

## 2. The understanding of science

- 2.1 Theories, laws and hypotheses are concepts used by scientists. Though these concepts are connected, there is no progression from one to the other. These words have a special meaning in science and it is important to distinguish these from their everyday use.
- 2.2 Theories are themselves integrated, comprehensive models of how the universe, or parts of it, work. A theory can incorporate facts and laws and tested hypotheses. Predictions can be made from the theories and these can be tested in experiments or by careful observations. Examples are the germ theory of disease or atomic theory.
- 2.3 Theories generally accommodate the assumptions and premises of other theories, creating a consistent understanding across a range of phenomena and disciplines. Occasionally, however, a new theory will radically change how essential concepts are understood or framed, impacting other theories and causing what is sometimes called a “paradigm shift” in science. One of the most famous paradigm shifts in science occurred when our idea of time changed from an absolute frame of reference to an observer-dependent frame of reference within Einstein’s theory of relativity. Darwin’s theory of evolution by natural selection also changed our understanding of life on Earth.
- 2.4 Laws are descriptive, normative statements derived from observations of regular patterns of behavior. They are generally mathematical in form and can be used to calculate outcomes and to make predictions. Like theories and hypotheses, laws cannot be proven. Scientific laws may have exceptions and may be modified or rejected based on new evidence. Laws do not necessarily explain a phenomenon. For example, Newton’s law of universal gravitation tells us that the force between two masses is inversely proportional to the square of the distance between them, and allows us to calculate the force between masses at any distance apart, but it does not explain why masses attract each other. Also, note that the term law has been used in different ways in science, and whether a particular idea is called a law may be partly a result of the discipline and time period at which it was developed.
- 2.5 Scientists sometimes form hypotheses—explanatory statements about the world that could be true or false, and which often suggest a causal relationship or a correlation between factors. Hypotheses can be tested by both experiments and observations of the natural world and can be supported or opposed.
- 2.6 To be scientific, an idea (for example, a theory or hypothesis) must focus on the natural world and natural explanations and must be testable. Scientists strive to develop hypotheses and theories that are compatible with accepted principles and that simplify and unify existing ideas.
- 2.7 The principle of Occam’s razor is used as a guide to developing a theory. The theory should be as simple as possible while maximizing explanatory power.

- 2.8 The ideas of correlation and cause are very important in science. A correlation is a statistical link or association between one variable and another. A correlation can be positive or negative and a correlation coefficient can be calculated that will have a value between +1, 0 and -1. A strong correlation (positive or negative) between one factor and another suggests some sort of causal relationship between the two factors but more evidence is usually required before scientists accept the idea of a causal relationship. To establish a causal relationship, i.e. one factor causing another, scientists need to have a plausible scientific mechanism linking the factors. This strengthens the case that one causes the other, e.g. smoking and lung cancer. This mechanism can be tested in experiments.
- 2.9 The ideal situation is to investigate the relationship between one factor and another while controlling all other factors in an experimental setting; however, this is often impossible and scientists, especially in biology and medicine, use sampling, cohort studies and case control studies to strengthen their understanding of causation when experiments (such as double blind tests and clinical trials) are not possible. Epidemiology in the field of medicine involves the statistical analysis of data to discover possible correlations when little established scientific knowledge is available or the circumstances are too difficult to control entirely. Here, as in other fields, mathematical analysis of probability also plays a role.