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The System

THE "SYSTEM" COMPRISES EVERYTHING THE scientist uses to perform an experiment. To attempt to falsify a hypothesis, answer a question, or validate a model, the scientist needs a "system" in place so that experiments can be conducted. Whereas the "framework" (discussed in Section 1) governs the way that the scientist thinks about an experiment, the system comprises everything the scientist uses to conduct the experiment. A straightforward way to think about the system is to understand that it comprises what is usually listed in "Materials and Methods" in a scientific paper; but we go beyond the components listed there.

When talking about their system, many scientists gravitate to the most dominant aspect of their work. For example, people who work on the fruit fly *Drosophila* as a model organism to study genetics might say that their system is *Drosophila.* Although that is definitely part of their system, it is not the entire system.

If a scientist is using an antibody to try to detect a protein, the antibody is a critical part of the scientist's system. The system also includes the equipment and reagents used to prepare the protein lysate and the methods used in separating proteins on a gel and performing the eventual protein detection. These components are all parts of the experimental system.

If a DNA vector is being used to introduce a gene into a cell—a process called transfection—that DNA vector is part of the system, as are the cell, the method used to do the transfection, and the method used to detect the gene in the cell.

By "everything," we mean that every aspect of performing the experiment is part of the system. This would include the temperature in the room, the type of test tubes or tissue-culture plates used, the food used for the animal that is being tested, whether or not the animal is active, the type of animal, and the animal's genetic makeup. Every aspect of the experiment is part of the experimental system.

The scientist is also part of the system. Imagine that the scientist is measuring blood pressure on a number of experimental subjects, in order to perform an experiment under the framework "What is the effect of a high-salt diet on blood pressure?" However, when applying the blood pressure cuff, the scientist causes distress to the subjects, which increases their blood pressure. Or imagine that the scientist is motivated only to record those effects that are particularly dramatic. We return to these

issues in Chapter 28, but the example is presented here to illustrate why the definition of the system includes the individual(s) conducting the experiment and those evaluating the data. The way the scientist must behave in conducting the experiment and evaluating the data is part of the system.

All of the methods, including the statistical methods used for data analysis, are components of the experimental system. The criteria used for declaring success or failure, or for determining whether a particular result occurred, are part of the system.

A scientist wishes to conduct a survey to determine the height of individuals who live in England. The framework question is "What are the heights of individuals who live in England?" In response to the question, the scientist is struggling to decide if everyone living in England should be included or whether it should be limited to just those who have been there for at least some significant period of time. Does the question literally mean everyone, or is the goal to assess the effect of living in England on height? In the latter case, the scientist might only want people who were born and raised in England. Does the question pertain to just adults who have stopped growing? If so, perhaps only people over the age of 21 should be surveyed. Certainly, if children are included, that would perturb the data, so the scientist might decide to stratify the results by age.

All of these decisions in response to the framework are part of the system, because they govern the experimental method that will be used. After settling the semantics issues—that is, what is meant by the question—the scientist will need to decide how s/he will measure height; must the individuals take off their shoes? What if a significant number of women wear high heels? On the other hand, what if it takes much longer to make people take off their shoes and this requires them to go to a special place to be measured? Might that result in causing a fair amount of participants to refuse to be in the study? What measuring device will be used? Will people be measured once or multiple times? Can the measurements be performed in an automated way so as to reduce human error? The answers to all of these questions inform the development of a method, and this method is part of the experimental system.

What sort of distributions should be graphed? Should the individuals be separated by gender, ethnic group, age, salary, and/or profession? Or does the scientist simply present a table with everyone's name and height? Will that be useful? Once there are some distributions, and the scientist starts to ask follow-up, comparative questions, such as whether there is a difference in height between the children of barristers and the children of bakers, what sort of statistics should be used to determine whether any differences found are significant?

The questions asked of the data and the manner in which they are answered, including the statistics used to answer them, are all part of the experimental system. In this section of the book, we focus on the essential importance of validating the experimental system before performing actual experiments. We highlight aspects of the system that are important to validate for the successful conduct of an experiment.

In the next chapter, we introduce the concept of system validation in more detail.