1.5 Extending tests beyond the lab

Typically, we think of tests as **manipulative** experiments; in other words, the scientist manipulates the conditions of the experiment, creating a situation that does not exist outside of the lab, and which allows for the greatest control of confounding variables. Indeed, the controlled experiment is the standard for testing in science. In some cases, controlled experiments are not feasible, but we may still be able to test hypotheses through **observational experiments**, using comparative methods and "natural experiments." For instance, if we wanted to test the hypothesis that the number of species on an island is determined by the size (area) of the island, we could compare the number of species on lots of islands of different sizes. Although we can't create a control treatment for such a study, we can still try to control for confounding variables by how we sample islands. For instance, we can restrict our sample to islands within a certain range of latitudes, in order to control for the effect of latitude.

As another example, consider the three-spined stickleback (*Gasterosteus aculeatus*; Figure 1.1). These fish are found in marine and freshwater environments in the northern part of the Northern Hemisphere; marine populations have managed to establish themselves in inland lakes and streams numerous times. In the marine populations, the fish are "armored" with bony plates and spines along their flanks and undersides. Some freshwater populations retain this armor, but in others this armor is greatly reduced or even absent. One hypothesis is that the armor, which costs the fish considerable energy to make, is an adaptation for protection against predators. Based on this hypothesis, we would predict that sticklebacks would be well-armored when populations are in places with many predators. If we looked at different lakes with sticklebacks, we would predict that we'd find armored fish in the lakes with predators and unarmored fish in those that lack predators. We would not be manipulating the lakes or the fish populations, but instead we would rely on the natural occurrence of lakes that have sticklebacks but that differ in the presence or absence of predators.

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Figure 1.1. A three-spined stickleback (*Gasterosteus aculeatus*).

Observational experiments obviously lack some of the opportunities for controlling and manipulating conditions that manipulative experiments enjoy, but that is not to say that observational experiments cannot be as powerful, and they are often necessary. Nor are observational experiments only typical of studies involving observations of plants and animals in the field. Much of what we know about astronomy comes from careful observation of the night sky. Many studies important for our understanding of human health are actually observational studies. A prominent example involves the investigation of the alleged relationship between the measles-mumps-rubella (MMR) vaccine and autism in children. Several observational studies in Finland, Denmark, and the United States examined vaccination and hospital records looking for correlations between autism and vaccination, including the timing of both. In some cases, the researchers compared the incidence of autism in children who had been vaccinated with that of children who had not been vaccinated; the latter group acted as a control group. No significant difference was found in the incidence of autism in children who had and who had not been vaccinated, and there was no relationship between when children were vaccinated and the development of autism. Despite the fact that this experiment could not be carried out in a laboratory, it still provides conclusive evidence regarding the lack of a causal relationship between vaccines and autism.

1.6 Where do we go from here?

An elegant test might allow us to reject competitors and settle on a particular hypothesis. Regardless, while a hypothesis can be falsified, it can be supported but can't be deductively proved to be absolutely true, so there may still be room for more testing. Other scientists may repeat a test to see if they can corroborate the results. More often, answering one question leads to other questions, and the process begins again.