wrong	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
right	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	
score	100	98.8	97.6	96.4	95.2	94.0	92.9	91.7	90.5	89.3	88.1	86.9	85.7	84.5	83.3	82.1	81.0	79.8	

Biologist at Work!

Name ______________________________

Observation: Organisms have parts which can be measured in terms of length. Suppose you previously made some measurements on yourself. With those measurements in mind, you would now have a “human ruler.” You could measure a centimeter at a time with one of your fingernails, and could measure longer lengths by “walking” with your thumb and index finger.

Which of your fingernails comes closest to 1 cm in width? [Right / Left] [Thumb / Index / Middle / Ring / Pinkie]

What is the length between your thumb tip and extended index finger tip? [ ] cm

Question: Is my right hand the same size as my left hand?

Hypothesis: My hands are the same size.

Prediction: If my hands are the same size, then the width across my left hand should be the same as the width across my right hand.

Experiment: Width across knuckles of: left hand [ ] cm ... right hand [ ] cm

Was this really an experiment? [Yes No]

If no, why not? ______________________________

____

If this is not an experiment, what is it? ______________

Analysis:

The width of my left hand is: [wider than / the same as / narrower than] that of my right hand.

Decision:

The hypothesis: “My hands are the same size” is: [rejected not rejected]

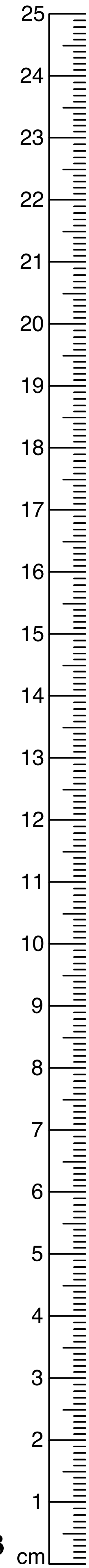
There is very little doubt about the outcome here because you have asked a discrete question with a measurable answer.

Did the prediction thoroughly test the hypothesis? [Yes No]

If not, what else might we measure to more thoroughly test the hypothesis? (hint: the key word is “size”!)

1. __________________ 2. __________________

Most investigations yield not only answers but more questions as well. Scientists are curious people! We might also wonder whether the results of our study can be generalized to the entire human population, for example.



Koning, Ross. E. 1994. Biologist at Work. *Plant Physiology Information Website*.
http://plantphys.info/organismal/labdoc/biologistatwork.doc

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Observation: You now know something about your own two hands. You also notice that not everyone in the room is the same size overall.

Question: In spite of different absolute body sizes, does everyone have hands of equal width?

Hypothesis: The human population has hands of equal width. [a null hypothesis]

Prediction: If the human population has hands of equal width, then a sample of the human population should have hands of equal width.

Notice that we cannot go out and measure the hands of the entire human population, so we must settle for a sample. We hope we can take a representative sample (that is a random sample). Our sample will be all the people in this laboratory.

Would this be a random sample of the population? | Yes No |

If it is not a random sample, why isn't it?______________________________

____

We also hope that our sample is sufficiently large. In spite of any shortcomings in our sample, we will continue our analysis since we lack a better sample.

Experiment: Your instructor will help you post your hand width data along with your classmates' data on the board.

By collecting lots of data, do we now have an experiment? | Yes No |

If no, why not? ____

____

If this is not an experiment, what is it? ____________

Analysis: Clearly we have various widths in each sample and must now include an assessment of this variation in preparing for our decision. Calculate the mean (average) width and the standard deviation of the samples. The latter gives us some measure of the variation (or spread) around the mean. Most calculators will determine the mean and standard deviation for you, using the formulae shown below, but we will let a computer do this work for us!

$$\text{mean} = \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \text{standard deviation} = \sqrt{\frac{\left(\sum (x_i^2)\right) - (\bar{x})^2 n}{n-1}}$$

We will use Microsoft Excel™ to help us with these calculations.

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After powering up the computer, select Excel from the dock at the bottom of the screen. This should open a dialog box, which you can dismiss by clicking on the blue "Open" button. A blank spreadsheet will appear on the monitor screen. In the cell A1 type "Left" and in the cell B1 type "Right." Enter the data from the board in the columns beneath the words (left hand data in A2 to A25, and right hand data in B2 to B25). To calculate the means: In A26 type "=average(A2:A25)" and hit return. Copy A26 and paste it into B26. To calculate the standard deviations: In A27 type "=stdev(A2:A25)" and hit return. Copy A27 and paste it into B27. To fix the rounding problems, select A26:B27 and then select Format-Cells-Number- and set the decimal places to one more than we have precision in our measurements (in this case millimeters, so we want two decimal places—the default). Record your values in the chart:

	Left hands in sample:	Right hands in sample:
Mean width (cm)		
Standard Deviation (cm)		
Student's t-test p value		same different

In general, if the spread about a mean (Standard Deviation) is greater than the difference between the two means, we worry whether what we are observing is meaningful or not. But how will we know with reasonable certainty? We need to do a statistical test of our hypothesis.

Student's T-Test:

Excel can quickly carry out a t-test, which compares the means of two samples and gives us a probability (p-value) that the deviation we observed is consistent with the null hypothesis. In A28 type: "=ttest(A2:A25,B2:B25,2,1)"hit return, and select Format-Cell-Number and set 3 decimal places. In general we choose to reject a null hypothesis when this value is less than the arbitrary value (α) of 5% (0.05…so now you see why we chose three decimal places). In B28 type: "=if(A28>0.05,"Same","Different") and hit return. You can see that Excel can even automate your decision making. The beauty of a spreadsheet is that once you have produced it, you can change any of the raw data numbers and the rest of the calculations are repaired automatically!

Some details: the ttest function in Excel compares the two data ranges you told it were of interest (A2:A25 and B2:B25). We told it to perform a two-tailed (2) test and that our data were paired (1), meaning we had left and right hand data from the same person in each row of our data chart. The returned p-value was compared to an α value, which is suitable for everyday biology projects. In some kinds of projects you might want to allow more error (more than 5%), but in others you might want to allow less error. But 5% makes a reasonable balance between Type I and Type II statistical errors for "typical" tests of null hypotheses.

Decision: Based upon Student's T-test, the hypothesis:

"The human population has hands of equal width" [is   is not] rejected.

There are two reasons for this decision:

The sample providing the data was: ____

The statistical test tells us: ____

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Charting your Data:

Select A1:B25, then choose Insert-Chart, select XY (Scatter), select the icon without lines, click on the blue Next button. Select the Next Button again. Under Chart options, however, enter suitable Axis titles for the chart. Be sure your axis titles have units (cm). Your instructor will show you how to use Chart Options later to eliminate the figure title, gridlines and the key, and how to double-click the plot-area to eliminate its shading but add a complete border for it. Then the instructor will demonstrate how to click on the data series points to make better black symbols for the data points to get closer to a proper graph.

Once the graph is formatted properly, the instructor will demonstrate how Chart-Add Trendline-Linear-Options-Display Equation-Display r^2 value. This step will produce a line through the data points representing a regression analysis, meaning that it produces a best-fit line showing the relationship between the two variables in the scatter plot.

The equation is shown in the $y = mx + b$ form, where x and y are the hand widths, m is the slope of the line, and b is the y-intercept. The r^2 value is a statistical representation of how well your data fit his linear regression line; values above 95% (0.95) have a really excellent fit to the equation, and lower values fit less-well. You do NOT have to have a 95% value to decide there is a relationship…but it would sure be nice! Direct relationships have positive slopes, inverse relationships have negative slopes, and stochastic relationships do not have linear fits.

Copy your final graph and paste it into a Word™ document. Add a caption to it on the same page for printing. Append your final sheet to this worksheet for grading.

The relationship between these two variables is: direct stochastic inverse

Extending your Data:

Using your linear regression analysis equation, how wide would you predict the right hand be for a child with a left-hand-width of 3.5 cm? ___.___cm

What would you estimate would be the width of a right hand of an amputee who has a left-hand width of 7.5 cm? ___.___cm

A basketball player has a right-hand width of 12.5 cm. How wide would you predict is his left hand? ___.___cm

The estimate of the child's hand width is an interpolation extrapolation

The estimate of the amputeees's hand width is an interpolation extrapolation

The estimate of the basketball player's hand width is an interpolation extrapolation

Which kind of estimate is most reliable/justifiable? interpolation extrapolation

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Observations: A single bag of beans was purchased from the store. Some of the beans were soaked in water overnight, the rest from the same bag remain dry. Clearly the soaking has had some effect upon length.

Question: Does soaking beans cause them to expand?

Hypothesis: Soaking does not cause beans to expand. [null hypothesis]

Prediction: If soaking causes beans to expand, then beans will be significantly larger when they are soaked than beans which have been kept dry.

Experiment: A sample of beans was divided into two sub-samples. One sub-sample was placed in water, the other sub-sample was kept in dry conditions. Use a balance to its greatest precision to determine the weight of each of 10 beans from each sub-sample.

Soaked Beans	Dry Beans

Was this really an experiment? Yes No

If no, why not? ________________________________

____

If not an experiment, what is it?________________

	Soaked Beans	Dry Beans
Mean Weight (g)		
Standard Dev.		

Analysis: Carry out a t-test to see whether there is any significant difference between the two sub-samples. In this case the formula for t-test needs to end with 2,3. We still want a two-tailed test, but we do not have paired data this time. Therefore the 3 tells Excel that our two data sets come from different distributions.

p-value: ________ αValue: ________

Based on the t-test, are the two means significantly different? yes no

Decision:

Based on Student's T-test, the hypothesis:

"Soaking does not cause beans to expand" is: rejected not rejected

Our hypothesis used the term "expand" and our prediction used the term "larger." In our experiment we tested the weight of the soaked beans.

What weight adjective would describe the soaked beans? ______________________

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Observation: Our soaked beans sure do seem larger than the dry beans, but how can we measure the volume of an oddly shaped living-bean?

Question: Does soaking beans cause them to expand?

Hypothesis: Soaking does not cause beans to expand. [null hypothesis]

Prediction: If soaking does not cause beans to expand, then beans will not be significantly larger when they are soaked than beans left dry.

Experiment: Measure the volume of bean seeds by displacement of water in a graduated cylinder. Put exactly 14 mL of water in the graduated cylinder. Now slowly add beans until the water level comes just below the 25 mL mark; do not put in more than 10 beans. Calculate the volume per bean by dividing the total volume of beans added by the number of beans added.

	Soaked Beans	Dry Beans
Final Liquid Level	mL	mL
Starting Level	-14 mL	-14 mL
Total Volume of Beans Added	mL	mL
Number of Beans Added	beans	beans
Volume per Bean	mL/bean	mL/bean

Is this really an experiment? [Yes No]

The group of dry beans receiving no treatment is the ________________ group.

The group of soaked beans is called the ________________ group.

Analysis: Examining the volume per bean, there is a striking difference.

Can we perform a t-test on these data? [Yes No]

The degrees of freedom calculation ($=N_1+N_2-2$) specifies how free you are to do a t-test.

How free are we do to this test? The degrees of freedom are: ________________________

How could we redo our measurements so that we could use a t-test for our analysis?

1. ____

2. ____

We will not make any further measurements, but perhaps we may satisfy our need for significance by recalling that scientists find 5% error acceptable.

Calculate the ratio of the volume per soaked bean to the volume per dry bean. [ ]

The soaked beans occupy [%] of the volume of the dry beans.

Is there at least a 5% difference between the beans? [Yes No]

Decision:

Based on a displacement test, the hypothesis:

"Soaking does not cause beans to expand" is: [rejected not rejected]

By having hypotheses rejected, are we poor scientists? [Yes No]

Why did we not have the option to "prove" any of our hypotheses? ________________

____

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