Scientific Methods and Human Knowledge

Eric R. Pianka

At the end of the Pleistocene (10,000 years before now), only about 500 generations ago, humans were still hunter/gatherers, living off the land in small bands or tribes. Natural selection shaped these ancestral human populations, both physically and mentally, to cope with the natural world around us, our environment. Like all animals, we dwell in a three-dimensional world that we perceive on a local spatial scale within a limited time horizon. Because our ancestors possessed very limited knowledge about how the world worked, they benefited by actively seeking evidence of connections among apparently unconnected events. As a result, humans today seem to be predisposed to look for causal connections by linking events whether or not they appear to be connected. We want to understand and 'know' things in order to exploit our environment to our own ends. Our brains, shaped by natural selection, allow us to do this fairly well for immediate events and simple local phenomena using our five senses and logic.

However, more complex, large scale, time delayed, and elusive things beyond the reach of manipulation, direct observation, or our senses are another matter. If we don't simply ignore them, we tend to resort to supernatural 'explanations,' invoking phenomena beyond those our sensory systems can detect. Some have even suggested that our tendency to believe in such supernatural phenomena might have a genetic basis (Morrison 1999). Our ability

to believe and place faith in supernatural phenomena has doubtless helped humans to make apparent ‘sense’ of otherwise puzzling or inexplicable things. A predisposition for unquestioning belief in authority could spare each generation from repeating mistakes or having to rediscover or verify things that have already been discovered. It might also help us reach consensus on ‘explanations’ that cannot be verified. Many must have died in the process of finding out which plants and fungi were edible. Our ancestors no doubt sat around campfires telling one another stories, passing on such vital information from one generation to the next — this was the origin of human knowledge and the beginning of our domination of planet Earth.

Development of verbal language allowed us to exchange and expand ideas and concepts better, no doubt facilitating control of our environment, and thereby our survival and reproduction. However, language is a double-edged sword: words help us formulate concepts, but at the same time, they limit the directions our thought processes can take. The ways in which we can envision the natural world around us are constrained by the words we develop, especially by the attitudes they convey. Words, nouns in particular, can have very different referents between humans. For example, the word ‘mountain’ means something quite different to someone raised in Colorado versus someone raised in Georgia. Precise definitions or universal agreement are needed to insure accurate passage of understanding.

Frail and limited as we are, humans have struggled long and hard to understand the world around us. Bound by our limited senses and life spans, we have nevertheless managed to begin to understand a fair bit about matter and nature. While we have difficulty imagining worlds with more than three dimensions or things without limits, it is a tribute to our intellect that we have words for concepts as elusive as hypervolumes, eternity, and infinity. Nevertheless, we are much more comfortable with three dimensions, and things that begin and end.

Humans explain events and phenomena in two very different ways. One approach to knowing (sense 1, common sense) involves thinking and is objective, based on making repeatable observations that allow us to predict nature and future events — this rational logical approach to knowing led to scientific methodology (Moore 1999). Another, very different, non-objective approach to 'knowing' (sense 2, faith-based) is based primarily upon the invocation of supernatural explanations, bolstered by authorities who claim to have special access to supernatural sources. This non-scientific approach, championed by religions, has helped many humans accept and cope with things they couldn't do anything about or understand rationally. Unfortunately, the power conferred on religious leaders has often led to serious abuses and resistance to accepting the rational understanding of the functioning of nature as demonstrated by new scientific discoveries. These two diametrically opposed ways we interpret and 'know' (sense 1 versus sense 2)

about our environments have contributed to the regrettable past and modern day conflicts between science and religion.

Human intelligence has also evolved so that we have remarkably good abilities to detect intentions of other humans in social interactions. We seem to have a propensity for mysticism and a tendency to emphasize explanations that invoke intention over those based on sheer mechanism, situation, or circumstances. Indeed, humans may be predisposed to see intentions in their friends and enemies. Likewise, predators 'want' to kill us and prey 'want' to escape from us. We even look for meaning and purpose in inanimate things such as the climate or the universe.

Everyone, religious or not, relies on objective rational thinking to handle problems encountered in everyday life. Thus, we all know we must eat to stay alive, things fall down not up or sideways, we must avoid collisions when driving, we must balance our budgets, etc. Remarkably, many people switch back and forth between rational knowing (sense 1) to faith-based 'knowing' (sense 2) with ease. Our brains may be organized in ways that promote such duality.

Adamant insistence on faith-based 'I know' coupled with careless use of words like 'believe' and 'truth' have provided numerous opportunities to foment confusion and have allowed science to be deliberately maligned and misrepresented. Thus, religious leaders have often rejected new scientific evidence because it reduced the domain of processes over which religion could claim authority. As a

result, scientific investigators have sometimes been vilified as Galileo was during the inquisition — scientists have even been executed because their views conflicted with mystical belief systems.

For various reasons, even many educated people still entertain faith-based systems of belief. They are comfortable with 'proofs' based on ancient mythology as the unchangeable 'truth'. People who 'know' something or 'believe' in supernatural 'proof' are thus unable and/or unwilling to use logic and reason to comprehend reasoned alternatives — they cannot improve their understanding without substantial changes in their world view and thinking processes. Religious beliefs can only be changed when a believer or an authoritative leader has some new 'revelation' or changes faith. Sometimes, politically-motivated charismatic leaders start up their own new faith.

In contrast, scientific methods unrelentingly demand that we keep an open mind, leading to a continually improved understanding of the natural world about us. Scientists should never claim to 'believe' or to have access to the 'truth' (one who does will surely be last to find it!). Let us consider some definitions of science:

> "Science is a set of cognitive and behavioral methods to describe and interpret observed or inferred phenomena, past or present, aimed at building a testable body of knowledge open to rejection or confirmation." (Shermer 2001).

In a 1986 U. S. Supreme Court case (Edwards v. Aguillard) an *amicus curiae* brief was tendered by a community of Nobel Laureates, who defined science as follows:

> "Science is devoted to formulating and testing naturalistic explanations for natural phenomena. It is a process for systematically collecting and recording data about the physical world, then categorizing and studying the collected data in an effort to infer the principles of nature that best explain the observed phenomena."

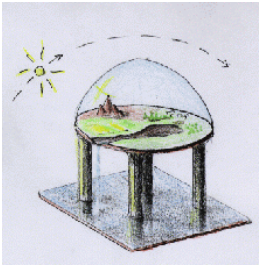
Their brief goes on to explain, somewhat apologetically, science's inability to explain putative 'supernatural' events and phenomena:

> "Science is not equipped to evaluate supernatural explanations for our observations; without passing judgment on the truth or falsity of supernatural explanations, science leaves their consideration to the domain of religious faith. Because the scope of scientific inquiry is consciously limited to the search for naturalistic principles, science remains free of religious dogma and is thus an appropriate subject for public-school instruction."

Scientists do not concern themselves with anything supernatural, but are interested only in the natural world. Motivated by curiosity about their surroundings, they assume an organized reality exists in

nature and that objective principles can be formulated, which will adequately reflect that natural order. ***This pivotal assumption that an external organized reality exists is NOT based on faith, but is verified every day by observing predictable repeatable events such as day is followed by night.*** A scientist 'believes' that an organized reality exists, but in a fundamentally different and much more rational way than a religious person 'believes' in his/her deity. Scientists go to great lengths to satisfy their desire to understand natural events and phenomena. They continually cross check one another to verify currently accepted explanations. For a scientist, reason and logic always trump authority and faith as a way of knowing (Moore 1999, Pianka 2000).

Superficial commonsense perceptions led our ancestors to invoke the long-standing notion of a 'flat Earth and moving Sun.' Under this now archaic geocentric view, Earth did not move but was at the center of the universe, with the Sun moving across the sky. Early mariners were actually afraid of falling off the flat Earth (strangely, people did not seem to be overly concerned about either what supported this flat Earth or about ocean waters spilling off and draining into some sort of bottomless abyss — why didn't the oceans drain dry?).



Over time, our understanding of the world around us has improved steadily as human knowledge has expanded. Our quest for understanding has liberated and enlightened many of us. However, the capacity for ambiguity inherent in language has also provided a ready mechanism that has unfortunately permitted some to obfuscate, conflate, and misinterpret those same ideas and concepts. Communication is impaired when people use the same words in different ways, whether deliberately or not. Many commonly used words suffer because of just such a 'failure to communicate.' Problems arise especially when words convey divergent attitudes. In the context of scientific versus vernacular terminology, key words such as 'fact,' 'know,' 'truth,' 'proof,' 'faith,' 'belief,' 'design' and 'theory' are widely misconstrued because they convey different meanings to different audiences. Another term that is a source of considerable confusion is 'random.' Let us consider some of these.

Most people consider a 'fact' as 'what really happened.' However, many 'facts' are not so clean and simple – most involve varying levels of interpretation. Consider, for example, the apparently simple 'fact' that the Sun rises each morning. Daily we receive new evidence confirming this 'fact.' We can be quite confident that the Sun will rise again tomorrow. Under the now defunct concept of a 'flat earth and moving Sun', the Sun's movement across the sky was viewed from the perspective of a fixed nonmoving earth at the center of the universe. Indeed, references to sunrise and sunset are based on this interpretation, which is supported by our superficial

commonsense perceptions. Understandably, we think of our selves at the center of things and interpret other events and phenomena from such an anthropocentric frame of reference. But our understanding of cosmic events was greatly enhanced when instead of thinking of the Sun as moving, it is viewed as the center of a solar system, and Earth is interpreted as a rotating globe orbiting around a small star. Our vocabulary hasn't caught up — clearly, we should refer to 'sunrise' as 'spinup' and 'sunset' as 'spindown' (Pianka 2000). In contrast, since the moon does revolve around Earth, it is appropriate to call its movements 'moonrise' and 'moonset'. Nietzsche once wrote "there are no facts, only interpretation." He somewhat overstated the case, since repeatable observable events certainly qualify as 'facts' even though they may often not be clean of interpretation. We view the Sun's position change relative to the horizon every day, even though 'sunrise' is a misinterpretation. Although it took a long while to become accepted, the heliocentric solar system perspective has now replaced the geocentric concept in the minds of most people. Hopefully, it won't take as long for people to begin to accept Darwin's logical argument of natural selection.

Some people seem to need to believe in a deity to make sense of their existence and the phenomena they perceive around them. Perhaps 'knowing' that an omnipotent caring entity looks over us helps in confronting and coping with our human weaknesses and limited life spans. People are expected to outgrow their belief in the Tooth Fairy, the Easter bunny, and Santa Claus, but not the cherished myth of a caring god. Everybody wants to believe in an

afterlife, as comforting and irrational as that may be (but see below).

Unfortunately, some people of faith still favor ancient creation myths over an evolutionary explanation for our own origin, and some religious moderates that reject ancient myths still believe that a god intervened to create humans and establish moral values. Darwin's ideas threatened to dethrone humans as such exalted creatures. Many people remain convinced that humans are fundamentally different from other life forms — they find it odious even to contemplate that we might have descended from a common ancestor of the great apes — despite the fact that the vast majority of our genes are shared with chimpanzees and gorillas. Indeed, these apes have the same blood group types as humans. All vertebrates share the same basic body plan. They are bilaterally symmetric, with a head, brain, nose, two eyes, paired forelimbs and hindlimbs, stomach, intestine, heart, kidneys, liver, and assorted other internal organs. Even a tiny fish or lizard shares all these features with humans. How can we not be related by descent? [Creationists might argue that good design(s) are/were used repeatedly, but it is easier to explain shared derived traits as evidence of descent from a common ancestor.] Scientific evidence is overwhelming that all life on Earth arose from a single common ancestor. Your blood plasma approximates the salt concentrations of the oceans because life arose there. The genetic code is universal for all life forms on Earth. Right now, genes that first evolved in bacteria billions of years ago in Earth's primeval seas operate

respiratory metabolism within your body that keep you alive from second to second. Green plants capture solar energy using genes perfected by ancient photosynthetic bacteria, providing the energetic foundation that supports all life on Earth. (Such microbes generated most of the oxygen that makes up Earth's current atmosphere, without which you could not exist.) Such scientific evidence tells us that humans are simply one terminal branch of the vast tree of life. Microbes, fungi and plants are our distant cousins. Some eastern philosophies share the belief that we are one part of a huge river of life flowing through time. Hence we do have an afterlife, after all, in the form of the ongoing tree of life, especially our descendants.

Because words like 'know,' 'truth,' 'proof,' 'faith,' and 'belief' convey an attitude of certainty, they lock our thinking in place, inhibiting change and improvement in our understanding of the natural world around us. The illusion of certainty has held back advances in human knowledge (Dawkins and Ward 1996).

Science, especially at introductory levels, is too often taught as fact-based transmission of information, with inadequate attention paid to its process. People are taught that science is a body of answers, deliverable in absolutes ('learn this for your exam') when they should be taught to think of science as a way of asking questions about the natural order of things. As a result, most people, including many who have taken several science courses, do not

appreciate the scientific process of logical inquiry, especially the tentative and probabilistic nature of many scientific conclusions.

A widespread misconception is that science can explain everything — quite the contrary, science thrives on uncertainty because it always remains tentative (in science, nothing is ever known for certain). Scientists must always remain open minded, discarding weak explanations in favor of ones that better explain observed events. The strength of scientific methods is that, if these processes are adopted and followed rigorously, understanding and knowledge will improve steadily over time. Dogmatic faith-based belief systems impair such progress by vigorously defending and maintaining the status quo of archaic systems of 'belief', preventing us from reaching our full human potential. Despite such impediments, scientific methods have brought human understanding a long way.

Unfortunately, scientists are people and people are fallible and subject to becoming dogmatic — not all scientists practice the methods of science correctly nor use potentially confounding words properly. And, although plenty of zealots stand ready to pounce on any such mistake to discredit scientists, unlike religion, science has powerful built in self-correcting mechanisms.

Another much abused term with varied meanings is 'random.' The dictionary definition is 'without definite direction' or 'lacking a definite plan, purpose, or pattern' or 'equi-probable.' Often the word is used to describe anything capricious or unpredictable,

which usually means that something is simply so poorly understood that it appears indeterminate. Invoking 'randomness' may often merely be a cover up for our ignorance. Because the basic source of genetic change is 'random' mutations, proponents of intelligent design mistakenly argue that 'evolution is random.' In actuality, natural selection favors highly non-random organisms whose adaptations to cope with their environments enhance their reproductive success.

Scientists begin an investigation by formulating hypothetical statements about how reality might work, called hypotheses (also known as models). All hypotheses make simplifying assumptions — some sacrifice precision for generality, whereas others sacrifice generality for precision (Levins 1966). Some hypotheses actually sacrifice certain aspects of realism itself! Hypotheses are "mere caricatures of nature designed to convey the essence of nature with great economy of detail" (Horn 1979). Many hypotheses are not 'correct' or 'true.' Even a demonstrably false hypothesis can be useful in developing improved understanding. Any given hypothesis merely represents one particular attempt to explain reality. Hypotheses are like circus mirrors that do not reflect reality perfectly. Most hypotheses are to some extent incorrect, but scientists use them because nature is too complex to be investigated without employing simplifying assumptions. Hypotheses generate predictions that can be tested by confronting them with reality. Some types of hypotheses, such as historical ones involving

evolutionary changes, are judged by their explanatory power, rather than their ability to predict.

When a hypothesis's predictive or explanatory powers fail, it is either discarded or revised. If a hypothesis does not conform adequately to reality, it is replaced by another that reflects the real world more accurately. The process of scientific inquiry is thus self-regulating; as time progresses, knowledge expands and is continually refined and improved to mirror external reality more and more accurately.

Observation and experiment play a vital role in science. They are used to test models, to refute inadequate hypotheses, and thus they help us to formulate improved interpretations of natural phenomena. Some natural events cannot be manipulated. Thus, we cannot stop the Sun's fusion or Earth's rotation to test current ideas, but each daily observation of spinup or spindown nevertheless strengthens our confidence in the accepted interpretation of celestial events. Note, however, that such repeatability may be consistent with a hypothesis that is later shown to be incorrect. For example, predictions derived from a geocentric world view survived tests for centuries until Copernicus and Galileo provided convincing contrary evidence. This is why all scientific hypotheses and theories remain tentative and are always subject to being replaced when a superior explanation is discovered. Darwin's rational view of nature should now replace the archaic faith-based dogma of a mythical creator.

In time, a well-substantiated hypothesis is elevated to become a robust scientific ‘theory’ (non-scientists often comment ‘it’s just a theory,’ invoking a much more speculative and demeaning attitude). Eventually, reliable scientific theories can even attain the status of ‘law,’ such as the laws of motion or the laws of thermodynamics. Darwin’s mechanism of Natural Selection is truly a unifying theory of life, not even restricted to DNA-based life on Earth, but it presumably would apply to any self-replicating entity (any life form) anywhere in the entire megaverse (Cosmos). Natural Selection is as close to a ‘law’ as we can get in biology. People’s world views and personal philosophies would benefit greatly from embracing “Darwin’s Dangerous Idea” (Dennett 1995), rather than naively rejecting it outright and refusing to examine the evidence for it. We are extremely fortunate to be able to learn from past genius and research effort. In a few hours of careful reading, you can now master material that required many lifetimes to acquire.

Darwin ended “The Origin of Species” with “It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being growth with reproduction; inheritance which is almost implied by reproduction; variability

from the indirect and direct action of the conditions of life, and from use and disuse; a ratio of increase so high as to lead to a struggle for life, and as a consequence to natural selection, entailing divergence of character and the extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life . . .”

While an evolutionary perspective may dethrone humans as divine creations, it greatly enriches our understanding of the real world, much more so than one that invokes some mythical god who intervenes at his whim.

Acknowledgments

I thank Chris Bell, Daniel Bolnick, Valerius Giest, David Hillis, Mitch Leslie, Gordon Orians, Michael Pianka and Sam Sweet for useful discussion and for criticism and comments. Some of these readers are more tolerant of organized religion than I am and would not agree with some parts of this essay.

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