What is Science?

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Science is the concerted human effort to understand, or to understand better, the history of the natural world and how the natural world works, with observable physical evidence as the basis of that understanding[1]. It is done through observation of natural phenomena, and/or through experimentation that tries to simulate natural processes under controlled conditions. (There are, of course, more definitions of science.)

Consider some examples. An ecologist observing the territorial behaviors of bluebirds and a geologist examining the distribution of fossils in an outcrop are both scientists making observations in order to find patterns in natural phenomena. They just do it outdoors and thus entertain the general public with their behavior. An astrophysicist photographing distant galaxies and a climatologist sifting data from weather balloons similarly are also scientists making observations, but in more discrete settings.

The examples above are observational science, but there is also experimental science. A chemist observing the rates of one chemical reaction at a variety of temperatures and a nuclear physicist recording the results of bombardment of a particular kind of matter with neutrons are both scientists performing experiments to see what consistent patterns emerge. A biologist observing the reaction of a particular tissue to various stimulants is likewise experimenting to find patterns of behavior. These folks usually do their work in labs and wear impressive white lab coats, which seems to mean they make more money too.

The critical commonality is that all these people are making and recording observations of nature, or of simulations of nature, in order to learn more about how nature, in the broadest sense, works. We'll see below that one of their main goals is to show that old ideas (the ideas of scientists a century ago or perhaps just a year ago) are wrong and that, instead, new ideas may better explain nature.

So why do science? I - the individual perspective

So why are all these people described above doing what they're doing? In most cases, they're collecting information to test new ideas or to disprove old ones. Scientists become famous for discovering new things that change how we think about nature, whether the discovery is a new species of dinosaur or a new way in which atoms bond. Many scientists find their greatest joy in a previously unknown fact (a discovery) that explains something problem previously not explained, or that overturns some previously accepted idea.

That's the answer based on noble principles, and it probably explains why many people go into science as a career. On a pragmatic level, people also do science to earn their paychecks. Professors at most universities and many colleges are expected as part of their contractual obligations of employment to do research that makes new contributions to knowledge. If they don't, they lose their jobs, or at least they get lousy raises.

Scientists also work for corporations and are paid to generate new knowledge about how a particular chemical affects the growth of soybeans or how petroleum forms deep in the earth. These scientists get paid better, but they may work in obscurity because the knowledge they generate is kept secret by their employers for the development of new products or technologies. In fact, these folks at Megacorp do science, in that they and people within their company learn new things, but it may be years before their work becomes science in the sense of a contribution to humanity's body of knowledge beyond Megacorp's walls.

Why do Science? II - The Societal Perspective

If the ideas above help explain why individuals do science, one might still wonder why societies and nations pay those individuals to do science. Why does a society devote some of its resources to this business of developing new knowledge about the natural world, or what has motivated these scientist to devote their lives to developing this new knowledge?

One realm of answers lies in the desire to improve people's lives. Geneticists trying to understand how certain conditions are passed from generation to generation and biologists tracing the pathways by which diseases are transmitted are clearly seeking information that may better the lives of very ordinary people. Earth scientists developing better models for the prediction of weather or for the prediction of earthquakes, landslides, and volcanic eruptions are likewise seeking knowledge that can help avoid the hardships that have plagued humanity for centuries. Any society concerned about the welfare of its people, which is at the least any democratic society, will support efforts like these to better people's lives.

Another realm of answers lies in a society's desires for economic development. Many earth scientists devote their work to finding more efficient or more effective ways to discover or recover natural resources like petroleum and ores. Plant scientists seeking strains or species of fruiting plants for crops are ultimately working to increase the agricultural output that nutritionally and literally enriches nations. Chemists developing new chemical substances with potential technological applications and physicists developing new phenomena like superconductivity are likewise developing knowledge that may spur economic development. In a world where nations increasingly view themselves as caught up in economic competition, support of such science is nothing less than an investment in the economic future.

Another whole realm of answers lies in humanity's increasing control over our planet and its environment. Much science is done to understand how the toxins and wastes of our society pass through our water, soil, and air, potentially to our own detriment. Much science is also done to understand how changes that we cause in our atmosphere and oceans may change the climate in which we live and that controls our sources of food and water. In a sense, such science seeks to develop the owner's manual that human beings will need as they increasingly, if unwittingly, take control of the global ecosystem and a host of local ecosystems.

Lastly, societies support science because of simple curiosity and because of the satisfaction that comes from knowledge of the world around us. Few of us will ever derive any economic benefit from knowing that the starlight we see in a clear night sky left those stars thousands and even millions of years ago, so that we observe such light as messengers of a very distant past. However, the awe, perspective, and perhaps even serenity derived from that knowledge is very valuable to many of us. Likewise, few of us will derive greater physical well-being from watching a flowing stream and from reflecting on the hydrologic cycle through which that stream's water has passed, from the distant ocean to the floating clouds of our skies to the rains and storms upstream and now to the river channel at which we stand. However, the sense of interconnectedness that comes from such knowledge enriches our understanding of our world, and of our lives, in a very valuable way. By understanding the stars in our sky and the rivers under our bridges, we better understand who we are and our place in the world. When intangible benefits like these are combined with the more tangible ones outlined above, it's no wonder that most modern societies support scientific research for the improvement of our understanding of the world around us.

How Research becomes Scientific Knowledge

As our friends at Megacorp illustrate, doing research in the lab or in the field may be science, but it isn't necessarily a contribution to knowledge. No one in the scientific community will know about, or place much confidence in, a piece of scientific research until it is published in a peer-reviewed journal. They may hear about new research at a meeting or learn about it through the grapevine of newsgroups, but nothing's taken too seriously until publication of the data.

That means that our ecologist has to write a paper (called a "manuscript" for rather old-fashioned reasons). In the manuscript she justifies why her particular piece of research is significant, she details what methods she used in doing it, she reports exactly what she observed as the results, and then she explains what her observations mean relative to what was already known.

She then sends her manuscript to the editors of a scientific journal, who send it to two or three experts for review. If those experts report back that the research was done in a methodologically sound way and that the results contribute new and useful knowledge, the editor then approves publication, although almost inevitably with some changes or additions. Within a few months (we hope), the paper appears in a new issue of the journal, and scientists around the world learn about our ecologist's findings. They then decide for themselves whether they think the methods used were adequate and whether the results mean something new and exciting, and gradually the paper changes the way people think about the world.

Of course there are some subtleties in this business. If the manuscript was sent to a prestigious journal like *Science* or *Nature*, the competition for publication there means that the editors can select what they think are only the most ground-breaking manuscripts and reject the rest, even though the manuscripts are all well-done science. The authors of the rejected manuscripts then send their work to somewhat less exalted journals, where the manuscripts probably get published but are read by a somewhat smaller audience. At the other end of the spectrum may be the *South Georgia Journal of Backwater Studies,* where the editor gets relatively few submissions and can't be too picky about what he or she accepts into the journal, and not too many people read it. For better or worse, scientists are more likely to read, and more likely to accept, work published in widely-distributed major journals than in regional journals with small circulation.

To summarize, science becomes knowledge by publication of research results. It then may become more general knowledge as writers of textbooks pick and choose what to put in their texts, and as professors and teachers then decide what to stress from those textbooks. Publication is critical, although not all publication is created equal. The more a newly published piece of research challenges established ideas, the more it will be noted by other scientists and by the world in general.

Science and Change (and Miss Marple)

If scientists are constantly trying to make new discoveries or to develop new concepts and theories, then the body of knowledge produced by science should undergo constant change. Such change is progress toward a better understanding of nature. It is achieved by constantly questioning whether our current ideas are correct. As the famous American astronomer Maria Mitchell (1818-1889) put it, "Question everything".

The result is that theories come and go, or at least are modified through time, as old ideas are questioned and new evidence is discovered. In the words of Karl Popper, "Science is a history of corrected mistakes", and even Albert Einstein remarked of himself "That fellow Einstein . . . every year retracts what he wrote the year before". Many scientists have remarked that they would like to return to life in a few centuries to see what new knowlege and new ideas have been developed by then - and to see which of their own century's ideas have been discarded. Our ideas today should be compatible with all the evidence we have, and we hope that our ideas will survive the tests of the future. However, any look at history forces us to realize that the future is likely to provide new evidence that will lead to at least somewhat different interpretations.

Some scientists become sufficiently ego-involved that they refuse to accept new evidence and new ideas. In that case, in the words of one pundit, "science advances funeral by funeral". However, most scientists realize that today's theories are probably the future's outmoded ideas, and the best we can hope is that our theories will survive with some tinkering and fine-tuning by future generations.

We can go back to Copernicus to illustrate this. Most of us today, if asked on a street corner, would say that we accept Copernicus's idea that the earth moves around the sun - we would say that the heliocentric theory seems correct. However, Copernicus himself maintained that the orbits of the planets around the sun were perfectly circular. A couple of centuries later, in Newton's time, it became apparent that those orbits are ellipses. The heliocentric theory wasn't discarded; it was just modified to account for more detailed new observations. In the twentieth century, we've additionally found that the exact shapes of the ellipses aren't constant (hence the Milankovitch cycles that may have influenced the periodicity of glaciation). However, we haven't gone back to the idea of an earth-centered universe. Instead, we still accept a heliocentric theory - it's just one that's been modified through time as new data have emerged.

The notion that scientific ideas change, and should be expected to change, is sometimes lost on the more vociferous critics of science. One good example is the Big Bang theory. Every new astronomical discovery seems to prompt someone to say "See, the Big Bang theory didn't predict that, so the whole thing must be wrong". Instead, the discovery prompts a change, usually a minor one, in the theory. However, once the astrophysicists have tinkered with the theory's details enough to account for the new discovery, the critics then say "See, the Big Bang theory has been discarded". Instead, it's just been modified to account for new data, which is exactly what we've said ought to happen through time to any scientific idea.

Try an analogy: Imagine that your favorite fictional detective (Sherlock Holmes, Miss Marple, Nancy Drew, or whoever) is working on a difficult case in which the clues only come by fits and starts. Most detectives keep their working hypotheses to themselves until they've solved the case. However, let's assume that our detective decides this time to think out loud as the story unfolds, revealing their current prime suspect and hypothesized chronology of the crime as they go along. Now introduce a character who accompanies the detective and who, as each clue is uncovered, exclaims "See, this changes what you thought before - you must be all wrong about everything!" Our detective will think, but probably have the grace to not say, "No, the new evidence just helps me sharpen the cloudy picture I had before". The same is true in science, except that nature never breaks down in the last scene and explains how she done it.

Science and Knowledge

So what does all this mean? It means that science does not presently, and probably never can, give statements of absolute eternal truth - it only provides theories. We know that those theories will probably be refined in the future, and some of them may even be discarded in favor of theories that make more sense in light of data generated by future scientists. However, our present theories are our best available explanations of the world. They explain, and have been tested against, a vast amount of information.

Consider some of the information against which we've tested our theories:

- We've examined the DNA, cells, tissues, organs, and bodies of thousands if not millions of species of organisms, from bacteria to cacti to great blue whales, at scales from electron microscopy to global ecology.
- We've examined the physical behaviour of particles ranging in size from quarks to stars and at times scales from femtoseconds to millions of years.
- We've characterized the 90 or so chemical elements that occur naturally on earth and several more that we've synthesized.
- We've poked at nearly every rock on the earth's surface and drilled as much as six miles into the earth to recover and examine more.
- We've used seismology to study the earth's internal structure, both detecting shallow faults and examining the behavior of the planet's core.
- We've studied the earth's oceans with dredges, bottles, buoys, boats, drillships, submersibles, and satellites.
- We've monitored and sampled Earth's atmosphere at a global scale on a minute-by-minute basis.
- We've scanned outer space with telescopes employing radiation ranging in wavelength from infrared to X-rays, and we've sent probes to examine both our sun and the distant planets of our solar system.
- We've personally explored the surface of our moon and brought back rocks from there, and we've sampled a huge number of meteorites to learn more about matter from beyond our planet.

We will do more in the centuries to come, but we've already assembled a vast array of information on which to build the theories that are our present scientific understanding of the universe.

This leaves people with a choice today. One option is to accept, perhaps with some skepticism, the scientific (and only theoretical) understanding of the natural world, which is derived from all the observations and measurements described above. The other option, or perhaps an other option, is to accept traditional understandings[3] of the natural world developed centuries or even millenia ago by people who, regardless how wise or well-meaning, had only sharp eyes and fertile imaginations as their best tools.

What Is Science Questions from Article

You should find the answers to these questions in article. Highlight /underline the answers, and indicate the question number in the article.

1. **What is science?**
2. **Where does the concept of data fit into this explanation of science?**
3. **What is the significance of searching for "patterns" in…………?**
4. **Why science?**
5. **Why science "individual perspective"?**
6. **What do most university professors do in addition to teach students?**
7. **How are scientists at corporations different from scientists(professors) at Universities?**
8. **Why science "Societal perspective"?**
9. **How does research become scientific knowledge?**
10. **What is a manuscript?**
11. **What are the crucial parts of a manuscript?(4)**
12. **How does the work of scientist change the way people think about the world?**
13. **How do we make progress toward a better understanding of nature?**
14. **What does heliocentric mean?**
15. **Explain why science leads to theories, and not necessarily absolute truths?**