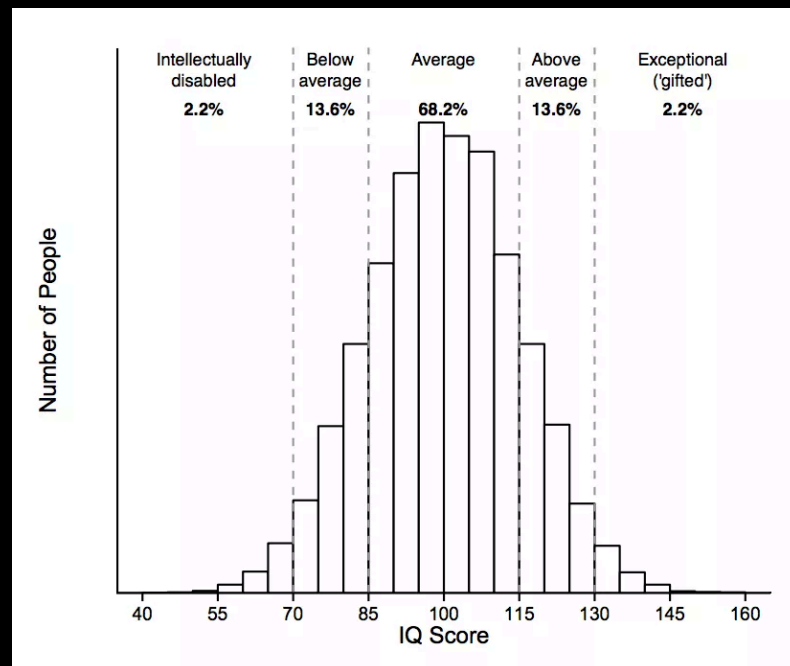
$$\text{Var}(\frac{1}{n} \sum X_i) = \frac{1}{n^2} \sum \text{Var}(X_i) = \frac{1}{n^2} \times \sum \sigma^2 = \frac{n}{n^2} \sigma^2 = \frac{\sigma^2}{n}$$

Where “s” is the standard deviation of the sample & n is the number of samples

In practice we have to assume “s” is the standard deviation of the *sample*.

# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



## Step 1: Write down Null & Alternative Hypotheses

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

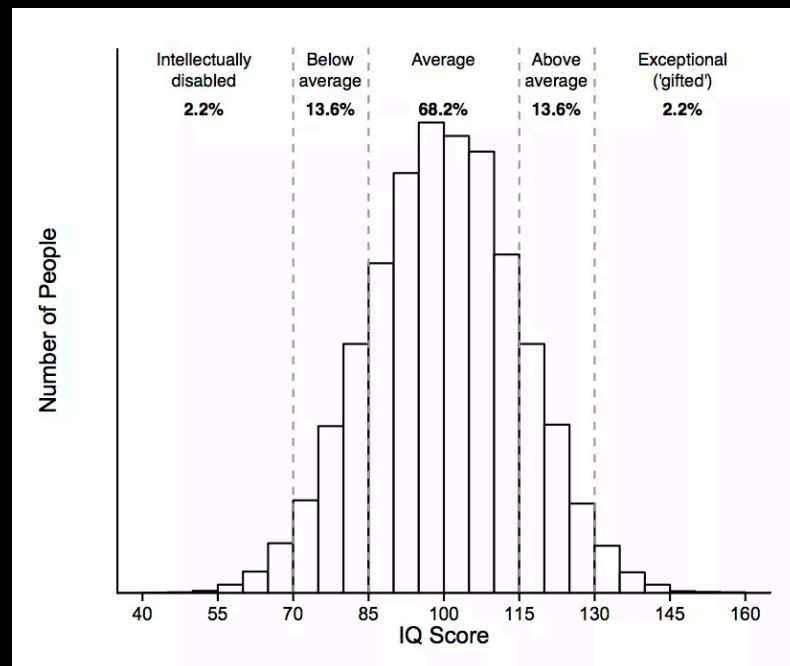
## Step 2: Write down assumptions & conditions about the underlying population distribution

1. # of samples  $> 30$
2. no evidence of strong skew
3. assume independent samples

use normal distribution,  
test statistic will be a Z-score

# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



**Step 1: Write down Null & Alternative Hypotheses**

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

**Step 2: Write down assumptions & conditions about the underlying population distribution**

use normal distribution, test statistic will be a Z-score

**Step 3.1: Calculate test statistic**

$$Z = (\text{point estimate} - \text{null value}) / SE$$

$$SE = SD / n^{1/2}$$

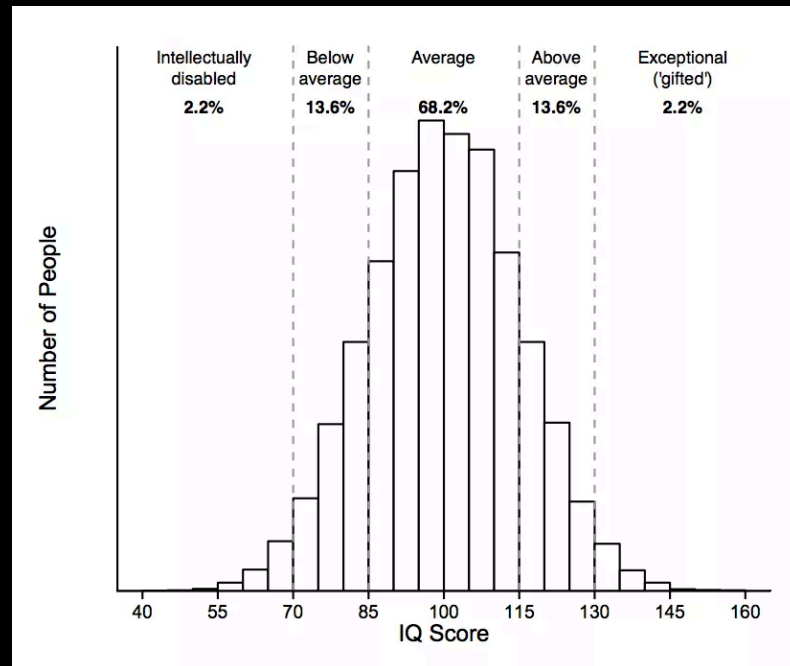
1. point estimate = sample mean = 105
2. null value = population mean = 100
3. SD = 15
4. n = 30

$$Z = (105 - 100) / (15 / 30^{1/2}) = 1.83$$



# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



**Step 1: Write down Null & Alternative Hypotheses**

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

**Step 2: Write down assumptions & conditions about the underlying population distribution**

use normal distribution, test statistic will be a Z-score

**Step 3.1: Calculate test statistic**

$$Z = (\text{point estimate} - \text{null value}) / \text{SE} : Z = (105 - 100) / (15 / 30^{1/2}) = 1.83$$

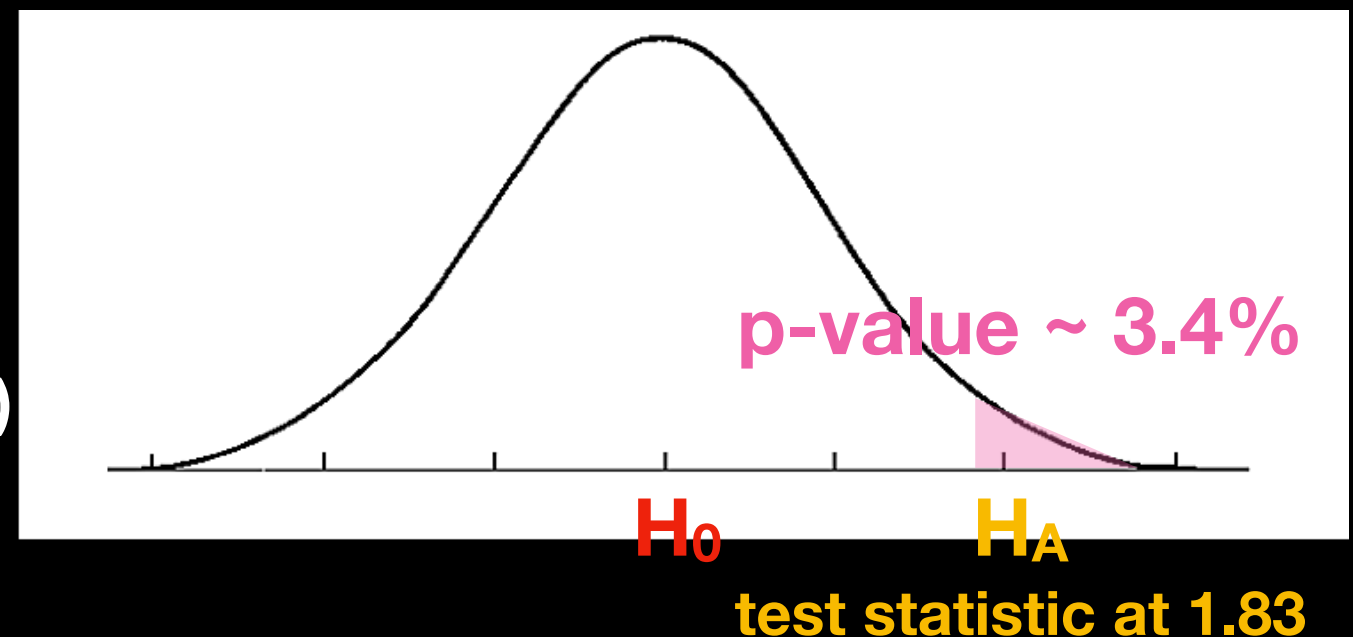
**Step 3.2: Calculate p-value**

$$\text{p-value} = 1 - \text{pnorm}(1.83)$$

OR

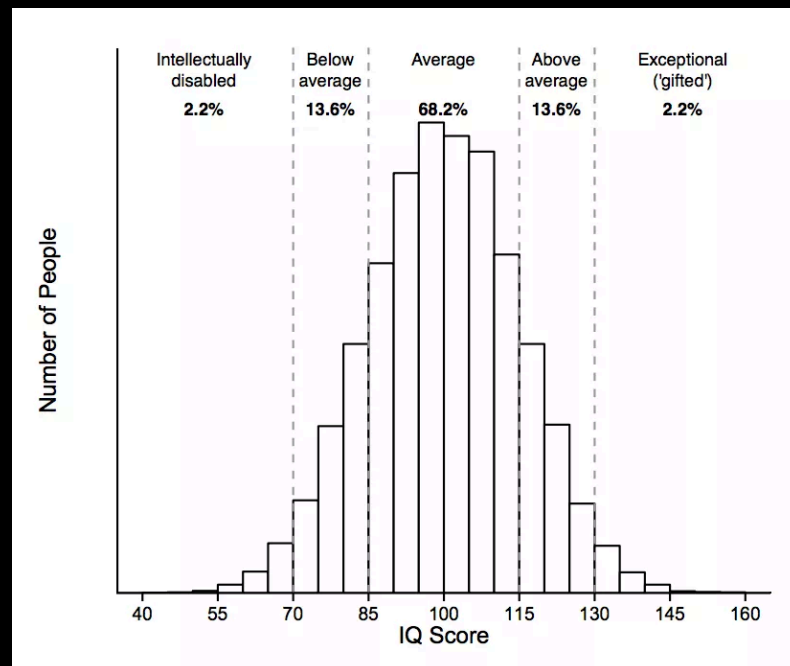
$$\text{p-value} =$$

$$1 - \text{pnorm}(105, \text{mean}=100, \text{sd}=15/30^{**}0.5)$$



# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



**Step 1: Write down Null & Alternative Hypotheses**

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

**Step 2: Write down assumptions & conditions about the underlying population distribution**

use normal distribution, test statistic will be a Z-score

**Step 3.1: Calculate test statistic**

$$Z = (\text{point estimate} - \text{null value}) / \text{SE} : Z = (105 - 100) / (15 / 30^{1/2}) = 1.83$$

**Step 3.2: Calculate p-value**

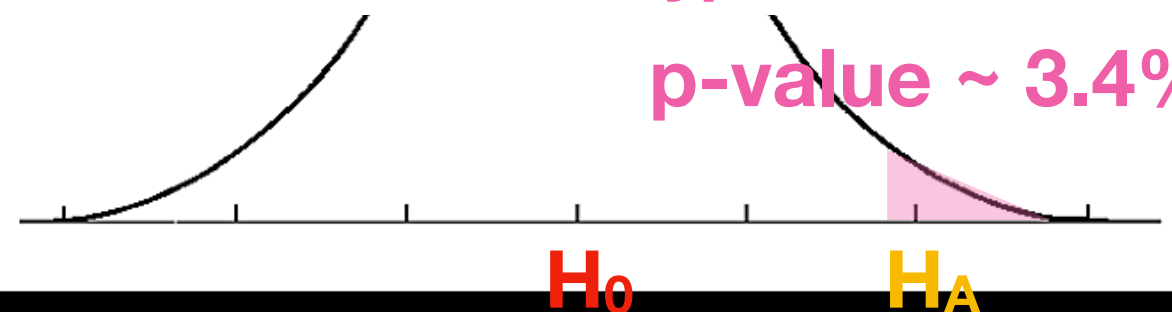
$$\text{p-value} = 1 - \text{pnorm}(1.83)$$

OR

$$\text{p-value} =$$

$$1 - \text{pnorm}(105, \text{mean}=100, \text{sd}=15/30^{**}0.5)$$

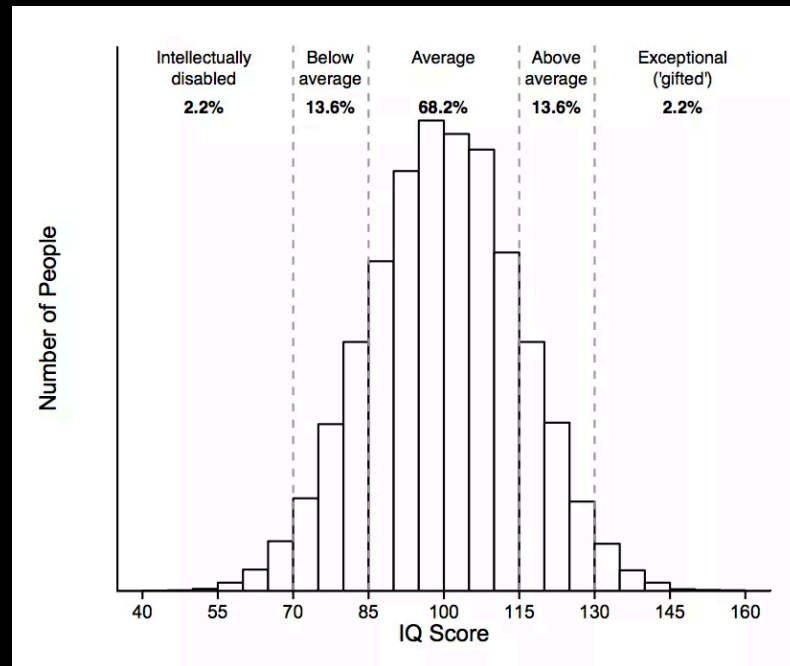
“how likely is it that the measurement I have is by chance given that the underlying distribution follows what I assumed in the null hypothesis”



test statistic at 1.83

# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



## Step 1: Write down Null & Alternative Hypotheses

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

NOTE: one sided

(right handed) test!

## Step 2: Write down assumptions & conditions about the underlying population distribution

use normal distribution, test statistic will be a Z-score

## Step 3.1: Calculate test statistic

$$Z = (\text{point estimate} - \text{null value}) / \text{SE} : Z = (105 - 100) / (15 / 30^{1/2}) = 1.83$$

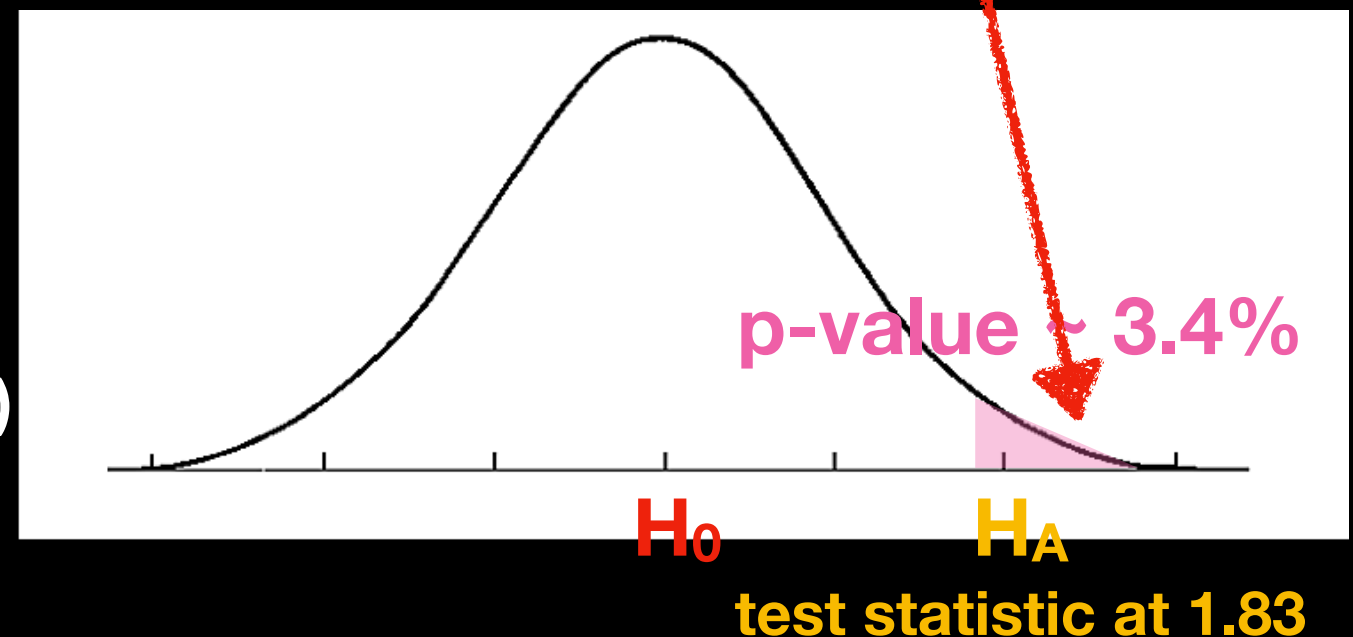
## Step 3.2: Calculate p-value

$$\text{p-value} = 1 - \text{pnorm}(1.83)$$

OR

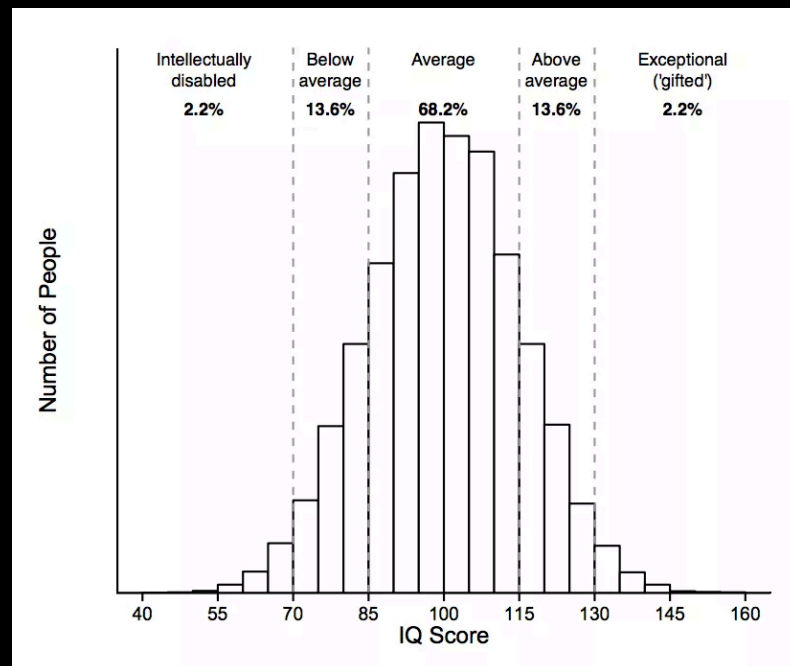
$$\text{p-value} =$$

$$1 - \text{pnorm}(105, \text{mean}=100, \text{sd}=15/30^{**}0.5)$$



# Practice #1

A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



**Step 1: Write down Null & Alternative Hypotheses**

$$H_0: \mu_{\text{students}} \leq 100$$

$$H_A: \mu_{\text{students}} > 100$$

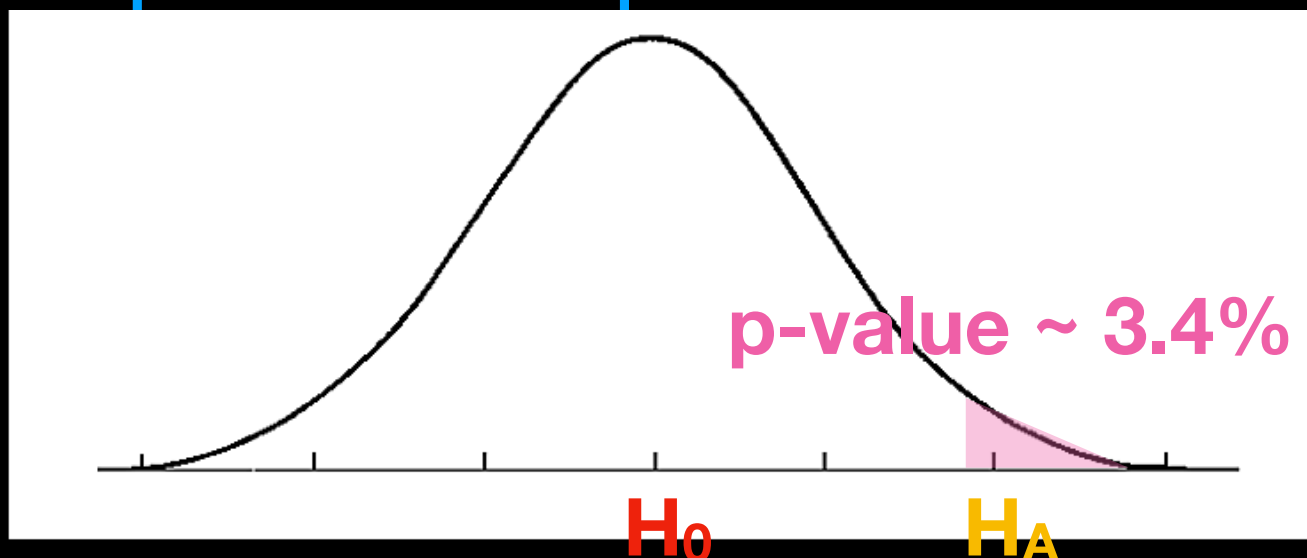
**Step 2: Write down assumptions & conditions about the underlying population distribution**

use normal distribution, test statistic will be a Z-score

**Step 3.1: Calculate test statistic**

$$Z = (\text{point estimate} - \text{null value}) / \text{SE} : Z = (105 - 100) / (15 / 30^{1/2}) = 1.83$$

**Step 3.2: Calculate p-value**



**Step 4: Compare p-value to level of significance & conclude**

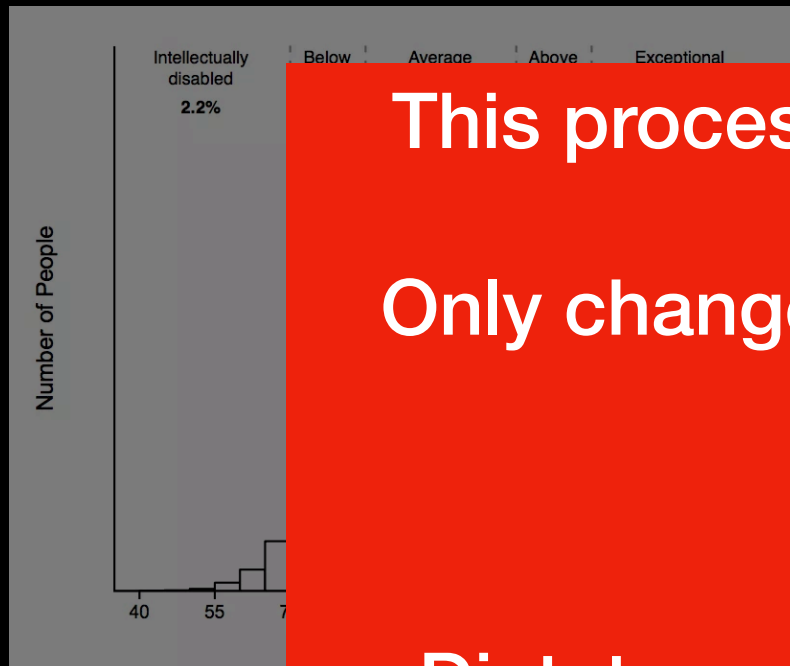
$\alpha = 0.05$  (typical, unless otherwise specified)

$$0.034 < 0.05$$

so we say we reject the null hypothesis, and there is evidence that the students in the school have above average intelligence

# Practice #1

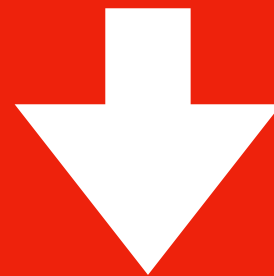
A principle at a certain school claims that the students in his school are above average intelligence. A random sample of 30 students' IQ scores have a mean score of 105. Is there sufficient evidence to support the principle's claims (ignoring the inherent biases in IQ tests)? The mean population IQ is 100 with a standard deviation of 15.



Step 1: Write down Null & Alternative Hypotheses

This processes is essentially all we do in Ch. 5, 6 & 7

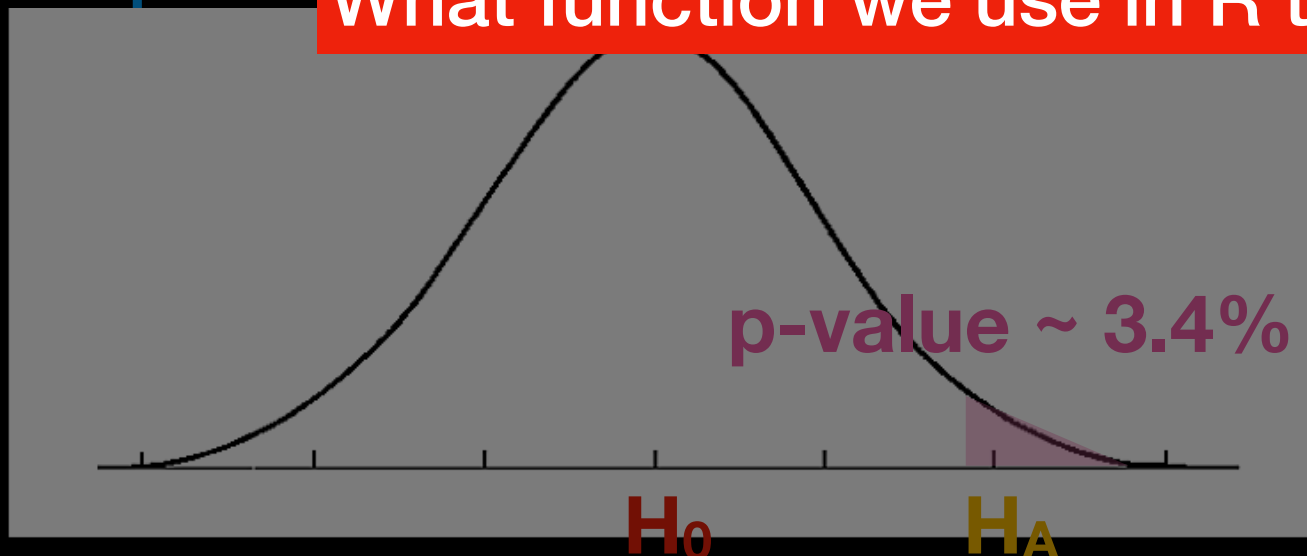
Only changes are what distribution we use (in Step 2)



Dictates what test statistic we calculate in Step 3.1  
&

What function we use in R to calculate p-value in Step 3.2

Step 3.2:



$\alpha = 0.05$  (typical, unless otherwise specified)

$$0.034 < 0.05$$

so we say we reject the null hypothesis,  
and there is evidence that the students in  
the school have above average intelligence

# Practice #2

The administrator at your local hospital states that on weekends the average wait time for emergency room visits is at most 10 minutes. Based on discussions you have had with friends who have complained on how long they waited to be seen in the ER over a weekend, you dispute the administrator's claim. You decide to test your hypothesis. Over the course of a few weekends you record the wait time for 40 randomly selected patients. The average wait time for these 40 patients is 11 minutes with a standard deviation of 3 minutes. Do you have enough evidence to support your hypothesis that the average ER wait time exceeds 10 minutes? You opt to conduct the test at a 5% level of significance.

**Step 1: Write down Null & Alternative Hypotheses**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**

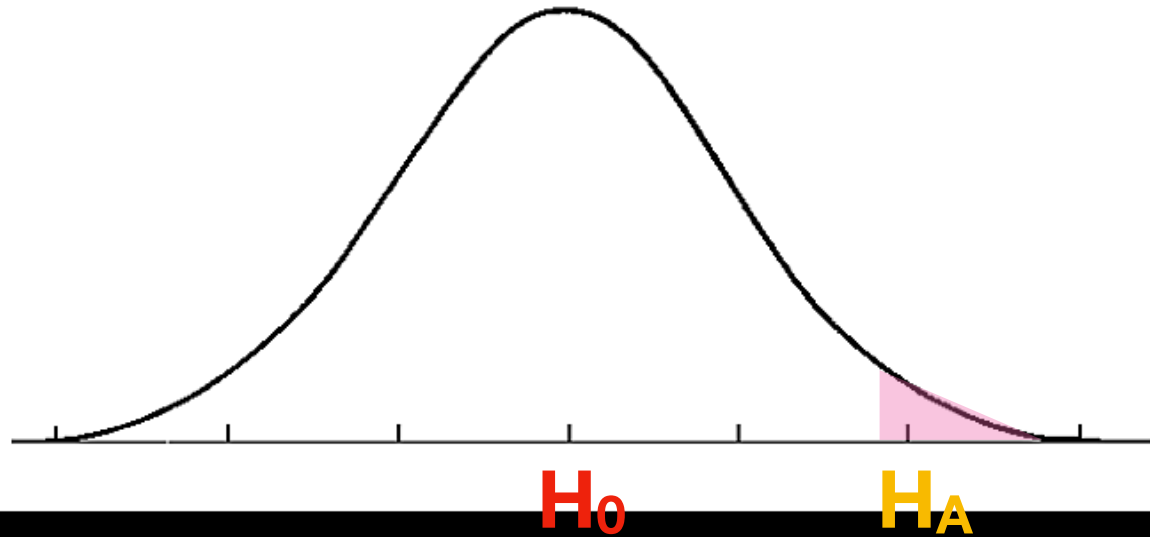
**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**

# Practice #2 & #2.5

$H_0: \mu_{\text{wait}} \leq 10 \text{ min}$

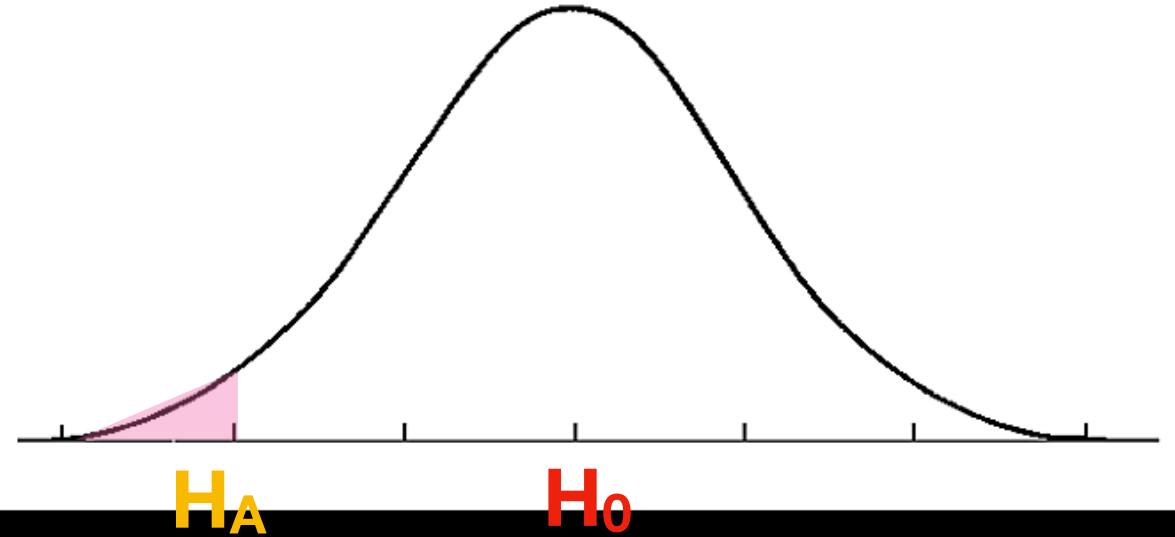
$H_A: \mu_{\text{wait}} > 10 \text{ min}$



“right tailed test”

$H_0: \mu_{\text{wait}} \geq 10 \text{ min}$

$H_A: \mu_{\text{wait}} < 10 \text{ min}$



“left tailed test”



# Practice #2.75

## What changes?

The administrator at your local hospital states that on weekends the average wait time for emergency room **is exactly 10 minutes**. Based on discussions you have had with friends who have **mentioned it often does not take 10 minutes** to be seen in the ER over a weekend, you dispute the administrator's claim. You decide to test your hypothesis. Over the course of a few weekends you record the wait time for 40 randomly selected patients. The average wait time for these 40 patients is **9** minutes with a standard deviation of 3 minutes. Do you have enough evidence to support your hypothesis that the average ER wait time **is not 10 minutes**? You opt to conduct the test at a 5% level of significance.

**Step 1: Write down Null & Alternative Hypotheses**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**

**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**



# Practice #2.75

## What changes?

The administrator at your local hospital states that on weekends the average wait time for emergency room **is exactly 10 minutes**. Based on discussions you have had with friends who have **mentioned it often does not take 10 minutes** to be seen in the ER over a weekend, you dispute the administrator's claim. You decide to test your hypothesis. Over the course of a few weekends you record the wait time for 40 randomly selected patients. The average wait time for these 40 patients is **9** minutes with a standard deviation of 3 minutes. Do you have enough evidence to support your hypothesis that the average ER wait time **is not 10 minutes**? You opt to conduct the test at a 5% level of significance.

**Step 1: Write down Null & Alternative Hypotheses**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**      **Think on it for a moment!**

**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**

# Practice #2.75

## What changes?

The administrator at your local hospital states that on weekends the average wait time for emergency room **is exactly 10 minutes**. Based on discussions you have had with friends who have **mentioned it often does not take 10 minutes** to be seen in the ER over a weekend, you dispute the administrator's claim. You decide to test your hypothesis. Over the course of a few weekends you record the wait time for 40 randomly selected patients. The average wait time for these 40 patients is **9** minutes with a standard deviation of 3 minutes. Do you have enough evidence to support your hypothesis that the average ER wait time **is not 10 minutes**? You opt to conduct the test at a 5% level of significance.

**Step 1: Write down Null & Alternative Hypotheses**  $H_0: \mu_{\text{wait}} = 10 \text{ min}$   
 $H_A: \mu_{\text{wait}} \neq 10 \text{ min}$

**Step 2: Write down assumptions & conditions about underlying population distribution**  
Assume normality, independence, #samples > 30

**Step 3.1: Calculate test statistic**

$$Z = (\text{point estimate} - \text{null value}) / \text{SE} : Z = (9 - 10) / (3/40^{1/2}) = -2.11$$

**Step 3.2: Calculate p-value**

$$\text{p-value} = 2 \times \text{pnorm}(-2.11) = 2 \times 0.018 = 0.035$$

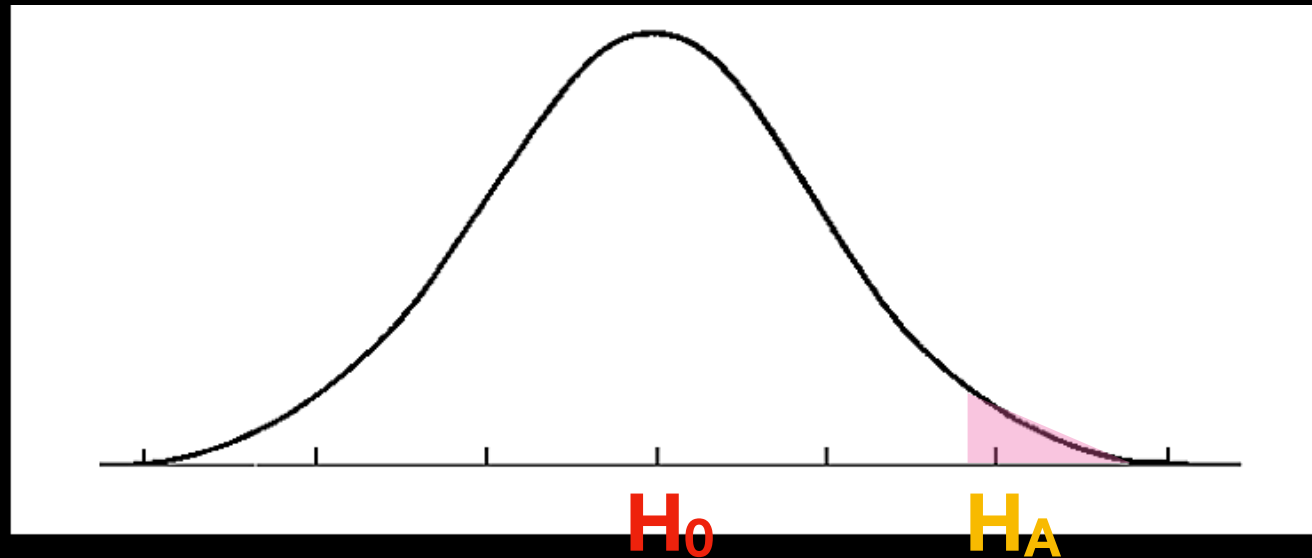
**Step 4: Compare p-value to level of significance & conclude**

$0.035 < 0.05$  so we can reject the null hypothesis and say that it is likely the wait time is **NOT** exactly 10 minutes on average

# Practice #2 & #2.5 & #2.75

$H_0: \mu_{\text{wait}} \leq 10 \text{ min}$

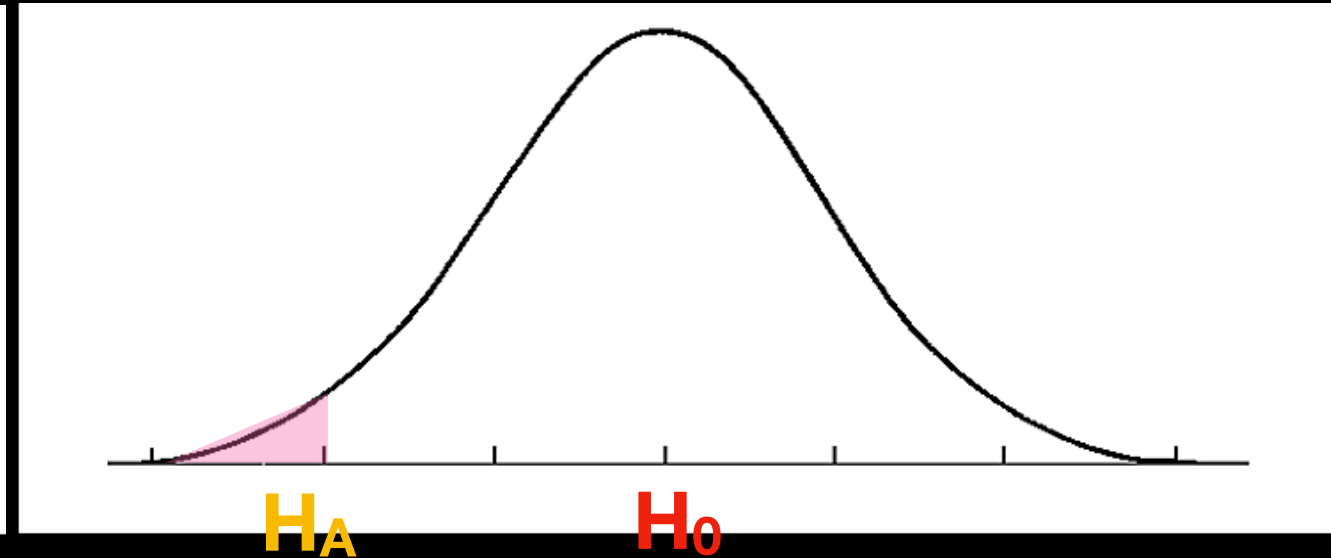
$H_A: \mu_{\text{wait}} > 10 \text{ min}$



“right tailed test”

$H_0: \mu_{\text{wait}} \geq 10 \text{ min}$

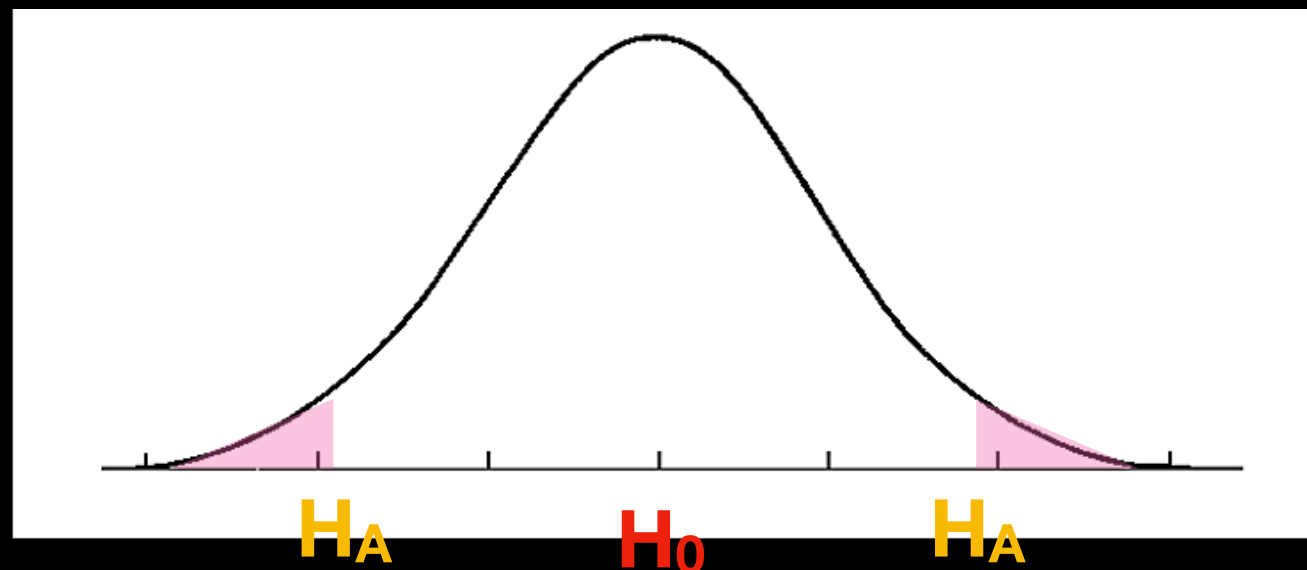
$H_A: \mu_{\text{wait}} < 10 \text{ min}$



“left tailed test”

$H_0: \mu_{\text{wait}} = 10 \text{ min}$

$H_A: \mu_{\text{wait}} \neq 10 \text{ min}$



“two tailed test”

# Practice #3

Is there a difference in serum uric acid levels between populations with and without Down's syndrome? A dataset from individuals without Down's syndrome has a sample mean of  $\bar{x}_1 = 4.5$  and standard deviation  $SD_1 = 1$  for a sample of 35 individuals. The dataset from individuals with Down's syndrome has a sample mean of  $\bar{x}_2 = 3.5$  and standard deviation  $SD_2 = 1.5$  for a sample of 45 individuals.

**Step 1: Write down Null & Alternative Hypotheses**

**What do these look like?**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**

**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**

# Practice #4

An e-commerce research company claims that 60% or more graduate students have bought merchandise on-line. A consumer group is suspicious of the claim and thinks that the proportion is lower than 60%. A random sample of 80 graduate students show that only 22 students have ever done so. Is there enough evidence to show that the true proportion is lower than 60%? Conduct the test at a 0.05 level of significance.

**Step 1: Write down Null & Alternative Hypotheses**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**

**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**

# Practice #4

An e-commerce research company claims that 60% or more graduate students have bought merchandise on-line. A consumer group is suspicious of the claim and thinks that the proportion is lower than 60%. A random sample of 80 graduate students show that only 22 students have ever done so. Is there enough evidence to show that the true proportion is lower than 60%? Conduct the test at a 0.05 level of significance.

**Step 1: Write down Null & Alternative Hypotheses**

**Think on it!**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**

**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**

# Hypothesis Testing Framework (Ch. 4-6)

The general outline of the process:

1. Set the hypotheses.

For a single mean this will look like:

$H_0: \mu = \text{null value}$

$H_A: \mu < \text{or } > \text{ or } \neq \text{ null value}$

2. Check assumptions and conditions

3. Calculate a test statistic and a p-value

4. Make a decision, and interpret it in context

- If p-value  $< \alpha$ , reject  $H_0$ ,  
there is sufficient evidence for  $[H_A]$
- If p-value  $> \alpha$ , do not reject  $H_0$ ,  
there is not sufficient for evidence for  $[H_A]$

**But things can go wrong!**

# Decision errors

Hypothesis tests are not flawless.

In the court system innocent people are sometimes wrongly convicted, and the guilty sometimes walk free.

Similarly, we can make a wrong decision in statistical hypothesis tests as well.

The difference is that we have the tools necessary to quantify how often we make errors in statistics.



# Decision errors (cont.)

There are two competing hypotheses: the null and the alternative. In a hypothesis test, we make a decision about which might be true, but our choice might be incorrect.

		Decision	
		fail to reject $H_0$	reject $H_0$
Truth	$H_0$ true	✓	Type 1 Error
	$H_A$ true	Type 2 Error	✓

A **Type 1 Error** is rejecting the null hypothesis when  $H_0$  is true.

A **Type 2 Error** is failing to reject the null hypothesis when  $H_A$  is true.

We (almost) never know if  $H_0$  or  $H_A$  is true, but we need to consider all possibilities.

# Hypothesis Test as a trial

If we again think of a hypothesis test as a criminal trial then it makes sense to frame the verdict in terms of the null and alternative hypotheses:

$H_0$ : Defendant is innocent

$H_A$ : Defendant is guilty

Which type of error is being committed in the following circumstances?

Declaring the defendant innocent when they are actually guilty

Declaring the defendant guilty when they are actually innocent

		Decision	
		fail to reject $H_0$	reject $H_0$
Truth	$H_0$ true	✓	Type 1 Error
	$H_A$ true	Type 2 Error	✓

# Hypothesis Test as a trial

If we again think of a hypothesis test as a criminal trial then it makes sense to frame the verdict in terms of the null and alternative hypotheses:

$H_0$ : Defendant is innocent

$H_A$ : Defendant is guilty

Which type of error is being committed in the following circumstances?

Declaring the defendant innocent when they are actually guilty

*Type 2 error*

Declaring the defendant guilty when they are actually innocent

		Decision	
		fail to reject $H_0$	reject $H_0$
Truth	$H_0$ true	✓	Type 1 Error
	$H_A$ true	Type 2 Error	✓

# Type 1 error rate

As a general rule we reject  $H_0$  when the p-value is less than 0.05, i.e. we use a **significance level** of 0.05,  $\alpha = 0.05$ .

This means that, for those cases where  $H_0$  is actually true, we do not want to incorrectly reject it more than 5% of those times.

In other words, when using a 5% significance level there is about 5% chance of making a Type 1 error if the null hypothesis is true.

$$P(\text{Type 1 error} \mid H_0 \text{ true}) = \alpha$$

This is why we prefer small values of  $\alpha$  -- increasing  $\alpha$  increases the Type 1 error rate.

# Choosing a significance level

Choosing a significance level for a test is important in many contexts, and the traditional level is 0.05. However, it is often helpful to adjust the significance level based on the application.

We may select a level that is smaller or larger than 0.05 depending on the consequences of any conclusions reached from the test.

If making a Type 1 Error is dangerous or especially costly, we should choose a small significance level (e.g. 0.01). Under this scenario we want to be very cautious about rejecting the null hypothesis, so we demand very strong evidence favoring  $H_A$  before we would reject  $H_0$ .

If a Type 2 Error is relatively more dangerous or much more costly than a Type 1 Error, then we should choose a higher significance level (e.g. 0.10). Here we want to be cautious about failing to reject  $H_0$  when the null is actually false.

# Practice #5

The average IQ of the adult population is at least 100. A researcher believes the average IQ of adults is lower. A random sample of 5 adults are tested and scored:

69, 79, 89, 99, 109 (SD = 15.81)

Is there enough evidence to suggest the average IQ of adults is lower based on this sample?

**Step 1: Write down Null & Alternative Hypotheses**

**Step 2: Write down assumptions & conditions about underlying population distribution**

**Step 3.1: Calculate test statistic**

**Step 3.2: Calculate p-value**

**Step 4: Compare p-value to level of significance & conclude**

