What is Science?

Slide 1 – One of the most pressing questions we ponder today is just that. Is science a thing, or a way to know things, a field of inquiry? Is it an absolute, or is malleable, changing and evolving over time? And, whether we consider it a process or a product, can we or should we trust it? The best course of action is to discuss it and develop our own opinion.

Slide 2 – Before we talk about science, though, it is more appropriate to consider nature first, since the goal of any branch of science is to develop an understanding of it. Nature is the sum of all of those phenomena that happen in the physical universe. It is simply a term we use to represent what is both known through observation and unknown until we learn more about it. While it is convenient to do so, if we objectify or anthropomorphize nature, we take away from its essence, often to our own detriment. Nature is amoral – it is neither good, nor bad. Assigning these values adds nothing to the truth but instead muddles our understanding.

Slide 3 – Doing science is a process: A process is something one does – an activity or activities one follows to achieve a specific result. A product is what is derived from a specific process or processes. When we “do science” (the process) we are performing a very specific set of activities designed to, hopefully, give us answers (the product) about how nature works. While the common conception about science is that it is a vast body of knowledge that is somehow unchanging, this could not be farther from the truth. Science is not a product, therefore statements like “trust the science” are inherently false.

Slide 4 - The concept that performing science is a rigid, step-by-step process is not always appropriate. While there is certainly a pattern to the process, it is subject to the individual performing the work. What is most important is that the findings one discovers are valid, meaning that they can be observed by more than the original researcher and are repeatable by anyone else who performs the same steps, even if those steps are modified. Findings that cannot be verified and repeated are not valid, therefore not to be trusted. However, nature does not always follow the rules we think we know…

Slide 5 - Over the centuries we have pondered the appropriate way to study nature and what has become obvious is that not everyone agrees upon the best way to do so. Most commonly, we are all taught that the best way to do science is to follow a set of steps called the **Scientific Method**. By following these steps, we hope to apply a universal standard that allows us to achieve the validity of our findings, since anyone following the same steps should be able to receive the same results, provided that we are objective about what we set out to learn and unbiased in our opinion before we begin.

Slide 6 - The Scientific Method begins with observation. We see or observe something that we don’t immediately understand. This leads to the next step, the question. When, where, why, how? Maybe just one of those or maybe all of them. Though it isn’t always possible, the best approach is generally to try to answer one of these at a time. The next step is dependent upon the researcher and their own philosophy about how the process should proceed. Traditionally, one would develop an hypothesis, or potential explanation for the observation that is falsifiable, meaning that the explanation simply may not be correct. If not, then an alternative must be considered.

Slide 7 - An hypothesis, if we follow the philosophy of **deductive reasoning**, is a potential explanation. Some like to think of it as a prediction or “educated guess,” but this would be entirely reliant upon one’s prior knowledge. What if the observation we make is of something entirely new that we know absolutely nothing about? A really good hypothesis is a testable statement. One does not need prior knowledge, so long as that statement is not subject to bias held by the investigator that may skew the rest of the process in a more favorable direction. Also, to limit one’s inherent drive to be correct, the hypothesis need not follow the observation at all or even be developed by the investigator if it is already inherent to the analysis. This is the basis for the use of statistics.

Slide 8 – In the deductive method, the investigator develops an hypothesis, then designs an experiment to test its validity. In the inductive method, the investigator gathers relevant data first, then tests an hypothesis, generally referred to as null, meaning that the target phenomenon either does or does not occur.Both methods are equally appropriate when care is taken to remove bias.

Slide 9 - A well-designed experiment considers all of the variables that could impact its outcome and removes all but the one being studied. If multiple factors are thought to contribute to the phenomenon, they must be isolated as well. Independent variables are the “cause” of the phenomenon being studied or are factors that may influence the outcome. They are thus separate from the dependent variable(s) being studied. Dependent variables are the “effect” of the independent variable(s). Independent variables are rigorously controlled by the investigator.

Slide 10 – Here’s an example. Suppose the investigator chooses to determine if plants grow better in light or in darkness. Since most plants grow in both light and darkness in nature, the investigator may choose to include a “control” variable in which plants are exposed to both in a more natural way or may choose to study both conditions, called treatments (light, dark) for comparison. Independent variables other than light that might impact growth, such as the amount of water a plant receives, the type and amount of soil it grows in, the humidity, and the size of the container and the time period for the experiment all must be held the same, with only the presence or absence of light altered. Since there also might be genetic variation in each plant, multiple replicates must be produced for both light and non-light conditions. In general, a larger number of replicates reduces the probability that any result is simply owing to random chance.

Measurements of growth such as root length, shoot length, dry biomass and root to shoot ratio (a measure of energy expenditure) can each be analyzed separately.

Slide 11 - Once all of the data is gathered, values for each data point can be averaged for each treatment. The averages can be compared against one another or subjected to further statistical analysis which determines the probability that results noted for each are significantly different enough not to be the result of random chance.

Since statistical analyses are based upon the testing of a null hypothesis, significant differences can act as evidence of a specific pattern in nature, especially if, when the experiment is repeated, results are the same for each independent researcher. Remember, repeatability is the key to acceptance as scientific fact.

Slide 12 - Once proper experimentation and analysis have been done, conclusions can be drawn from the results. Independent verification through similar experimentation insures validity of the findings, which can then be accepted by the greater whole. Keep in mind, however, nature can and does act in unpredictable ways. That’s why understanding science is important.

Key Words and Terms

process hypothesis

product deductive method

valid inductive method

repeatability null hypothesis

Scientific Method control

observation treatment