THE NATURE OF MODERN SCIENCE & SCIENTIFIC KNOWLEDGE

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I. THE GOAL & REALM OF MODERN SCIENCE

Modern science endeavors to understand and explain how the NATURAL world works and how it got to be the way that it is, NOT merely to collect "facts" about, or simply describe, the different parts of the natural world.

"Natural" here refers to EMPIRICAL or "sensible," that is, only that which we can detect—somehow—with our senses and for which there is usually widespread agreement. Another sense of "natural" is that it entails explanations that are detailed, precise and possess predictive power.

Keep in mind that the fringes of the natural world or realm can be somewhat fuzzy. Science is nonetheless LIMITED to the study of the natural world and cannot study or explain "supernatural" or metaphysical events or beings — which is not to say they may not exist!

II. THE UNCERTAINTY & LIMITS OF SCIENTIFIC KNOWLEDGE

In addition to being limited to studying the natural world, scientific knowledge (especially at the level of explanation) is limited by being inherently UNCERTAIN to varying degrees, that is, NOT absolutely, eternally and infallibly TRUE. This "built-in" or intrinsic uncertainty is due in part to the following **assumptions** and **limitations**:

Some <u>Assumptions</u> of Scientific Knowledge:

A. THE WORLD IS REAL. In other words, the physical universe exists apart from our sensory perception of it.

B. HUMANS CAN ACCURATELY PERCEIVE AND UNDERSTAND the physical universe. In other words, we can learn correctly how the natural world works and operates.

C. Empirically-accessible processes (that is NATURAL PROCESSES) are SUFFICIENT to explain or account for natural phenomena or events. In other words, scientists must explain the natural in terms of the natural.

D. Scientists ASSUME THAT NATURE "OPERATES" UNIFORMLY in both space and time (unless we have evidence to the contrary) in order to arrive at conclusions that have general applicability and utility. (This is known as the PRINCIPLE OF UNIFORMITY.)

Some Limitations of Scientific Knowledge:

E. Since our scientific knowledge is based only on human sensory experience of the natural world, it is subject to the BIOLOGICAL LIMITATIONS OF OUR SENSES. For example, we cannot "see" either infrared or ultraviolet light and we cannot hear extremely high or low sounds. While improved technology has clearly enhanced our senses, there are still limits to technological accuracy and range.

F. The intrinsic or unconscious mental processing of our sensory data is rooted in our previous experiences and can result in either INACCURATE or BIASED PERCEPTIONS of the world. For example, it has been said that we "see" with our our minds, not our eyes despite the common notion that we see things "objectively".**

G. It is impossible to know if we have thought of EVERY POSSIBLE ALTERNATIVE EXPLANATION and virtually impossible to control for EVERY POSSIBLE VARIABLE.

H. Scientific knowledge is necessarily CONTINGENT KNOWLEDGE (and therefore uncertain), rather than absolute knowledge (which is certain and eternally true). There are at least two reasons for this:

1. Scientific knowledge (including any given scientific explanation) is based only on available EVIDENCE that MUST BE EVALUATED and assessed (and is therefore subject to more than one possible interpretation) rather than on "proof" (which is indisputable & irrefutable).

2. The HISTORY of science DEMONSTRATES very clearly that SCIENTIFIC KNOWLEDGE IS SUBJECT TO MODIFICATION in light of new evidence and new ways of thinking. Indeed, the very questions and problems that science regards important at any given time are reflective of intellectual, sociological and political considerations that change over time.

NEVERTHELESS...

It is *extremely* important to understand that *despite* the inherent tentativeness or uncertainty of scientific *explanations* (and perhaps to a lesser extent, descriptive "*facts*") SCIENTIFIC KNOWLEDGE IS THE MOST RELIABLE KNOWLEDGE we can have about the NATURAL world and how it works. This is because scientists have developed a methodology for learning based on principles of CRITICAL THINKING that can enhance or increase greatly the reliability of scientific knowledge.

(**The double wording in this last sentence (item F above) is NOT a mistake; it is a visual "trick" intended to illustrate the idea of the sentence.)

III. THE REAL "SCIENTIFIC METHOD": CRITICAL THINKING

A. Assumptions and current knowledge (even "facts") are subject to regular REVIEW and RE-ASSESSMENT—especially in light of new evidence.

B. Ideally, scientific observations and/or experimental results require INDEPENDENT DUPLICATION and confirmation by others in order to gain credibility and acceptance.

C. Whenever possible, additional, INDEPENDENT DATA SETS are sought as supportive or corroborative evidence for an explanation. (Such evidence is termed CONCORDANT evidence.)

D. Scientific knowledge is PUBLIC KNOWLEDGE in that it is available for scrutiny and study by anybody who cares to do so.

E. EXPERTISE in knowledge is highly regarded, but there is no reliance on, or recourse to, any absolute authority to determine "the truth."

DANGER: BEWARE OF RELATIVISM!!

In the absence of certainty regarding the absolute truth of scientific explanations, scientists use **COMPARATIVE CRITICAL THINKING** to determine which explanation is MORE LIKELY TO BE CORRECT WHEN COMPARED TO THE ALTERNATIVES.

Such a comparative approach to evaluating knowledge enables one to avoid the pitfalls of "**relativism**" which is the view that any and all explanations are equally valid or worthy and that truth is merely a matter of opinion with there being no way for one to determine which opinion or explanation is *more* accurate, *more* likely to be correct, *better* supported and reasoned.

COMPARATIVE CRITICAL THINKING uses explicit CRITERIA (termed "epistemic" criteria) to evaluate the merits of one explanation compared to another. As already noted, ANY scientific explanation MUST deal only with empirical (natural) data but scientists consider one explanation BETTER than another the more it...

A. is consistent with known natural processes;
B. accounts for more data (especially separate, independent data sets);
C. has more reliable or greater predictive power;
D. accounts for previously unexplained or puzzling phenomena;
E. has fewer anomalies or exceptions left unexplained;
F. is simpler and less complicated (Occam's Razor); and
G. provides a fertile field for further research.

Since we can only compare the explanations (theories) we know about (or have thought of!) at a given point in time, we can never safely conclude that we have determined the one absolutely "best" or "true" explanation because we can never be certain that someone in the future won't develop a completely new theory that is even better than our "best" efforts today.

But by engaging in the comparative evaluation and assessment of alternative available explanations, modern science has developed a powerful and effective method for dealing with the uncertainty inherent in our scientific knowledge.

In at least one sense, the history of science is a record of our scientific efforts to REDUCE THE DEGREE OF UNCERTAINTY associated with our knowledge and understanding of how the natural world works and how it got to be the way that it is. In this sense then, by eliminating faulty or incorrect explanations, science can be said to "progress" and our confidence in some specific scientific knowledge—indeed, in the entire scientific process—can increase.

IV. SOME FORMS OF SCIENTIFIC KNOWLEDGE

FACT : a confirmed or, at least, agreed-upon empirical observation (or conclusion if referring to an "inferred" fact).

Scientific facts, even what appear to be simple observations, are themselves embedded in or rooted in the theories the observer holds.

HYPOTHESIS : a proposed explanation of certain "facts" that must be empirically testable in some conceivable fashion. (Plural: "hypotheses.")

A scientific hypothesis is really not proven true or correct; rather, it is either rejected (or "falsified") because it is determined to be inconsistent with the data, or, if not rejected, regarded as being "provisionally true" and kept as a working hypothesis to be used until found to be faulty in light of new evidence or further testing. Hypotheses that have withstood numerous, rigorous tests and not found to be "false" are often regarded as "facts" since they are effectively beyond rational dispute.

THEORY : an integrated, comprehensive explanation of many "facts" and an explanation capable of generating additional hypotheses and testable predictions about the way the natural world looks and works.

Scientific theories represent our best efforts to understand and explain a variety of what appear to be interrelated natural phenomena. Examples include the theory of relativity, cell theory, plate tectonics theory ("continental drift") and the theory of biological evolution through natural selection ("Darwinian" and "neo-Darwinian" theory).

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