**But how do I know if I’m right?**

Checking your answers is an essential part of science. And no, we don’t mean checking them in the back of the book (although that is good too). Anytime you get an answer, whether that answer comes from an experiment you conducted, a statistical analysis, or from some mathematical computations, you should take a minute to ask yourself whether that answer makes sense. This is a habit of many practicing scientists, engineers, and other professionals - they do it so automatically, most don't even recognize it as part of their own problem-solving process.

Although you might be more used to problems from your classes that have just one right answer, in scientific research often the true answer is not actually known. It is not possible to "look up" the right answer. Instead, we have to ask ourselves if the answer seems plausible and if our approach seems reasonable.

There are many reasons that you might not yet be in the habit of checking your answers. No one may have shown you the utility of checking your own answers. You may be too worried or anxious to remember to stop and consider whether your answer makes sense. Or maybe you want to get it over with as soon as possible. In any case, EVERYONE makes mistakes. Learning to more easily recognize mistakes, correct them, and learn from that experience will make you a much more effective student, scientist, and human being.

**Some helpful things to consider when checking your answers (you might need to use more than one):**

* **Units and scale**: Given the units of measure, do the numbers look about the right size? Did you just calculate that there are only 25 people in New York City? Or is your average whale length only 10 cm? You already know a lot about how big things are, just from being alive. Don’t turn off your common sense!
* **Averages**: The average should be somewhere in the middle of your list of values—if your average is a lot bigger or smaller than most of your values, something is probably wrong.
* **Direction of changes**: Should things be getting bigger or smaller with your experimental procedure? For example, if you are doing a serial dilution of a chemical, the solution should end up being a lower concentration than when you started (i.e. be more dilute).
* **Does it add up? :** For example, if your numbers are percentages, do they add up to 100%? If your numbers are proportions or frequencies, do they add up to 1?
* **Convert to a measure you’re more comfortable with:** Sometimes it’s helpful to convert from percentages to raw numbers or vice versa. 10% of students on campus is how many people? Or roughly convert your units to something you’re more familiar with (meters to feet, etc). Sometimes even thinking of numbers as money can help, since that’s one common use of numbers in our everyday lives.
* **Compare to what you see:** If the data are presented visually, does your answer match the pattern you see when looking at the data?

**Activity: Practice checking for reasonable answers**

For each of the following examples please answer these questions: **Is the answer reasonable? Why or why not? What information did you use to check this?** Try not to check the answer by re-doing the computation. Instead, use your common sense and what you know about the world.

Example*:* We measured the heights (from the ground to the top of their head) of 100 dogs found on campus, and the average height was 200 cm.

*This answer is not reasonable—200 cm is two meters, and I know that a meter is more than 3 feet (or that most humans are less than 2 meters, or…). So this would mean most dogs are taller than 6-foot-tall humans, which seems unlikely.*

1. We sampled 3 bags of M&Ms, and found that the fraction of blue M&Ms was 1/3, 1/4, and 1/2, in the three bags, respectively. The average fraction of blue was 3/4.



1. You read an online nutrition website that suggests your ideal diet should have 30% of your calories from fats, 40% from carbohydrates, and 50% from protein.
2. An anti-vaccination campaign creates a poster suggesting 30 million babies have severe, permanent reactions to vaccinations in the U.S. every year.
3. Researchers found that male spiders ran on average 1 cm/s more slowly after amputation of one of their pedipalps (Figure 1)

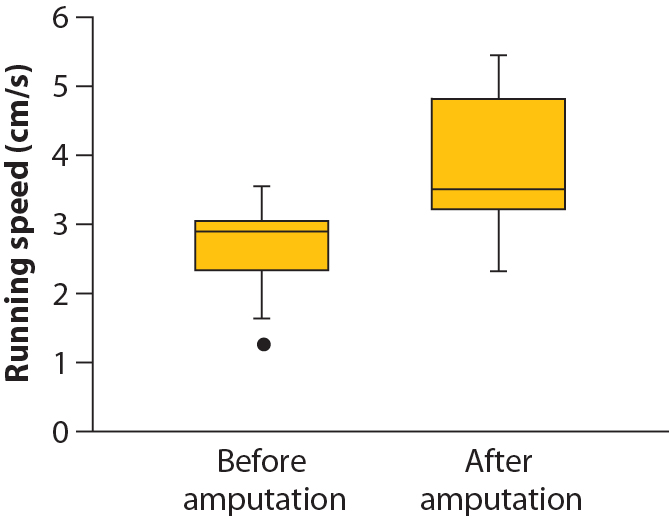


Figure 1: Male spider running speeds before and after amputation. Data from Ramos et al. (2004); Figure from Whitlock and Schluter (2015).

1. The concentration of lead in the Flint, Michigan municipal water supply was reported to be 105 g/L.
2. You are doubling a recipe for pancakes. The original recipe used 2/3 cup flour, 1/2 cup milk, and 1 egg, so instead you use 1 1/3 cups flour, 1 cup milk, and two eggs.
3. The probability of randomly choosing an Environmental Science major or a Biology major from a group of students is 1.34.

1. The p-value for my statistical test is -8.3 x 10-12.