The Acquisition of Scientific Knowledge via Critical Thinking: A Philosophical Approach to Science Education

Dr. Isidoro Talavera, Philosophy Professor and Lead Faculty, Department of Humanities & Communication Arts, Franklin University, Ohio, USA.

Abstract

There is a gap between the facts learned in a science course and the higher-cognitive skills of analysis and evaluation necessary for students to secure scientific knowledge and scientific habits of mind. Teaching science is not just about *how* we do science (i.e., focusing on just *accumulating undigested facts and scientific definitions and procedures*), but *why* (i.e., focusing on helping students learn to *think scientifically*). So although select subject matter is important, the largest single contributor to understanding the nature and practice of science is not the factual content of the scientific discipline, but rather the ability of students to think, reason, and communicate critically about that content. This is achieved by a science education that helps students directly by encouraging them to analyze and evaluate all kinds of phenomena, scientific, pseudoscientific, and other. Accordingly, the focus of this treatise is on critical thinking as it may be applied to scientific claims to introduce the major themes, processes, and methods common to all scientific disciplines so that the student may develop an understanding about the nature and practice of science and develop an appreciation for the process by which we gain scientific knowledge. Furthermore, this philosophical approach to science education highlights the acquisition of scientific knowledge via critical thinking to foment a skeptical attitude in our students so that they do not relinquish their mental capacity to engage the world critically and ethically as informed and responsibly involved citizens.[1]

I. Introduction: Science as Natural Philosophy, Critical Thinking, and Epistemology

Science was in antiquity fully a part of philosophy. But today, science and philosophy still share a strong connection besides *…their advancing frontiers [where] there is no sharp distinction to be made between science and philosophy;*[2] or, those philosophical questions that deal with foundational matters not directly addressed by science itself. In between the frontiers and foundations of science, there are the branches of science (positivist social sciences and natural sciences) that, as epistemologies, seek knowledge about how society (and the relationships among individuals within a society), the world, and universe around us works. For understood more broadly, the word *science* means *knowledge* (as it is derived from the Latin word *scientia*). This is consistent with the observation that science may be taken as the systematically organized body of knowledge we know about the natural or physical world.[3] And, because science is primarily concerned with knowledge claims and inquiries about physical reality, it may be considered a

[1]Under the leadership of Dr. Kody Kuehnl (Biologist, Chair of the Department of Science & Mathematics, Franklin University), the undergraduate courses, *Understanding Science* and *Introduction to Scientific Analysis & Reasoning*, and the graduate course, *The Nature and Practice of Science*, have been designed and developed by the author on the basis of this treatise (which has been in the works for the past 10 years).
[2]Lambert and Brittan, *An Introduction to the Philosophy of Science*, xii.
[3]For more on how science provides a special way of knowing about the world, see John A. Moore, *Science as a Way of Knowing*.

subfield of the Theory of Knowledge (also known as Epistemology). But, the Theory of Knowledge is a field of Philosophy.

To be sure, as Amy Cools notes in Science & Philosophy: A Beautiful Friendship: *[t]here's been some very public dig-taking between the science and philosophy camps lately. Lawrence Krauss, Neil DeGrasse Tyson, Stephen Hawking, and other scientists are saying philosophy's become irrelevant…*, but Cools reminds us that not only is (honest or true) philosophy not in competition with science, but science itself needs philosophy. As she goes on to note,

> *Looking outwards at the world provides the raw material for any system of thought. After all, as Aristotle, Hume, and the other empiricist philosophers point out, all knowledge begins with the information we receive through our senses. There is no reason to think that we could think at all if we have never heard, seen, felt, tasted, or smelled anything to think about. However, it's thinking that allows us to achieve more than just sensing the world would. And philosophy is the human species' way of taking the art of thinking as far as it can go: in doing philosophy we examine what the information we receive through our senses might mean in a larger context and in a deeper way….And as we ask and as we look, in the interplay between the input of our senses and the organization of information through our thought, science then affords reality 'the opportunity to answer us back', as Rebecca Newberger Goldstein so beautifully puts it in <u>Plato at the Googleplex: Why Philosophy Won't Go Away</u> (2014, p.34). But philosophy not only provides the impetus and the direction for scientific inquiry: once we find out the facts, it helps us figure out what to make of them. At every step of the way, from the application of the rules of logic, to the justification of why we should value or emphasize one set of facts over another in any specific application the formulation of scientific theories relies heavily on philosophy….[P]hilosophy is prior to, and necessary for, science. To separate philosophy from science is as unhelpful as divorcing the individual from the species: one does not function without the other.* In short, *[t]here is no honest philosophy without science, but there is no science at all without philosophy.*

Not surprisingly, then, because its main focus is to seek knowledge about the composition and order of everything in the physical universe, science may be characterized as *natural* philosophy.[4] As such, it seeks **to analyze and evaluate arguments**[5] for competing hypotheses in order to (hopefully) discover whether our beliefs correspond with the natural world and/or discover whether there are good reasons and arguments for believing so. And, by learning how to formulate, analyze, and evaluate arguments, the characteristics, methodology, and limitations of science may be contrasted to other alleged sources of knowledge. Accordingly, the

---

[4]Colodny, *Beyond the Edge of Certainty: Essays in Contemporary Science and Philosophy*, The Ethical Dimension of Scientific Research, 276.

[5]As noted by Kuhn, Teaching and Learning Science as Argument, 810: *A conception of science as argument has come to be widely advocated as a frame for science education …. Bricker and Bell (2009) identify argumentation as a 'core epistemic practice' of science and accordingly claim that the goal of science education must be not only mastery of scientific concepts but also learning how to engage in scientific discourse.* Underlying the individual skill in dialogic argumentation, however, is the skill of analyzing and evaluating arguments, which is the core part of critical thinking. Accordingly, throughout this treatise we use the term *argument* the way logicians do, to refer to a logical structure.

nature and practice of science is given expression in how the science student and/or scientist uses critical thinking—in what critical thinking makes them do with the means and methods of science, in how critical thinking describes and codifies the physical world, in which aspects of reality critical thinking focuses on, and in which beliefs critical thinking rightly avoids. So, since epistemology and critical thinking are the appropriate focus of attention for understanding the production of scientific knowledge, the foregoing strongly suggests a philosophical approach[6] to science education that highlights the acquisition of scientific knowledge via critical thinking.[7]

Nevertheless, there is a gap between the facts learned in a science course and the higher-cognitive skills of critical thinking necessary for students to secure scientific knowledge and scientific habits of mind.[8] This is problematic because most students do not major in science and will never need to do science themselves (although they may be required to take some science course(s)). Nonetheless, the chances are high that they will have to deal with some scientific issue that will affect their lives, which requires a level of higher-cognitive skills of critical thinking necessary to either support or challenge the possible solutions provided by the scientific community. In contrast, this is problematic because teaching those who major in science in a traditional university curriculum is usually much prescribed. Accordingly, these students require instruction focused entirely on facts and scientific procedures and on getting them right. In this learning outcomes-based approach, the passivity associated with just memorizing such content in a science course is at the expense of abstract thought, logic, and the reasoning process.[9] For, *…students should learn to do their own thinking about scientific questions from the beginning. Once students give up on trying to do their own scientific thinking and start passively taking in what their textbooks tell them, the spirit of science, the scientific attitude and frame of mind, is lost*.[10]

---

[6]Pecorino, Critical Thinking and Philosophy, 141-145.
[7]As noted by Rowe, *et al*., Redesigning a General Education Science Course to Promote Critical Thinking, 1-2: *A primary goal of education in general, and higher education in particular, is to improve the critical-thinking skills of students (Facione et al., 1995; Van Gelder, 2005; Bok, 2006). Sadly, higher education appears insufficient to the task, with recent studies (Arum and Roksa, 2010; Arum et al., 2011; Pascarella et al., 2011) showing minimal gains in students' critical-thinking and analytical skills during their undergraduate careers, reducing their employment potential upon graduation (Arum and Roksa, 2014).*
[8]As noted by Rowe, *et al*., Redesigning a General Education Science Course to Promote Critical Thinking, 1: Not only do *[r]ecent studies question the effectiveness of a traditional university curriculum in helping students improve their critical thinking and scientific literacy*…[but, it has also been shown that] *emphasizing the process and application of science rather than just scientific facts can lead to improved critical thinking and scientific literacy*.
[9]As noted by Rowe, *et al*., Redesigning a General Education Science Course to Promote Critical Thinking, 2: *Commonly identified causes of the impotency of science courses, especially the introductory courses taken by the majority of college students, are their tendency to focus on scientific 'facts' rather than on the nature of science (Johnson and Pigliucci, 2004; Alberts, 2005), often reinforced by exams that reward memorization over higher-order thinking (Alberts, 2009; Momsen et al., 2010); the reluctance to directly engage students' misconceptions (Alters and Nelson, 2002; Nelson, 2008; Alberts, 2005; Verhey, 2005); the failure to connect 'science as a way of knowing' with decisions faced by students in their daily lives (Kuhn, 1993; Walker et al., 2002); and the resistance of faculty trained in more innovative pedagogical approaches to actually employ them (Ebert-May et al., 2011). The traditional approach to science education not only fosters scientific illiteracy, but also alienates many students from science (Seymour and Hewitt, 1997; Ede, 2000; Johnson, 2007) and, ultimately, jeopardizes America's global competitiveness (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2010).*
[10]Paul (with Binker), Chapter 38: Critical Thinking and Science, 612.

Unfortunately, whether you major in science or not, a standardized science curriculum is usually spoon-fed to a captive audience of students to meet the demands of instruction focused entirely on facts and procedures and on getting them right.[11] As a result of all of this, convergent thinking is encouraged. However, critical thinking is typically incompatible with convergent thinking. For, *[i]f everyone is thinking alike, then no one is thinking.*[12] Furthermore, given the broad range of individual differences of our students in most science classrooms, and that these students must be actively involved in determining how they are going to learn, not all standardized science programs will be able—or even want—to develop critical thinking skills.[13] Nevertheless, that students must be actively involved in what is learned in a science course is important, since *critical thinking [as a purposeful mental activity] is an active skill-building process, not a subject for passive academic study. Moreover, . . . it cannot be mastered through knowledge of norms and rules alone.*[14]

To compound the problem, many science instructors are simply not able to master and teach critical thinking well[15] and/or are not entirely effective in passing on scientific knowledge or critical thinking skills because they are themselves suffering from cognitive dissonance. As noted by Eve and Dunn,

> *[a] review of recent reports on the state of education in the U.S. indicates that there is much concern today over whether science teachers have received adequate instruction in the philosophy and methodology of science. Because this type of training is a critical tool for distinguishing between bogus scientific beliefs and valid scientific findings, it is likely that some teachers may not have the educational foundation necessary for recognizing pseudoscientific claims….*[So, for example,] *while there are many qualified and even exemplary biology teachers, the number of those who* [do] *not exhibit adequate scientific reasoning skills is significant enough to justify alarm.…*[Moreover,] *a significant proportion of high school life science and biology teachers hold many beliefs which are at odds with mainstream science….* [Thus,] *many teachers are not only failing to impart basic information on the scientific method to their students, but are also likely to be misinforming students because of their own beliefs in pseudoscience.*[16]

---

[11]Walker, *et al*., 2002.
[12]Attributed to Benjamin Franklin, among others.
[13]See Talavera, The Problem of Teaching Critical Thinking: Three Approaches, parts of this paragraph were adapted.
[14]Mayfield, 5.
[15]Unfortunately, learning to teach critical thinking (and assessing an instructor's success teaching it) is not quite so straightforward as the outcome-based minded may think—pragmatically linking, for example, critical thinking with Bloom's Taxonomy. No matter how practical it *sounds*, this is an example of picking the wrong tool for the job. For, this approach is flawed. In *Critical Thinking: What Every Person Needs to Survive in a Rapidly Changing World* (Chapter 31: Bloom's Taxonomy and Critical Thinking Instruction: Recall is not Knowledge), the philosopher Richard W. Paul argues that while Bloom's distinctions themselves are important, the common understanding of their link to critical thinking is largely misconceived. In contrast, our model for this treatise is a philosophical approach across the curriculum that is based on the reality that philosophy students *... are among the few majors who actually receive formal training in critical thinking, through courses explicitly designed for that purpose, as well as through rigorous training in logical and conceptual analyses of any course material to which they are exposed* (Johnson and Pigliucci, Is Knowledge of Science Associated with Higher Skepticism of Pseudoscientific Claims? *The American Biology Teacher*, 547).
[16]Psychic Powers, Astrology & Creationism in the Classroom? Evidence of Pseudoscientific Beliefs Among High School Biology & Life Science Teachers, 13-21.

Such conflict of interests is a serious problem, since learning also occurs by doing what the teacher models. Accordingly, such compromised instructors are in no position to encourage their students to interrupt lectures with questions, partly to raise the plane of comprehension, partly to keep them (divergently and critically) thinking, and partly to generate self-discovered and self-appropriated learning through discussion. For, the very act of thinking critically in a science class is a way of engaging the material, wrestling with it, struggling to comprehend or to take issue, but in any case entering into the subject. And, to do otherwise undermines the values and epistemological presuppositions of the teaching of critical thinking, and undercuts the fundamental shift in the educational philosophy required to avoid limitations for critical thinking curriculum construction.

Finally, teaching science is not just about ***how* we do**[17] science (i.e., focusing on just *accumulating undigested facts and scientific definitions and procedures*), but ***why*** (i.e., focusing on helping students learn to *think scientifically*). So although select subject matter is important, the largest single contributor to understanding the nature and practice of science is not the factual content of the scientific discipline, but rather the ability of students to think, reason, and communicate critically about that content. This is because

> *[a] critical approach to teaching science is concerned less with students accumulating undigested facts and scientific definitions and procedures, than with students learning to 'think scientifically.' As students learn to think scientifically they inevitably do organize and internalize facts, learn terminology, and use scientific procedures. But they learn them deeply, tied into ideas they have thought through, and hence do not have to 're-learn' them again and again.*[18]

This is achieved by a science education that helps students directly by encouraging them to develop the critical thinking skills necessary to analyze and evaluate all kinds of phenomena, scientific, pseudoscientific, and other. Accordingly, critical thinking may help to introduce the major themes, processes, and methods common to all scientific disciplines. This is so that the student (or citizen) may develop an understanding about how science works and develop an appreciation for the process by which we gain scientific knowledge. But, this also requires that we foment a skeptical attitude in our students so that they do not relinquish their mental capacity to engage the world critically and ethically via analysis and evaluation. For, without a skeptical attitude, natural human biases and limitations would inevitably lead a person to hang on to a preferred belief and ignore or resist all other alternatives. And, this could lead to a gradual hardening of beliefs that would seriously impede scientific inquiry and the attainment of scientific knowledge.

As we shall see, this philosophical approach to science education not only seeks to perfect and sharpen the tools of thought to help rein in, modify, and/or correct beliefs about the natural or

---

[17]**How we *do*** science should not be confused with **how we *know* it**. **How we *do*** science focuses on ***what* we know** (facts, definitions, and procedures); ***how* we know** focuses (at the very least) on analysis, which is a key component of critical thinking (we will adopt throughout a common core definition of *critical thinking* that emphasizes the elements of *analysis* and *evaluation*). Accordingly, a science course intended to provide insights into scientific reasoning and its critical method would be handicapped, if it simply focused on *how* science works or put all its eggs in the *analysis* basket. Unfortunate title aside, see *How Science Works* by Norton for an excellent introduction to analysis in the scientific approach and its product.

[18]Paul (with Binker), Chapter 38: Critical Thinking and Science, 610.

physical world, but to highlight what is perhaps the most valuable result of all science education—critical thinking skills that help the informed and responsible citizen and trained scientist alike do the thing that must be done, when it **ought** to be done, whether it is popularly accepted or not. All this suggests that science is not limited to observations, measurements, and experiments (i.e., empiricism), but also requires a healthy dose of methodological skepticism,[19] a good deal of logic providing good reasons and arguments for believing (i.e., rationalism), and ethical analysis and evaluation (i.e., ***critical ethics***[20]) to combat the impediments to knowledge: cognitive dissonance, bias, and intellectual dishonesty.

II. The Story of the Blind Men and an Elephant: The Problem of the Acquisition of Scientific Knowledge

For those engaged in the process of the acquisition of scientific knowledge, there must be the realization that our beliefs do not always correspond with reality; we must set up a way to critically know reality on its own terms. One way to do this is to try to overcome obstacles to reliable reasoning and clear thinking by focusing on a common core understanding of critical thinking that is more about taking some **argument** apart, via analysis, and evaluating whether some derived conclusion follows from the evidence. This is important because without critical thinking there will be problems that influence the quality and reliability of scientific knowledge.

Consider, for instance, the story of **the blind men and the elephant**.[21] This story represents the problem of how people typically distort or misunderstand the process of the acquisition of knowledge. For in this metaphor, an epistemological problem surfaces—a group of blind men are trying to *know* what an elephant (sight unseen) is, but can only focus narrowly on a part of this animal they perceive primarily through the sense of touch. Depending on the part of the elephant each is touching, the whole elephant may be taken to be (like) a fan (the elephant's ear), wall (the elephant's side), tree (the elephant's leg), snake (the elephant's trunk), spear (the elephant's tusk), and rope (the elephant's tail). In a nutshell, the blind men distort or misunderstand what they supposedly *know* about an elephant when each defines knowledge too narrowly and then derives false general conclusions. In this treatise, we will connect this to the importance of developing critical thinking skills, which not only helps us to better understand and evaluate all sorts of scientific claims and arguments, but helps us to analyze and evaluate popular sources of (mis)information.

One interpretation of this ancient parable is that **belief** based on one's experience cannot *by itself* constitute knowledge because it is inherently limited by its failure to account for other reality or a totality of reality. To be sure, that each observation must correspond with (all) the physical parts of the elephant begs the question. For, the problem of the blind men and the elephant is that each belief is based on evidence limited to just a mere touch so that each individual can (at best) be partly right. As a result, even if held dogmatically, there is a slim chance that each belief would paint the picture of the reality sight unseen of the elephant. Moreover, as we shall see later

[19]Walker, *et al*., 2002.
[20]Here we use the term in a noteworthy and possibly new fashion. More about *critical ethics* later.
[21]Here I follow Lee's approach to bookend the content of his *The Scientific Endeavor: A Primer on Scientific Principles and Practice* using the same metaphor (by addressing **the blind men and the elephant** in **Section II** and then in **Section IX**).

on, **belief is not knowledge**. So, if we limited what we *know* to just our sense of touch of an elephant's ear (a **descriptive study** where correlation plays no part), we would more than likely come up short with the strongly held belief that an elephant was **like** a fan (or some similar opinion).

This highlights the problem of getting to know the elephant as reasoning from a **part** to a **whole**. Here we argue from observations about some part of a thing's characteristics to a claim about the entire thing. One side of the problem of knowledge, then, is to ask whether an individual can *empirically* know that this is an elephant. One way to answer this question is by evaluating, for instance, **the fan-belief argument** as follows.

1) **Part** of the elephant is (like) a fan.
----
2) Thus, the **whole** elephant is a fan.

This informal way of reasoning constitutes a leap from a single observation to a general conclusion about what is possibly *out there* in the physical world. This is because attempts to generalize properties by drawing conclusions from the part to the whole take the following form (let **X** be a **thing** or **group of things**).

1) Part of **X** has a specific property.
----
2) Thus, the whole **X** has a specific property.

So, when we look at this argument form critically (i.e., via analysis and evaluation) we can see that the derived conclusion need not always follow from the premise. The problem with arguments that adopt this form is that they are **inductive** arguments.[22] Informal logic here would note that such inductive arguments are weak and/or not cogent; probability and statistics would note the low probability for the conclusion, given the small sample observed. Either way, we can see why there is **uncertainty** involved when one takes such leaps from what is observed (by any of our senses) to what is the general case. Accordingly, we can understand why the blind men of the story may *each be partly in the right, but all be in the wrong about the elephant*.[23]

A variant form of reasoning from a **part** to a **whole** is known as reasoning from a **sample** to a **population**. Here we usually make a statement about a sample (an observation about some of a group's characteristics) that is generalized as a statement about a population (a claim about the whole group).[24] However, when we look at this form of reasoning we can also see that the

[22]In **inductive** arguments, the premises are intended to provide some (strong or weak) evidence for the conclusion and so **the conclusion follows with some uncertainty**; in **deductive** arguments, the premises are intended to prove the conclusion and so the **conclusion follows with certainty**. See Induction and Scientific Reasoning (http://www.youtube.com/watch?v=w-bm-Cxg40E&feature=related), Inductive Arguments (http://home.southernct.edu/~gillilandr1/Tutorial/3.htm), and What is a *STRONG* argument? (http://www.youtube.com/watch?v=LXMAR63TVDI&feature=related)). Accessed Jan. 7, 2016.
[23]See The Blind Men and the Elephant by John G. Saxe (https://www.youtube.com/watch?v=bJVBQefNXIw). Accessed Jan. 5, 2016.
[24]See Sampling Population Sample and Generalizability (http://www.youtube.com/watch?v=IOBYsdgGhVw). Accessed Jan. 7, 2016.

derived conclusion need not always follow from the premise. Someone, for example, may sample at a fruit stand a peach that is spoiled and conclude that all peaches there are spoiled. The premise (**A peach is spoiled at this fruit stand**) does not adequately support the conclusion (**All peaches are spoiled at this fruit stand**). Again, this means that the reason provided as evidence for the conclusion is inadequate for accepting the conclusion. The problem with arguments like these is that they are inductive arguments. And, this means that the certitude of the conclusion varies and is probabilistic at best. Accordingly, we have to be skeptical about reasoning like this all the time. If not, then we commit the **fallacy of hasty conclusion**.

A **fallacy** is **an argument that has gone wrong**, **but can often be mistaken for a good argument**. Unfortunately, there are many ways people accept conclusions for the wrong reasons. For instance, reasons that are unacceptable, irrelevant, or insufficient do not adequately support the conclusion of an argument. This suggests that a fallacy is committed when an argument under consideration does not justify accepting its conclusion. This happens when the premise or premises do not adequately support the conclusion. This means that the reason or reasons provided as evidence for the conclusion are inadequate for accepting the conclusion. Consider again, for instance, an example of the previous argument form (gone wrong) that attempts to generalize properties by drawing conclusions from the part to the whole (**part-whole fallacy**):

1) **Part** of the aging population has lived to a healthy ripe old age.
---
2) Thus, the **whole** of the aging population will live to a healthy ripe old age.

We can clearly see why this is an argument gone wrong because it involves fallacious reasoning. A fallacy is committed because this argument does not justify accepting its conclusion that the whole of the aging population will live to a healthy ripe old age. That is to say, the premise (**Part of the aging population has lived to a healthy ripe old age**) does not adequately support the conclusion (we know, for example, that given that the premise is true, the conclusion can still be false). This means that the reasons provided as evidence for the conclusion are inadequate for accepting the conclusion.

The **fallacy of biased sampling** is related to all this, since we should not make generalizations about the whole by just studying a part. So, we should not make generalizations about the whole of the aging population living to a healthy ripe old age by just studying a part of the aging population that has lived to a healthy ripe old age. One can avoid such a fallacy by ensuring that all members of the population studied have an equal chance of being sampled to obtain a representative and unbiased part of the whole. Attempts to generalize properties by drawing conclusions from the part to the whole can also be seen in the **anecdotal fallacy**. When we provide an example or story from our own experience in an attempt to support a broad generalization, we commit the **fallacy of anecdotal evidence**.[25] The problem, of course, is that a mere example or story, no matter how entertaining or gripping, serves as limited evidence for a sweeping generalization. It is a weak **inductive** argument. Accordingly, we have to also be skeptical about reasoning like this.

[25]See The Problem with Anecdotes (http://www.youtube.com/watch?v=16E-4avtddE). Accessed Jan. 7, 2016.

III. The Problem of Induction

The underlying limitation of **inductive** arguments is known as **the Problem of Induction**.[26] As interpreted by the philosopher David Hume, the problem of induction is that many of our beliefs are at least partly about what is not presently being remembered or observed by us. The inference that the sun will rise tomorrow, for instance, is beyond the present testimony of our memory or senses. Hume noted in *An Enquiry Concerning Human Understanding*[27] that past experience ...*can be allowed to give direct and certain information of those precise objects only, and that precise period of time, which fell under its cognizance*. That such experience is extended to other objects and to future times is taken to be the problem of induction by Hume and his followers, since acquiring knowledge of general truths on the basis of induction requires more than what is observed in the past. And since, according to Hume, all our observations are of the past, for inductive inferences to be justified (sight unseen) the past must resemble the future. The Problem of Induction is a problem for science because *[s]cientific methodology generally starts from the observation of particular events and arrives at a generalization by the process of induction*.[28] In view of that, the Problem of Induction may be expressed in the following form.

1. All observed F's are G's.
----
2. Thus, all F's are G's.

So, for instance, we can set up the conclusion that **all swans are white** on the basis of the following argument.

1. All observed swans are white.
----
2. Thus, all swans are white.

But again, when we look at this argument form and its instantiation we can see that the derived conclusion need not always follow from the premise. Black swans found in Australia are a counterexample. So the premise does not adequately support the conclusion, for it may be true that all the swans we have observed are white, yet it would be clearly false that **all swans are white**.

A variant form of the above reasoning is making a list of white swans. So, when we generalize from one or more specific examples in support of a sweeping statement (or generalization) we obtain an **Argument by Example**. The general form of an Argument by Example is the following.

1) F_1 is a G.
2) F_2 is a G.

---

[26]See The Problem of Induction (http://www.youtube.com/watch?v=dz7fUIxaRb8) and Philosophy of Science: Hume's Problem of Induction, Two Solutions? (http://www.youtube.com/watch?v=k09yrQwFIqo). Accessed Jan. 10, 2016.
[27]78.
[28]Levine and Elzey, *A Programmed Introduction to Research*, 23.

3) F_3 is a G.
i) …etc.
n) F_n is a G.
----
n+1) Thus, all F's are G's.

For example, an inductive argument about swans listing *n* premises (as many as you want to list) may be formulated as the following.

1) Swan #1 is a white swan.
2) Swan #2 is a white swan.
3) Swan #3 is a white swan.
i) …etc.
n) Swan #n is a white swan.
----
n+1) Thus, all swans are white.

However, when we look at this argument form and its instantiation we can see that the derived conclusion need not always follow from the premises. We may note, again, that in Australia there are black swans. So the premises do not adequately support the conclusion, for it may be true that all the swans we have observed are white, yet it would be clearly false that **all swans are white**.

It is important to note, however, that as the observed number of cases of white swans increases (i.e., evidence grows), the argument above gets **stronger**; as the observed number of cases of white swans decreases (i.e., evidence shrinks), the argument above gets **weaker**. So if you want to argue persuasively using this type of inductive argument, you must provide a great deal of evidence to make it a **strong** argument. When considering the **strength** of the inductive argument, however, each premise of the sequence of statements used to demonstrate a conclusion may be true, and the conclusion still turn out false. But even if the conclusion turns out false (given true premises), the argument may still be characterized as **strong**.

Strong inductive arguments are typically found in cases where the conclusion is highly **probable** based on the premises (i.e., **strong** evidence for the conclusion is provided). So, for instance, if a very reliable scientific organization states (or claims) that **90% of smokers get lung cancer**, we say that the argument for a **person probably getting lung cancer** is strong (although it may turn out that some people who have smoked all their lives won't get the disease!).

A **properly formed** argument by example gives more than one example, uses representative examples, provides background information, and considers counterexamples.[29] The reason we need to consider counterexamples is to test whether the sweeping statement (or generalization) goes too far beyond the evidence given. As mentioned earlier, this is because for inductive arguments even if each premise of the sequence of statements used to demonstrate the sweeping statement (or generalization) were true, the conclusion can still be false. So if the counterexample shows that a sweeping statement (or generalization) goes too far beyond the

[29] Weston, *A Rulebook for Arguments*, Chapt. 2.

evidence given, the sweeping statement (or generalization) may have to be revised, limited, or given up. But how many examples are necessary? This depends partly on the size of the set of examples in support of the sweeping statement (or generalization). If the size of the set of examples is small, for the inductive argument to be properly formed one must consider all, or the majority of, the examples. Before we can evaluate the one or more specific examples, however, we often need background information. For instance, suppose someone states that handbag thefts in a particular department store have increased 100 percent. Notice that background information would reveal that the sample is too small for one to reach the sweeping conclusion that theft is out of control, if this means that only two handbags were stolen rather than one in that particular department store.

How many examples are necessary also depends partly on their representativeness. So if the size of the set of examples is too large to list, for the inductive argument to be **properly formed** one must consider a representative sample. But all of this requires that we evaluate the set of examples in support of the sweeping statement (or generalization). Unfortunately, if the size of the set of examples is too large to list, for the inductive argument to be **properly formed** one must rely on some authority. Accordingly, we will sometimes have to rely on established polling companies or other very reliable organizations when considering sweeping statements (or generalizations). This means that we must **cite sources that know what they are talking about and are fair and objective**. Finally, we must **cross-check sources**—we must make sure that sweeping statements (or generalizations) are reliable by looking them up for verification in other sources.[30]

Of course, a great deal about how big the sample should be cannot be explained without a basic Statistics course. **Statistics** is a branch of study concerned with the collection, analysis, and evaluation of data to either describe the basic features of the data (descriptive statistics) or draw conclusions from the data (inferential statistics) of a study or experiment. It relies on a type of inductive reasoning that helps the investigator effectively communicate and present the results that rely on data (descriptive statistics), as well as learn something from data (inferential statistics). Accordingly, we can reformulate in statistical terms a **strong** inductive argument form to help make a working inference about the aggregate of swans from a large sample of such large flying birds.

1) **90%** of swans are white.
2) X is a swan.
----
3) Thus, X will probably be white.

But when considering the **strength** of the inductive argument (when X is instantiated), it may also be the case that each premise of the sequence of statements used to demonstrate the conclusion is **true**. So if we also have true premises, then we have a **cogent** (or convincing) argument. That is to say, a cogent argument is a **strong** argument with **true** premises. Only inductive arguments can be cogent. **Cogent** inductive arguments are typically found in **science**—where the conclusion is highly **probable** based on the premises (i.e., **strong** evidence for the conclusion is provided with verified premises).

[30]Ibid, Chapt. 4.

This points to a possible, though controversial, way out of the Problem of Induction suggested by Stephen Campbell in his *Flaws and Fallacies in Statistical Thinking*:

> *The principal function of many formal statistical procedures is to help researchers make valid inferences about the aggregate of items of interest from a sample of such items. When certain rules are followed and precautions taken, such inferences can enjoy a high probability of being correct. Moreover, they can be most helpful in contributing to sound decisions with less cost, less loss of time, and maybe even greater accuracy than if a complete census were undertaken. But these rules and precautions must be observed religiously; otherwise, sampling only serves to delude the decision makers and others into thinking that a conclusion has been reached in a scientific manner*.[31]

For a sample to be scientifically generalized it must first be *...precisely defined by means of a sampling frame, a set of criteria that make it clear for any specific thing whether or not it is a member of the population and whether or not it has the attribute of interest*.[32] Accordingly, a sampling frame may be secured by ensuring that the sample under consideration is not biased. There are several ways a sample may be biased: when it is **not** (1) **random**, (2) **large enough**, and/or (3) **representative**. These three notions characterize probability sampling and are found missing in non-probability sampling. The source of bias may be found in either the sampling process (e.g., convenience sampling, street surveys, mail out questionnaires, self-selection, etc.) or interview process (e.g., loaded questions, respondent lying, etc.).

Hence, reasoning from a sample to a population *in a scientific manner* so that a claim about a population (a claim about the entire group) is probable requires that we argue from observations about some of a group's members or characteristics to a claim about the entire group such that 1) Sample S is a proper subset of the population, 2) S is random, 3) S is large enough, and 4) S is representative. So, when we look at an argument form with these elements we can see that the derived conclusion may follow from the premises with a high probability of being correct. Since science relies heavily on this type of reasoning (of inferential statistics), some of the factors that influence the quality and reliability of a sampling or collection of scientific information has to do with the problems of bias and the limitations of sampling methods.

Finally, science sometimes has to do with attempts to forecast properties by drawing conclusions from the comparisons made among things (e.g., examples, cases, or states of affairs). This is called **Analogical Induction** and may be taken as a relevant form of inference in science. The goal here is to draw a conclusion from the comparisons made between two things so that if these two things are alike in some respects, then they will be alike in one or more respects. One may look at two things and reason that the more number of properties the two things have in common, the **stronger** the argument will be that the two things will be alike in other respects. The less relevantly similar they are, however, the less number of properties the two things have in common. And the less number of properties the two things have in common, the **weaker** the argument that the two things will be alike in other respects. A **properly formed Argument by Analogy**, then, provides a relevantly similar example.

[31]Campbell, *Flaws and Fallacies in Statistical Thinking*, 136.
[32]Moore and Parker, *Critical Thinking*, 342.

One way to state the general form of an Argument by Analogy is the following. The argument below states that because two things (**T_1** and **T_2**) are alike in many ways (things **T_1** and **T_2** have properties **P_1, P_2, P_3, P_4,**…, and **P_n** in common) they are also alike in one further specific way (P_{n+1}).

1) **T_1 has properties P_1, P_2, P_3, P_4,…, and P_n.** (as many properties as you want to list for thing #1)
2) **T_2 has properties P_1, P_2, P_3, P_4,…, and P_n and P_{n+1}. (P_{n+1}** is an extra property that thing #2 has)
3) **T_1 is like T_2.** (Because **T_1** and **T_2** have properties **P_1, P_2, P_3, P_4,…, and P_n** in common)
----
4) **Thus, T_1 has property P_{n+1}.**

Let's consider an Argument by Analogy with only three properties (P_1, P_2, and P_3).

1) T_1 has properties P_1 and P_2.
2) T_2 has properties P_1, and P_2, and P_3 (P_3 is an extra property that T_2 has)
3) T_1 is like T_2. (Because T_1 and T_2 have properties P_1 and P_2 in common)
----
4) Thus, T_1 has property P_3.

Specifically, if we let **T_1** be **people's bodies, T_2** be **Cars, P_1** be **may break down**, **P_2** be **develop major problems**, and **P_3** be **should be taken for regular service and checkups**, the Argument by Analogy produced is as follows.

1) People's bodies (have the properties that they) may break down and develop major problems.
2) Cars (have the properties that they) may break down and develop major problems and should be taken for regular service and checkups. (P_3 is an extra property that T_2 has)
3) People's bodies are like cars. (People's bodies and cars have properties P_1 and P_2 in common.)
----
4) Thus, people's bodies (have the properties that they) should be taken for regular service and checkups.

When we look at this **argument** critically (i.e., via **analysis** and **evaluation)** we can see that in this case the derived conclusion follows from the reasoning. But, we have to be skeptical about reasoning like this all the time. The problem with Arguments by Analogy is that they are **inductive arguments**. And, this means that the certitude of the conclusion varies and is probabilistic at best.

Again, let's consider another Argument by Analogy of the same type with only three properties, but with a different extra property that cars have. Specifically, if we let **T_1** be **people's bodies, T_2** be **cars**, **P_1** be **may break down**, **P_2** be **develop major problems**, and **P_3** be **can have their defective parts replaced**, the Argument by Analogy produced is as follows.

1) People's bodies (have the properties that they) may break down and develop major problems.
2) Cars (have the properties that they) may break down and develop major problems and can have their defective parts replaced. (P_3 is an extra property that T_2 has)

3) People's bodies are like cars. (People's bodies and cars have properties P_1 and P_2 in common.)
----
4) Thus, people's bodies (have the property that they) can have their defective parts replaced.

Notice that this time the conclusion is very uncertain. Although chances are that replaceable human body parts will be easily available in the future, given the present status of medical technology the conclusion is in doubt.

IV. Arguments about Causes

A **properly formed** argument about causes explains how cause leads to effect, proposes the most likely cause, avoids correlated events that are not necessarily related, avoids correlated events that may have a common cause, avoids either of two correlated events that may cause the other, and acknowledges that because causes may be complex rarely does one take hold of the one and only cause.

In an **Argument about Causes,** a correlation is the evidence supplied in an attempt to support a conclusion about causes. In this context, a correlation is a mutual relationship that is thought to exist between two events or types of events. Specifically, a (bivariate) **correlation** is an **association**, **relationship**, or a **correspondence between two variables** (or changing events, factors, or things). The *basic* form of this type of inductive argument may be symbolized as follows (let $\mathbf{E_1}$ be **Event #1** and $\mathbf{E_2}$ be **Event #2**).

1) E_1 correlates with E_2.
----
2) Thus, E_1 causes E_2.

But this argument form is fallacious. Consider a substitution instance that highlights the correlation between homicides and ice cream sales.

1. When ice cream sales increase, the rate of murders also increases.
----
2. Thus, ice cream causes murders.

So, for example, one may argue that because **an increase in ice cream sales** ($\mathbf{E_1}$) is (positively) correlated with **an increase in murders** ($\mathbf{E_2}$), **an increase in ice cream sales** ($\mathbf{E_1}$) caused **an increase in murders** ($\mathbf{E_2}$). This is a fallacy. As we learned earlier, a **fallacy** is an **argument** that has gone wrong, but can often be mistaken for a good argument. Unfortunately, there are many people that accept such a conclusion that something must be accompanied by something else (whether it's actually true or not) based on informal observation. Such correlation usually serves as the basis for superstitious belief or magical thinking (more about this later).

As we learned, our common core understanding of **critical thinking** is about taking some **argument** apart using **analysis** and **evaluating** whether some derived conclusion follows from the evidence. When we look critically at the **argument form** above, we can see that the derived conclusion ($\mathbf{E_1}$ **causes** $\mathbf{E_2}$) need not always follow from the premise ($\mathbf{E_1}$ **correlates with**

E_2). The correlation may be just coincidental. So, we must be careful. There are some pitfalls to consider when arguing from correlation to cause. For instance, E_1 and E_2 may not be related. Accordingly, correlation does not always involve causation (i.e., empirically observed correlation is a necessary, but not sufficient condition for causation). This means that the certitude of the conclusion may be in doubt. Accordingly, we have to be skeptical about this type of reasoning. If we're not skeptical about this type of reasoning, we might commit the **fallacy of correlation equals causation** (or, **fallacy of false or questionable cause**).

A variation of this is called ***Post hoc ergo propter hoc*** (Latin: *after this, therefore because of this*). For our purposes, this simply is interpreted as the argument form.

1. **X** occurs before **Y.**
----
2. Thus, **X** is the cause of **Y**.

For example, drinking a warm glass of milk before going to bed to get to sleep is a correlation we are familiar with. There is a mutual relationship that is thought to exist between drinking a warm glass of milk before going to bed (E_1) and sleepiness (E_2). Accordingly, if we let **E_1** be **drinking a warm glass of milk before going to bed** and **E_2** be **sleepiness**, then the basic **Argument about Causes** is revealed as follows.

1) Drinking a warm glass of milk before going to bed correlates with sleepiness.
----
2) Thus, drinking a warm glass of milk before going to bed causes sleepiness.

The pitfall here is to argue from correlation to cause without realizing that drinking a warm glass of milk before going to bed (E_1) and sleepiness (E_2) may not be related. For instance, maybe it is a mere coincidence that sleepiness is associated with drinking a warm glass of milk before going to bed. Given, for example, that a person may simply be very tired and would have experienced sleepiness anyway, it would be doubtful that drinking a warm glass of milk before going to bed *causes* sleepiness.

Another pitfall to consider when arguing from correlation to cause is that correlated events may have a common cause. For instance, maybe drinking a warm glass of milk before going to bed (E_1) should not be associated with sleepiness (E_2)—and thus, should not express a relation between cause and effect—because E_1 and E_2 may represent two effects of some third more basic factor. Given, for example, that a person may simply be very tired and would have experienced sleepiness anyway, it is reasonable to suppose that being very tired may be the common cause (E_0). So, drinking a warm glass of milk before going to bed (E_1) and sleepiness (E_2) may both be caused by one being very tired (E_0).

Furthermore, there is the pitfall that either of two correlated events may cause the other. Remember, a correlation is a mutual relationship that is thought to exist between two events or types of events. For a mutual relationship, however, the relationship may go both ways. And if the relationship goes both ways, then **E_1 correlates with E_2** means that **E_1 relates with E_2** or **E_2 relates with E_1**. The problem with this is that E_2 could lead to E_1 as reasonably as E_1 leads to E_2.

Accordingly, there are two possible ways to look at the basic form of the **Argument about Causes**: Form A and Form B.

Form A:	Form B:
1) E_1 correlates with E_2. --------------------------------	1) E_1 correlates with E_2. --------------------------------
2) Thus, E_1 causes E_2.	2) Thus, E_2 causes E_1.

Because of the possibility that the causal connection may run the other way (or perhaps it goes both ways) and we cannot determine the causal direction, we are not entitled to argue as Form A above. In such cases, it is best to not give too much weight to the conclusion and just acknowledge that because **causes may be complex** rarely does one take hold of the one and only cause.

For instance, there is a mutual relationship that is thought to exist between snowing (E_1) and coldness (E_2). Accordingly, if we let $\mathbf{E_1}$ be **snowing** and $\mathbf{E_2}$ be **coldness**, then there are two possible instances of the basic form of the **Argument about Causes**: Form A and Form B.

Form A:	Form B:
1) Snowing correlates with coldness. ---	1) Snowing correlates with coldness. ---
2) Thus, snowing causes coldness.	2) Thus, coldness causes snowing.

For this mutual relationship, the relationship may go both ways. And if the relationship goes both ways, then **snowing correlates with coldness** means that **snowing relates with coldness** or **coldness relates with snowing**. The problem with this is that coldness could lead to snowing as reasonably as snowing leads to coldness. Because of the possibility that the causal connection may run the other way (or perhaps it goes both ways) and we cannot determine the causal direction, we are not entitled to argue as Form A above. Again, in such cases it is best to not give too much weight to the conclusion and just acknowledge that because causes may be **complex** rarely does one take hold of the one and only cause.

For an argument about causes to be **properly formed**, then, it must do more than simply appeal to a supposed correlation in an attempt to support a conclusion about causes. That E_1 correlates with E_2 does not establish that E_1 causes E_2. An **Argument about Causes** must, for instance, also explain[33] how cause leads to effect. For our purposes, this may take the following general argument form:

---

[33]**Explanations** may be confused for **arguments**, since they resemble one another. In an **explanation**, the aim is to show **why** some claim (or conclusion) **in fact** is the case, which amounts to producing a single **statement** giving reasons (or details) for an accepted claim (or conclusion). This may be understood as taking the form: [the claim being explained] **because** [the explanation]. In contrast, in an **argument** the goal is to produce a sequence of statements (a set of premises and a conclusion) where the premises are **intended** to **prove** or at least provide some **evidence** for a claim (or conclusion). For example, **explaining** why O.J. Simpson murdered his wife is not the same as **arguing** that O.J. Simpson murdered his wife. Explaining **why-in-fact** O.J. Simpson murdered his wife takes it as a given that he did actually murder his wife and then proceeds to give reasons (or details) to account for this (in the extreme, possibly revealing a confirmation bias). So, for instance, one might say that **The *reason* O.J. Simpson murdered his wife is that he was a jealous husband**. This can also be expressed as [the claim being explained]

1) E_1 correlates with E_2.
2) [A statement explaining how E_1 causes E_2.][34]
----
3) Thus, E_1 causes E_2.

Furthermore, explaining how cause leads to effect may require an appeal to authority. When we provide a statement made by an authority figure in support of a conclusion, we obtain an Argument from Authority. The general form of an Argument from Authority is the following.

1) X (an authority on Z) says Y.
----
2) Thus, Y.

For example, if we let **X** be **the Surgeon General**, **Y** be **smoking causes cancer**, and **Z** be **health and medicine**, the inductive argument produced is as follows.

1) The Surgeon General (an authority on health and medicine) says smoking causes cancer.
----
2) Thus, smoking causes cancer.

This is an inductive argument because one may observe people who smoke and get lung cancer, but still find people who have smoked all their lives and won't get the disease (no matter what the authority says). To find people who have smoked all their lives and won't get the disease is called finding **counterexamples** to the argument. So the supposed authority may still fail to understand the big picture; or worse, may seek to mislead. Accordingly, the premises of the argument may still not provide full support for the conclusion.

A **properly formed** argument from authority cites its sources, provides informed sources, provides impartial sources, cross-checks its sources, and does not disqualify competing sources using personal attacks.[35] This means that one must quote or mention the authorities that are appealed to; that supposedly know what they are talking about; and, that supposedly are fair and objective. Moreover, one must cross-check sources. This means that one must make sure that the statements (or generalizations) **made by authorities** turn out to be reliable by looking at other

---

because [the explanation]. That is to say, **O.J. Simpson murdered his wife *because* he was a jealous husband**. But, one can mistakenly interpret this sentence as an **argument**, since the word *because* may be taken as a **premise indicator**. Under this interpretation the alleged argument looks like the following.

1) O.J. Simpson is a jealous husband.
----
2) Thus, O.J. Simpson murdered his wife.

But, this cannot be an argument if the conclusion is already taken as a given fact. This is because arguing that O.J. Simpson murdered his wife involves premises that provide reasons **for possibly accepting** the claim (or conclusion) that **O.J. Simpson murdered his wife**. (See Epstein and Kernberger, *The Pocket Guide to Critical Thinking*, Chapt. 5.1.)

[34]We will use the square brackets to signify a Meta Statement (i.e., a statement about a statement).

[35]Adapted from Weston, *A Rulebook for Arguments.*

sources for verification. Accordingly, for an argument about causes to be properly formed its sources must be cited and further explanation provided to explain why the source is an informed source. This introduces the following argument form.

1) E_1 correlates with E_2.
2) [A statement explaining how E_1 causes E_2.]
3) X (an authority on E_2) says E_1 causes E_2.
----
4) Thus, E_1 causes E_2.

Finally, for an argument about causes to be properly formed it must propose the most likely cause. The general form of this type of inductive argument may be symbolized as follows.

1) E_1 correlates with E_2.
2) [A statement explaining how E_1 causes E_2.]
3) X (an authority on E_2) says E_1 causes E_2.
4) [A statement showing that E_1 is the most likely cause.] {Given the hypothesis that **if E_1, then E_2**, use the **Principle of Adequacy** (more about this later).}
----
5) Thus, E_1 causes E_2.

So, consider again the *basic* form of this type of inductive argument

1) E_1 correlates with E_2.
----
2) Thus, E_1 causes E_2.

If we let **E_1** be **smoking** and **E_2** be **cancer**, then we generate the following *weak* **Argument about Causes.**

1) Smoking correlates with cancer.
----
2) Thus, smoking causes cancer.

But, we want a *strong* **Argument about Causes** such as the following.

1) Smoking correlates with cancer.
2) [A statement explaining how smoking causes cancer.]
3) The Surgeon General (an authority on cancer) says smoking causes cancer.
4) [A statement showing that smoking is the most likely cause.]
----
5) Thus, smoking causes cancer.

V. The Fallacy of Correlation Equals Causation

One way we can think about how events or actions are connected is by appealing to the notion of causation. **Causation**[36] is concerned with **causes** and **effects**. A **cause** is the reason *why* something happens. A **cause** is an event or action that directly makes something happen; an **effect** is *what* happens because of the cause—it is what happens as a result of the cause. The research **hypothesis** is an alleged **causal chain (or pathway)** that **predicts** a hypothesized relationship. From this point of view, **causation** is the capacity of one variable to directly influence another. **Causation** is important in **experimental** studies because it is the bridge that links the **independent** (**A**) and **dependent** (**B**) variables of the research **hypothesis** (If **A**, then **B**), enabling the experimenter to transcend mere correlation. For there to be **support for causation**, however, a systematic method for determining **causation** is necessary. This means that the **cause A** and **causal chain** (**A** *causes* **B**) need to be determined so that given the alleged cause **A**, the alleged effect **B** will result (i.e., the hypothesized relationship may be subject to **testing** by means of experimentation).

There are **four** criteria[37] for figuring out whether or not there is **evidence** for causation (so that **correlation *can* imply causation**): (1) **There exists a strong and consistent correlation, correspondence, or association.** (So that when the alleged cause **A** is present, the alleged effect **B** tends to be present as well and vice versa.) (2) There is a plausible **explanatory model that is consistent with the data** and **fits with other scientific understanding** so we can **explain the correlation**. (3) **There is precedence** so that the alleged cause **A** must **come before** the alleged effect **B**.[38] That is to say, we can **understand the underlying causal mechanism** for what causes what and in what direction. (4) We can predict, in advance, that **A** will cause **B**, since the alleged cause **A** is **plausible** and **likely** to produce the alleged effect **B (because confounding factors, third variables, or alternative explanations, have been eliminated or controlled)**. So, that ***larger*** values of the **explanatory variable** (i.e., the **dose** of, or **exposure** to, the cause) are associated with ***stronger*** responses (i.e., the effect).

Causation is important in *empirical* **science** because, when successfully attributed, the experimenter can establish **beliefs** that are **true** (i.e., the experimenter can establish that claims correspond with reality) and are **justified** (i.e., the experimenter can provide good arguments for believing each claim or deduced implication). According to Aristotle,

> *We suppose ourselves to possess unqualified scientific knowledge of a thing, as opposed to knowing it in the accidental way in which the sophist knows, when we think that we know the cause on which the fact depends, as the cause of that fact and of no other, and, further, that the fact could not be other than it is.*[39]

To be sure, **a goal of science is to figure out which patterns are real**—one way of achieving this is **to figure out which correlations are really causations**. But, as we have seen above, the

[36]For a philosophic enquiry into the ontological problem of causality and specific emphasis on the place of the causal principle in modern science, see Mario Bunge's *Causality and Modern Science.*
[37]Other sources may provide longer lists of the foregoing criteria in different order and/or form. But, all the basic elements for figuring out whether or not there is **evidence** for causation will still be there.
[38]With some exceptions: Battersby, 121.
[39]Posterior Analytics (Book 1, Part 2).

process of successfully attributing causation is itself not without problems, for the **causal chain** (or **pathway**) of events is often not that clear. For instance, can we be sure that **A** causes **B**, or is it, in fact, the other way around that **B** causes **A**? Or, is there a common factor, **C** that can cause one or the other or both? Or, could it be the case that the causal chain (or pathway) of events loops so that both **A** causes **B** and **B** causes **A**?

Moreover, some have difficulty determining what a correlation is and how it is established. And, unfortunately, this, in many cases, leads some to reason incorrectly (i.e., commit a fallacy) that correlation is the same thing as causation. For example, there is a widespread held belief that **fat consumption is linked to heart attacks** (this is a correlational claim). In other words, much fat in your diet is a **risk factor** for getting a heart attack. But, do you really believe that fat consumption is linked to heart attacks? Could it be that there is no *positive* **correlation**, **association**, **relationship**, or a **correspondence between these two changing things**? Consider, for instance, the paradox of high-fat diets that are associated with **reduced** heart disease (this is a *negative* **correlation**). The well-known *Mediterranean diet*, for example, is simply high-fat Greek food that is good for your health. Or, how about consumption of French cuisine that consists of much fat, but is associated with a relatively low rate of heart attack?[40] What is crucial here to realize is that only by **comparing** rates of the effect in those who are in the target category (e.g., high-fat diets that are associated with heart disease) with those who are not (e.g., high-fat diets that are associated with reduced or no heart disease), can we know if being in a particular category is **correlated** with some possible effect (e.g., getting a heart attack). Accordingly, when searching for correlations, we *…need to compare two samples before making claims about the population generally*.[41] Consider below the argument *form* for this line of fallacious thinking (premise 2 is usually suppressed by the person committing the fallacy).

1. X is correlated with Y.
2. Correlation is the same thing as causation.

----

3. Thus, X causes Y.

Let's apply this to thinking in regard to causal claims about autism. Some have claimed, for instance, that the real cause of increasing autism prevalence is **increases in organic food sales**.[42] This is because data shows that **increases in organic food sales** and **incidents of children diagnosed with autism** are very strongly associated. We may **operationalize** this as the **hypothesis**: **if children eat organic food, then they would get autism**. But, does this data presented as part of an **observational study** really show that **autism is caused by eating organic foods**? Of course not, since the data shows a **very strong positive correlation (note: r =**

[40]Battersby, 99 (adapted).
[41]Ibid, 105; 103 (adapted).
[42]See Suresh, Genetic Literacy Project: Autism Increase Mystery Solved: No, It's Not Vaccines, GMOs Glyphosate– or Organic Foods (https://www.geneticliteracyproject.org/2015/10/13/autism-increase-mystery-solved-no-its-not-vaccines-gmos-glyphosate-or-organic-foods/). Accessed August 5, 2016.

0.9971), *not* a causal link. The **argument** for this line of fallacious thinking **applied** to autism is as follows.

1. **Eating organic foods** is **correlated** with **autism**.

2. Correlation is the **same** thing as causation.

----

3. Thus, **eating organic foods causes autism**.

As we learned earlier, a variation of this is called ***Post hoc ergo propter hoc*** (Latin: *after this, therefore because of this*). For our purposes, this simply is interpreted as the **argument *form*** (**premises 2 and 3** are usually **suppressed** by the person committing the fallacy):

1. **X** occurs ***before*** (getting) **Y**.

2. **X** is **correlated** with **Y** (because of premise 1).

3. Correlation is the **same** thing as causation.

----

4. Thus, **X causes Y**.

Consider below the **argument** for this line of fallacious thinking **applied** to autism.

1. **Eating organic foods** occurs ***before*** (getting) **autism**.

2. **Eating organic foods** is **correlated** with **autism** (because of premise 1).

3. Correlation is the **same** thing as causation.

----

4. Thus, **eating organic foods causes autism**.

As we noted earlier, our common core understanding of **critical thinking** is about taking some **argument** apart using **analysis** and **evaluating** whether some derived conclusion follows from the evidence. So, when we look critically at the (now fleshed-out) **argument *forms*** above, we can see then that the derived conclusion need not always follow from the premises. Accordingly, because **empirically observed correlation is a necessary, but not sufficient condition for causation**, we have to be **skeptical** about this type of reasoning. If we're not skeptical about this type of reasoning, we might commit the **fallacy of correlation equals causation** (or, **fallacy of false or questionable cause**).

VI. The Problem of Pseudoscientific Beliefs

A) Reasons Why Pseudoscientific Beliefs Persist

The danger of confusing correlation with causation is that this can lead to bad assumptions, false (or bizarre) conclusions, and/or ignoring other possible factors (e.g., **lurking**, **extraneous, spurious,** or **confounding variables—more about this later**). Moreover, when we sidestep **how** (i.e., analysis) **and why** (i.e., evaluation) events or actions are really connected, we settle on mere **comfortable** or **psychologically available** observation. As a result, we run the danger of **believing** that something must be accompanied by something else—whether the association or pattern is actually real or not. The **belief** that an action or an event can have an effect on something even though there is no causal relation between the two is called a **superstition**. Accordingly, a superstition is a **false belief** based on a misguided identification of causation. At best, we can say that something accompanied by something else is **associated** or **correlated**. In the extreme, such correlation usually serves as the basis for **pseudoscientific beliefs**.[43]

Besides mistaking correlation for causation, some other reasons why pseudoscientific beliefs persist are the following.[44] (1) ***We don't know how dumb we are (the Dunning-Kruger Effect)*** — In general, uninformed people overestimate their own knowledge of the facts, don't recognize actual knowledge or expertise in other people, and don't realize how ignorant they are.[45] (2) ***We are incompetent (the Peter Principle)*** — This is the principle that in hierarchies (particularly in a business setting), people tend to rise to their level of incompetence when they are promoted. Applied to an **epistemological** hierarchy (where what is at issue is who *really* **knows** something), people tend to rise to *their level of ignorance* as they **self-promote** themselves as competent or knowledgeable in a field outside their limited knowledge base or belief system (e.g., an arm chair philosopher or a self-declared expert in science)—revealing their level of ignorance or incompetence because a *knowledge* base (which just might simply be a hardened belief) in one area does not secure a level of knowledge or competence in another.[46] (3) ***We don't even realize we're wrong (confirmation bias)*** — This is the tendency of people to prefer and accept information confirming an already-held belief, but ignore information showing the belief is false.[47] (4) ***We lie to ourselves (cognitive dissonance)*** — We try to make our inconsistent beliefs or anecdotal stories fit with competing reality, although uncomfortably in conflict with our hardened

---

[43]See Science of the Gaps (https://www.youtube.com/watch?v=dgN7a_vdIIc), The Threat of Pseudoscience (https://www.youtube.com/watch?v=Jv4KtAnjqzU), and The Pattern behind Self-Deception (https://www.youtube.com/watch?v=b_6-iVz1R0o). Accessed August 5, 2016.

[44]Adapted from Top 5 Ways We Suck (http://kooztop5.blogspot.com/2012/04/top-5-ways-we-suck.html). Accessed August 5, 2016.

[45]See Dunning-Kruger Effect (https://www.youtube.com/watch?v=NY9R7X3QzQY) and Why People Don't Realize They're Incompetent (https://www.youtube.com/watch?v=QRBmBzLusoY). Accessed August 5, 2016.

[46]See Peter Principle (https://www.youtube.com/watch?v=Uptw9GKt1og), Trading Psychology - The Peter Principle in Trading (https://www.youtube.com/watch?v=jtaKerfb9A4), and The Myth of Upward Promotion (https://www.youtube.com/watch?v=KvMT08dLceY). Accessed August 5, 2016.

[47]Confirmation Bias (https://www.youtube.com/watch?v=B_YkdMwEO5U), What is Confirmation Bias? (https://www.youtube.com/watch?v=hcucGn_X8AA), Pitfalls of Thinking: Confirmation Bias (1/2) (https://www.youtube.com/watch?v=u34BhEgO_es), and Cognitive Biases and the Authority of Science (https://www.youtube.com/watch?v=hZkkY2XVzdw). Accessed August 5, 2016.

belief system, dogmatic faith, or motivated reasoning.[48] (5) ... ***[O]ur educational system is not entirely effective in passing on the knowledge or the critical thinking skills necessary to significantly reduce belief in pseudoscience****…. [T]here is a great deal of evidence that the formal education system as it is currently structured in our nation is simply not well equipped to expose such beliefs as being unsupported by science….[S]ome teachers may not have the educational foundation necessary for recognizing pseudoscientific claims….* [Finally,] *many teachers are not only failing to impart basic information on the scientific method to their students, but are also likely to be misinforming students because of their own beliefs in pseudoscience.*[49]

This suggests that science education should also focus on analyzing and evaluating arguments typically marshaled for and against alleged sources of knowledge like pseudoscience in order to help the learner avoid being deceived by means of bogus sciences and extraordinary claims. However, in order to develop the critical thinking skills necessary to **analyze** and **evaluate** all kinds of phenomena, scientific, pseudoscientific, and other, we must, as noted earlier, be willing and able *to discover and overcome* ***personal prejudices*** *and* ***biases****; to formulate and present* ***convincing reasons in support of conclusions****; and to* ***make reasonable, intelligent decisions about what to believe and what to do***.[50]

This is important because there is a difference between knowledge and belief. To be sure, we all have different feelings, opinions, beliefs about things in our world, but when it comes to science it is important for an individual to be able to modify or correct beliefs molded by personal interest or upbringing (or indoctrination). The problem, however, is that many of our emotions, opinions, and beliefs are molded by personal interest, upbringing, or magical thinking, and/or are formed by means of our personal experiences and our judgments about those experiences. And, such **subjective** experiences are unsystematic and uncorroborated; they are not always reliable enough and they often mislead us. Moreover, natural human biases and limitations of upbringing (or indoctrination) inevitably lead us to hang on to a preferred belief and **ignore or resist all other alternatives**.

What is unfortunate about all this is that such hardened beliefs usually pass for knowledge. But, this may result in seriously impeding critical thinking because by conflicting with what amounts to better established **objective** beliefs, such hardened beliefs cannot align, nor demonstrate consistency, with **justified true** beliefs (i.e., knowledge) about physical reality. To be sure, anyone can have emotions, opinions, beliefs about anything, but the question remains whether these are **true** (i.e., the emotions, opinions, beliefs correspond with reality**—that means that facts matter**: this is empiricism's hold on science) and **justified** (i.e., there are good reasons and arguments for feeling, opining, or believing so**—that means that reason and logical thinking matter**: this is rationalism's hold on science). As a result, emotions, opinions, beliefs

[48]Cognitive Dissonance (https://www.youtube.com/watch?v=FT8eIAMLbo4), Cognitive Dissonance by Bo. Bennett (https://www.youtube.com/watch?v=gN-6nBs7sbI), TedxCanberra - Ash Donaldson - Cognitive Dissonance (https://www.youtube.com/watch?v=NqONzcNbzh8), and Telling Stories (https://www.youtube.com/watch?v=NfyoDgszas0). Accessed August 5, 2016.
[49]Eve and Dunn, Psychic Powers, Astrology & Creationism in the Classroom? Evidence of Pseudoscientific Beliefs Among High School Biology & Life Science Teachers, 11, 13, 21 (emphasis mine).
[50]Bassham, *et al*., *Critical Thinking: A Student's Introduction*, 1(emphasis mine).

(even if very strong) by themselves do not constitute knowledge. An example of this is Pseudoscience.

Pseudoscience is **a belief (or system of beliefs) masquerading as knowledge in an attempt to claim a scientific legitimacy**, which it lacks or cannot ever achieve on its own footings. Accordingly, one way we may draw the lines between science and pseudoscience is by highlighting that science is, at the very least, an exercise in **critical thinking** that typically relies on the reason or reasons provided as **evidence** for accepting a claim. So science is the effort to obtain knowledge about the natural or physical world through **reason** (enter rationalism) and/or **experimentation** (enter empiricism) so that the conclusions that should come out on top are the ones that have the best reasons or evidence on their sides. In this sense, productive scientific discussion must take place on a common **objective** ground. In contrast, **pseudoscience** lacks carefully controlled and thoughtfully interpreted experiments and/or reasoning for knowing the natural world and contributing to human advancement. This is because **pseudoscience** is a **belief (or system of beliefs)** whose practice usually takes place on **personal, ideological, cultural, or commercial** grounds.[51]

To be sure, humans have a strong desire to believe in pseudoscience and suspend critical thinking. Human beings often try to impose their beliefs on reality, but reality shows them up for fools. For instance, have you ever noticed how self-appointed psychics always seem eager to boast about their foretelling powers to the public, but never like to talk about how many of these predictions were correct? All of this is important because scientific knowledge should consist of correctable beliefs about the natural or physical world. But pseudoscience would fall short on this account, since in most cases it only brings belief to the table. Moreover, the evidential role of reasons to determine how good our reasons must be to adequately ground our beliefs is not crucial to pseudoscience. In contrast, having belief alone will not do when it comes to science where beliefs must be true and justified. Not surprisingly, then, the problem why pseudoscientific beliefs persist boils down to an appeal to a prevalent belief. The general form of arguments that appeal to prevalent belief is the following (Let s stand for a statement).

1) It is a prevalent belief that s.

----

2) Thus, s.

Consider a substitution instance of the above form:

1) It is a prevalent belief that ghosts interact with the physical world.

----

[51]This paragraph adapted from UC Davis ChemWiki by University of California, Pseudoscience (http://chemwiki.ucdavis.edu/Analytical_Chemistry/Quantifying_Nature/The_Scientific_Method/Pseudoscience) and List of Topics Characterized as Pseudoscience (http://en.wikipedia.org/wiki/List_of_topics_characterized_as_pseudoscience). Accessed August 5, 2016.

2) Thus, ghosts interact with the physical world.

But, all arguments of the above form are **invalid** arguments. To show this, the goal is to find a substitution instance (i.e., an example) of the above argument form so that if the premise were true, then the conclusion can still be false. In other words, the counterexample shows that the conclusion does not have to be true. So, truth is not preserved. Consider the following counterexample of the above form (as it applies to most young children that celebrate Christmas, for instance):

1) It is a prevalent belief that Santa Claus exists.

----

2) Thus, Santa Claus exists.

This means that the argument *form* is not valid because a substitution instance (i.e., an example) has been found that allows for a true premise and a false conclusion. That is to say, it is true that **It is a prevalent belief that Santa Claus exists**, but false that **Santa Claus exists**. In general, we certainly do not want to be guilty of using our reasoning and the information involved to derive something false from something true. So, when it comes to the statement that ghosts interact with the physical world, by playing upon what others believe, an appeal to prevalent belief does not provide evidence for a conclusion that must be verified in another manner. We need good reasons, not an often unsupported, exaggerated, or vague appeal to popular belief, to establish a conclusion.

What about appeals to authority? When we provide a statement made by an expert in support of a conclusion, we obtain an argument that appeals to authority. The general form of this argument is the following (Let **p** stand for a **person**, **x** an area of **expertise**, and **s** stand for a **statement**).

1) **p** (an expert on **x**) says **s**.

----

2) Thus, **s**.

Consider a substitution instance of the above form:

1) Jack (an expert on psychic matters) says ghosts interact with the physical world.

----

2) Thus, ghosts interact with the physical world.

But, although Jack (an expert on psychic matters) maintains that ghosts interact with the physical world, even experts can be mistaken. So it would not be correct for one to claim knowledge that ghosts interact with the physical world merely on authority, since clearly ghosts may not. And to complicate things further, we are not always sure of, or in agreement about, the credentials of the authority. By itself, expertise on psychic matters fails to elucidate and justifiably establish that authority, since such an authority must additionally show how we are to choose between competing beliefs or psychic authorities. Therefore, **an argument that appeals to authority is not**

valid because belief, no matter how strong or authoritative, does not provide evidence for the conclusion being endorsed. We need good reasons, not an appeal to a recognized authority, to establish a claim.

To be sure, there will always be conflicts with expert opinion. So we must cross-check sources to make sure that the statements (or generalizations) made by the authority turn out to be reliable by looking at other sources for verification. But this is not enough; we have to be careful because coherence with other sources does not necessarily justify a statement. For instance, there was a time when all the experts (whether religious or not) believed that the earth was the center of the universe.

Thus, as with the ghost argument above, adding any number of other experts on psychic matters does not necessarily justify the conclusion that ghosts interact with the physical world. That is to say, the following (inductive) argument does not necessarily justify its conclusion (Let p stand for a person).

1) Jack (an expert on psychic matters) says ghosts interact with the physical world.

2) Betty (an expert on psychic matters) says ghosts interact with the physical world.

3) John (an expert on psychic matters) says ghosts interact with the physical world.

:

n) p (an expert on psychic matters) says ghosts interact with the physical world.

----

n+1) Thus, ghosts interact with the physical world.

B) The Demarcation Problem

Things are not always that clear-cut and it can be difficult for some to tell the foregoing characterizations of pseudoscience apart from science.[52] In this regard, a particular problem for science is how and where to draw the lines between science and non-science. This is called **the demarcation problem** (or boundary problem). Although controversial, we may adopt a way of resolving this problem by providing a set of criteria, called **The Criteria of Adequacy**. Following Schick and Vaughn,[53] a hypothesis h_1 explains the evidence and accounts for it better than hypothesis h_2 whenever it is simpler (it makes less assumptions), does not raise more questions than it answers, makes testable predictions, fits well with established beliefs, and/or increases the amount of understanding (since it systematizes and unifies well our knowledge). This amounts to providing a set of criteria, called the criteria of adequacy, which a hypothesis has to meet to count as scientific, and then showing how a non-scientific hypothesis fails to meet the criteria. So, a

---

[52]Colodny, *Beyond the Edge of Certainty: Essays in Contemporary Science and Philosophy*, The Ethical Dimension of Scientific Research, 270-274.
[53]*How to Think about Weird Things: Critical Thinking for a New Age*, 50, 179-190.

hypothesis h_1 is scientific whenever it is **testable**, **fruitful**, **has a greater scope**, is **simpler**, and is **conservative**.[54]

Testability, for instance, is one of the specific features of a hypothesis promoted by the criteria of adequacy to determine whether a hypothesis counts as scientific or not. We test a hypothesis by evaluating whether it is true or false–whether its claims or deduced implications correspond with reality. Following the philosopher Karl Popper on this point, we may say that if a hypothesis is not testable, then it not scientific. So, if a hypothesis is scientific, then it must be testable. But this means, following Popper, that a hypothesis must take a risk in being found false (i.e., it is falsifiable). That is to say, the hypothesis will admit as evidence possible circumstances that could show it to be false. Accordingly, one way we can determine how and where to draw the lines between science and non-science is by establishing whether a corresponding hypothesis is falsifiable. Consider again, for example, the hypothesis that ghosts (e.g., disembodied souls or spirits of people who have died) interact with the physical world. Given that a ghost is, by definition, not physical, the hypothesis would certainly not take a risk in being found false, since it will not admit as evidence any possible physical or natural circumstances that could show it to be false. For how can something that is not physical ever causally interact with the physical objects of the world? So, physical experimentation is not feasible, since we cannot investigate causal relationships to test the hypothesis. Accordingly, since the ghost hypothesis is not falsifiable, it cannot be testable. But if the ghost hypothesis cannot be testable, it is not scientific. So, when it comes to ghosts, we can determine how and where to draw the line between science and pseudoscience by establishing whether the ghost hypothesis is falsifiable.

To determine whether the hypothesis that ghosts interact with the physical world is a scientific claim or not, we can also look at the hypothesis as an **epistemological** claim and inquiry allegedly about science. A key principle of knowledge and reasoning is the law of noncontradiction. A contradiction is a false statement with a particular type of inconsistency that can be easily recognized by the basic form of a statement and its negation. Contradictions occur when we try to characterize a thing as both having a property and lacking it at the same time and in the same way. As applied to the ghost hypothesis above, consider the statement **A ghost is physical** and its direct denial, **A ghost is not physical**. If we conjoin these two statements we get the statement that **a ghost is physical and a ghost is not physical**. But, contradictions are not

[54]**Testability**: The hypothesis makes testable predictions. This means that a hypothesis must take a risk in being found false, since we test whether a hypothesis is true or false by checking its claims or deduced implications. **Fruitfulness**: The hypothesis increases the amount of understanding, since it systematizes and unifies well our knowledge. **Scope**: The hypothesis has the power to unify and systematize greater amounts and types of knowledge by explaining and predicting events of the natural or physical world. **Simplicity**: The hypothesis makes fewer assumptions. The hypothesis does not raise more questions than it answers. **Conservatism**: The hypothesis fits well with established beliefs. So, for instance, even though we cannot be completely certain that hens produce eggs (since we are not all-knowing), we are justified in believing that they do because a different (non-scientific) hypothesis (say, for example, that the eggs magically appear) does not provide the best explanation of our sense experience. That is to say, the magic hypothesis is not as simple as the (scientific) hypothesis that hens produce eggs (e.g., Are we to assume that one or more magicians are behind the egg-laying process?); it raises more questions than it answers (e.g., Where are these invisible magicians and how do they operate?); it does not make testable predictions (e.g., Test whether hens will require roosters to lay fertilized eggs); it does not fit well with established beliefs (e.g., Hens do not always require roosters to lay eggs); and it does not increase the amount of understanding (e.g., Most hen eggs are produced in response to daylight patterns, not just roosters fertilizing the eggs).

logically allowed. So, it is not logically allowed for a ghost to be physical and not physical at the same time and in the same way.

This makes sense because we do not want people going around claiming inconsistent things that are and aren't the case at the same time and in the same way. Now, the problem of claiming inconsistent things is not just the problem of uttering a special class of false statements. The law of noncontradiction is in place not just to help one avoid false statements with a particular type of inconsistency. The law of noncontradiction is also a central principle of thought and communication without which we could not distinguish one thought or statement from another, for our thoughts and statements would not be consistently about one thing rather than the other. Moreover, every claim would be equally true (false), since the specific content of each statement would not be consistently true (false) about one thing rather than the other. Accordingly, logically allowing a ghost to be physical and not physical at the same time and in the same way would amount to claiming that there is no difference between being physical and being not physical. Accordingly, our thoughts and statements about being physical would not be consistently about one thing rather than the other. And such claims would be equally true (false), since the specific content of each statement would not have to be consistently true (false) about one thing rather than the other.

Note that we are now in the position to argue (via *reductio ad absurdum*) that if a ghost interacts with the physical world, then we are logically allowing a ghost to be both physical and not physical at the same time. But this is just an indirect way of deductively showing that the argument leads to an absurdity (i.e., a contradiction). The only way to avoid the absurdity is to reject the ghost hypothesis that leads to it. So, it is not the case that ghosts interact with the physical world. Thus, we can look at the ghost hypothesis as an epistemological claim and inquiry allegedly about science and determine how and where to draw the line between science and pseudoscience by establishing whether the hypothesis is falsifiable using critical thinking.

C) Clear Cut Demarcation: Science set against the Impossible

In the construction, examination, and consequences of scientific hypotheses or theories (and the possible experiments that would verify them), science is explicitly or derivatively concerned with **possible (necessary)** objects, actions, events, conditions, or propositions.[55] Accordingly, discourse in science may involve the fundamental inter-definable **modal** concepts of **possibility** and **necessity**. **Modality** is the manner (or mode) in which something (e.g., a property, truth, etc.) holds or is had. Modal concepts are important because in some key aspects, science is about the fundamental laws that govern the universe. And these physical principles define reality for us; they define what is possible. Accordingly, embedded in the very fabric of its claims and inquiries science involves modality. So, what science says may be understood in terms of some modal concept and considered a philosophical endeavor.

[55]Although throughout this discussion **proposition** is used interchangeably with **statement**, it is important to note a distinction found in philosophy between statements and propositions. A proposition can also be understood as the meaning of a statement. So, for example, the different statements **1+1= 2**, **One plus one is two**, and **Uno más uno son dos** propose or express the same proposition—the meanings that the different statements have is the same.

To be sure, objects, actions, events, conditions, or propositions may be characterized as possible or impossible. For something to be possible it must either be physically possible or logically possible. Because science studies certain aspects of the physical world, it is taken for the most part to be concerned with what is physically possible. For something to be physically possible, it must be consistent with the laws of nature (laws of Physics, Chemistry, etc.). Something is physically possible if and only if it does not violate any law of nature. For instance, it is physically possible for a spaceship to travel to the planet Mars and back. This does not violate a law of nature (e.g., Newtonian Physics).

However, for something to be physically possible it must also be logically possible. That is to say, it must also be consistent with the laws of logic. Something is logically possible if and only if it does not violate a law of logic. If it is not logically possible, it cannot be physically possible. So science cannot be simply taken to be only concerned with what is physically possible. But this does not work the other way around, for if it is logically possible, it need not be physically possible. For instance, given the laws of nature (e.g., Relativity Theory) it is not physically possible for a spaceship to travel faster than the speed of light, but it is logically possible (Think, for example, how the Star Trek shows produce logically possible adventures every time the Enterprise warps faster than the speed of light).

Accordingly, in science we are concerned with two basic forms of impossibility: the physically impossible and the logically impossible. As the spaceship example shows, a thing is physically impossible if and only if it does violate a law of nature (e.g., laws of Physics, Chemistry, etc.). In contrast, something is logically impossible if and only if it violates a law of logic. The most fundamental laws of logic may be expressed, according to Aristotle, as the following three principles. The law of noncontradiction says that contradictions are not logically allowed. So a thing cannot both have a property and lack it at the same time (and in the same sense). The law of identity says that all things are identical to themselves. The law of excluded middle says that a thing or its opposite must be the case (there is no other possibility; there is no middle ground). For example, anyone who is a bachelor (by definition) cannot at the same time (and in the same sense) be married. One cannot be both a bachelor and not-bachelor; one cannot be both not-married and married. So, a married bachelor is logically impossible. Or, for instance, anything that is square (by definition) cannot at the same time (and in the same sense) be circular. A thing cannot be both square and not square; a thing cannot be both not-circular and circular. So, a square circle is logically impossible. In short, because the law of noncontradiction says that contradictions are not logically allowed, a thing cannot both have a property and lack it at the same time (and in the same sense).

Moreover, if it is not logically possible, it cannot be physically possible. And, if it is not physically possible, it cannot be actually the case. The actual is a subset of the physically possible, which in turn is a subset of the logically possible. Paranormal phenomena are events or objects that seem (either physically or logically) impossible, given science. As applied to the ghost hypothesis above, since it is not logically allowed for a ghost to be physical and not physical at the same time and in the same way, it cannot be both physically possible and actually the case.

Note that just because something is possible it does not mean that it is actually the case. For instance, just because it is logically possible for the Star Trek Enterprise to warp faster than the speed of light, it does not mean that it is actually the case. Moreover, just because something is logically possible does not mean that we ought to believe it. A Possible World is a logically, if not physically, possible state of affairs, however probable or improbable, that completely describes the way the world could have been. Since there are infinitely many distinct possible ways the world could have been there are infinitely many distinct possible worlds. If we took the world that we live in to be the actual world (the way things actually are; everything that actually exists), then we would still have to be concerned with possibility, since the actual is a subset of the possible. So the actual world may be considered to be one of the many possible worlds. But although all that is actual is possible, not all that is possible is actual. For instance, the Star Trek shows describe a logically possible world of faster-than-light spaceships travelling. Although there are similarities, this is not the way things actually are.

Consequently, when we confuse science with pseudoscience, the demarcation (or boundary) problem is of no consequence, since science may be both about the fundamental laws that govern the universe and not; both about the physical principles that define reality for us and not; both about defining what is possible and not. Fundamentally, such contradictions suggest that what is perhaps the most needed outcome of all science education are critical thinking skills to help the informed and responsible citizen and trained scientist alike tell the difference between **good** versus **bad** science. For science, without being modulated by critical thinking, can also lead to fear, superstition, ideology, deception, intolerance, and dogma—even in the face of massive and well understood empirical evidence or facts. So, as Carl Sagan once noted,

> *If we teach only the findings and products of science—no matter how useful and even inspiring they may be—without communicating its critical method, how can the average person possibly distinguish science from pseudoscience?*[56]

Accordingly, **ethics** (as a branch of philosophy) comes into play in this account because those engaged in science, as *a systematic attempt to get around the limitations of pseudoscience (or, more generally, non-science),* must, using critical thinking, also focus on the higher cognitive skill of evaluation to be able to select among alternatives to tell the difference between **good** versus **bad** science—(enter **Critical Ethics**).

D) The Problem of Confusing Science with Scientism

Unfortunately, the problem of being able to tell the difference between **good** versus **bad** science also plays out for many in the general public who confuse science with **scientism**. To be sure, in the extreme, scientism is science *really gone **bad***. Scientism is an imperialistic ideology that champions a particular worldview and uncompromisingly seeks to extend the rule or influence of a set of goals and/or body of truths proposed by a dominant class of scientists (sometimes characterized as a priesthood[57]) to direct the scientific beliefs, expectations, and actions of others. As a result, scientism is criticized as turning human beings into mere machines stripped of any impulse beyond the material or mechanical. Thus, scientism is thought to be *hostile to human flourishing, dignity, thoughts, feelings, and desires.*[58]

---

[56]Sagan, *The Demon-Haunted World: Science as a Candle in the Dark*, 21.
[57]See Henry, *The Rise of the New Scientific Priesthood*; and, Feyerabend, *The Tyranny of Science*.
[58]Schick and Vaughn, 167.

Correspondingly, it is claimed that science must be characterized as a **mechanistic** worldview dominant in the scientific community. Accordingly, science is usually taken to be defending the comprehensive vision that the world (and everything in it) should operate like an immense machine stripped of free will or emotion—that is, hostile to human flourishing, dignity, thoughts, feelings, and desires. Moreover, it is maintained by some that this **mechanistic** worldview is based on some form of **materialism** that governs the scientific community. In short, science is characterized as supposedly defending the comprehensive vision that the world and everything in it should be composed of matter stripped of *spirit* or *soul*.[59]

This reduction may be rooted in the polemic in the history of philosophy about the continuing tension and dialogue between two sharply differing accounts of knowledge that has taken **empiricism** to be diametrically opposed to **rationalism**. Accordingly, there will be those who will privilege empiricism and take science to be merely a system for applying empirical knowledge. But, such *applied* science may be differentiated from *pure* science, emphasizing the application of scientific knowledge (i.e., technologies and inventions) to specific human needs—primarily about the application of science to produce something that (supposedly) works for the betterment of humankind.

Of course, technology does not always work for the good of humankind. As noted by Easton,

> *[T]he past has taught us that technological developments can have unforeseen and terrible consequences. Those consequences do 'not' belong to science, for science is nothing more (or less) than a systematic approach to gaining knowledge about the world. Technology is the application of knowledge (including scientific knowledge) to accomplish things we otherwise could not*.[60]

In this sense,[61] pure science may be compared to a knife that (when applied) can be used for bad (e.g., to fatally wound) and/or good (e.g., to perform a lifesaving surgery). Hence, pure science, like the knife, is in itself neither bad nor good. Accordingly, reasoning whether things really do (or do not) converge continuously toward betterment, is more of an argument applicable to technologies and inventions, than science. In view of that, it is a mistake to identify *pure* science with the adverse results of the material or machine-like results (or applications) of *applied* science.

To be sure, when the goal is the production of goods or gadgets to apply scientific knowledge to practical problems, we can point to the negative impact of some applied technologies and inventions that suggest an underpinning worldview (or theory) with a hostile materialistic or mechanistic inclination or emphasis. However, an understanding of science as fundamentally materialistic is problematic and too narrow, since modern science does not have a single notion of

[59]If the religionist avows that the origin of modern science itself is due in large part to a *materialistic* (or *mechanistic*) metaphysics of earlier periods in the history of science, then an inconsistency may be revealed as the theist turns-around in this discussion to also require the very opposite when arguing that the origin of science itself is due in large part to religion (i.e., a *theistic* metaphysics).
[60]*Taking Sides: Clashing Views in Science, Technology, and Society*, xv.
[61]As argued in Talavera, Science and Religion: Drawing the Line, 1-25.

what is the fundamental stuff of reality and modern science no longer attaches itself to the Newtonian mechanistic approach and to deterministic materialism.

This classical view of matter as characterized by Newtonian physics covers the range of that which we are most familiar with in our daily lives. That is, things much larger than atoms and much slower than the speed of light. However, this view of matter was replaced by quantum mechanics (with its emphasis on chance and indeterminacy), which focuses on the atomic level (and below) and the fundamental stuff of reality was reduced to wave-like or particle-like reality. As it is noted in *The Death of Materialism*: *Dramatic Discoveries that Challenge our Understanding of Physical Reality*.

> *An extension of the quantum theory, known as quantum field theory, goes beyond even this; it paints a picture in which solid matter dissolves away, to be replaced by weird excitations and vibrations of invisible field energy….Quantum physics undermines materialism because it reveals that matter has far less 'substance' than we might believe.*[62]

Furthermore, in contrast to quantum mechanics, one may argue that the classical view of matter was also replaced by relativity, which focuses on objects at near the speed of light and the fundamental stuff of reality is reduced to fields in space-time. Accordingly,

> *[f]rom Newton to Einstein, a single idea dominated: 'The world is made of nothing but matter'…. But this beautiful picture was crushed when special relativity triumphed…. If fields are not made from matter, perhaps 'fields' are the fundamental stuff. 'Matter must then be made from fields'.*[63]

So, when taken together, quantum mechanics and relativity shape science's present theories of the fundamental stuff of reality. Thus, relying on classical physics' deterministic materialism is problematic and too narrow, since modern science does not have a single notion of what is the fundamental stuff of reality and modern science no longer attaches itself to the Newtonian mechanistic approach and to deterministic materialism. Accordingly, to claim that science's underlying materialism strips humankind of free will or emotion, confuse a hostile material or mechanical gloss on science with science itself.

What is more, it is a mistake to identify science with scientism because science is not a worldview, it is a method for critical analysis and evaluation (i.e., critical thinking) used to gather and investigate observable, empirical, and measurable evidence to analyze and assess competing hypotheses (or theories) in order to (supposedly) discover truth (i.e., correspondence with reality). To be sure, at specific moments of history particular worldviews held by scientists have been considered to be dominant in the scientific community. But science should not be said to be dominated by any particular worldview, since worldviews in science have changed radically over the years. So, for instance, Newtonian mechanics is presently taken by the scientific community to be overturned by Einstein's relativity. Moreover, it may be very difficult to characterize science with any one dominate worldview, since at times incompatible worldviews may operate in parallel

---

[62]Davies and Gribbin, Chapt. 1.
[63]Smolin, 38.

in science. For example, taken together quantum mechanics and general relativity shape science's present understanding of the physical laws of the universe, but these worldviews are incompatible with one another.

Finally, if science just boils down to a form of absolutism, championing a particular worldview that uncompromisingly seeks to extend the rule or influence of a set of goals and/or body of truths proposed by a dominant class of scientists, then the methods and procedures of scientific investigation make no difference; there is little point in formulating and testing hypotheses to make comparative scientific judgments to investigate the natural or physical world. And, if circumstances invoking different principles of nature would make no difference, all that would matter would be prefabricated, all-purpose answers based on scientific authority. But, this actually amounts to affirming the dominant scientific view and closing the subject. Moreover, by itself the dominant scientific view fails to elucidate the **right** view (enter Critical Ethics), since one must additionally show how we are to choose between competing scientific views. Accordingly, there is no way to convince someone who does not share your scientific view that your view is the **right** one. Besides, we are not always sure of, or in agreement about, the credentials of the scientific authority, nor on how the authority would rule in ambiguous or new cases. All of this, in short, trivializes the subject of science and serves more to block critical ethics in science than to promote it.

So, science is not an imperialistic ideology, which champions a particular worldview that uncompromisingly seeks to extend the rule or influence of a set of goals and/or body of truths proposed by a dominant class of scientists to direct the scientific beliefs, expectations, and actions of others. In short, science **ought not** to be confused with scientism.

VII. Critical Ethics and Science

The foregoing strongly suggests that the focus of science is not just to seek knowledge about the composition and order of everything in the physical universe. As Schick and Vaughn note,

> ***Science is a systematic attempt to get around the limitations of personal experience.*** *It is a set of procedures designed to keep us from fooling ourselves. By performing controlled experiments, scientists seek to ensure that what they observe is not affected by these limitations, or at least is affected as little as possible. Thus, scientific work is largely the business of not taking any one person's word for it*.[64]

To be sure, humans have the tendency to …*ignore, oversimplify, distort, or otherwise unfairly dismiss evidence, sound reasoning, and/or alternative views*.[65] But, [*t*]*he ability to evaluate and to select among alternatives—as well as to know when the data do not permit selection—is called critical thinking. It is essential not only in science and technology but in every other aspect of life as well*.[66] So, to keep us from fooling ourselves and help us to curtail the tendency to ignore and misinterpret evidence that conflicts with our own beliefs, science seeks **analysis** and **evaluation**—rather than personal experience and desires, self-interest, or what is

[64]Schick and Vaughn, 154 (emphasis mine).
[65]Gross and Levitt, *Higher Superstition: The Academic Left and its Quarrels with Science*, 1 (quoted in Lee, 91).
[66]Easton, *Taking Sides: Clashing Views in Science, Technology, and Society*, v.

commonly believed in a peer group or community, to determine whether our beliefs are true and justified. Accordingly, as a form of critical thinking, science is required to help us think our way through our personal beliefs (or feelings) to increase our chances of getting at **justified true beliefs** (necessary, but not sufficient conditions for knowledge). This makes it less likely for us to be misled by all the unjustified and/or false beliefs we incessantly are exposed to in various parts of the world today.

When it comes to science, then, it is important for an individual to be able to modify or correct belief (opinion) molded by personal interest, motivated thinking, or upbringing (or indoctrination). Accordingly, when it comes to searching for scientific knowledge, a skeptical attitude must be employed so that one doubts what is believed—questioning what is believed, taken to be true, and/or supposedly justified. This requires that we foment a skeptical attitude and develop critical thinking skills to question our biases, hardened beliefs, and/or motivated reasoning. This is consistent with a common core understanding of critical thinking that is more about taking some **argument** apart, via **analysis**, and **evaluating** whether some derived conclusion follows from the evidence to make reasonable, intelligent decisions about **what to believe** and **what to do** (enter ethics). As Bassham and others note:

> …**[*C*]*ritical thinking*** *is the general term given to a wide range of cognitive skills and intellectual dispositions needed to effectively identify,* ***analyze****, and* ***evaluate*** *arguments and truth claims; to discover and overcome personal prejudices and biases; to formulate and present convincing reasons in support of conclusions; and to make reasonable, intelligent decisions about* ***what to believe*** *and* ***what to do***.[67]

Although it is a mistake to identify science with the actions of a scientist (or group of scientists) behaving in professionally unethical ways, we can say that **good science begins with good ethics**. To be sure, the scientist's **integrity** is the most important characteristic that guarantees that the knowledge produced via research is done properly. Although no code of behavior can ever be written down to make all of the scientist's actions or conduct consistently explicit, lessons can be learned to help establish some basic norms for expected behavior to deal with possible misconduct in science. When dealing with people, for instance, there must be **respect** given, good actions intended to benefit and **not harm**, and **justice** provided to the individual;[68] as noted by Lee, when dealing with data or ideas, for instance, there must be **honesty, no manipulation, precision, fairness** with regard to priority, **unbiased conduct** toward your rival's data and ideas, and **no compromises made or shortcuts taken** in trying to solve a problem.[69]

And, because the scientist's integrity is the most important characteristic that guarantees that the knowledge produced via research is done properly,[70] ethics is also an important factor to the advancement of science.[71] So, it is not enough to sharpen the tools of thought to help rein in,

---

[67]Bassham, *et al*., *Critical Thinking: A Student's Introduction*, 1(emphasis mine).
[68]See U.S. Department of Health & Human Services: The Belmont Report.
[69]Lee, *The Scientific Endeavor: A Primer on Scientific Principles and Practice*, 67.
[70]When dealing with people and data, this requires that we think critically about the ethical issues that may confront us so that lessons can be learned to help establish expected behavior to decrease misconduct in science.
[71]Colodny, *Beyond the Edge of Certainty: Essays in Contemporary Science and Philosophy*, The Ethical Dimension of Scientific Research, 261-276.

modify, and/or correct our beliefs about the natural or physical world, for perhaps the most valuable result of all science education is to make ourselves do the thing we have to do, when it **ought** to be done, whether we like it or not.[72] Accordingly, **ethics** (as a branch of philosophy) comes into play in this account because science, as *a systematic attempt to get around the limitations of personal experience,* focuses by necessity on **what ought to be done**. **To evaluate and to select among alternatives to do the thing that must be done, when it ought to be done, using critical thinking, we will call *Critical Ethics*.**

What is difficult for some to grasp, however, is the relevance of ethics to modern science so that the discussion of this treatise does not seem to be of purely theoretical interest or hostile to human flourishing, dignity, thoughts, feelings, and desires. Yet, to the conduct, the preservation, and development of the species, *[t]he search for and the application of knowledge is perhaps the human species' single most defining characteristic.*[73] This makes modern science, as the systematically organized body of knowledge we know about the natural or physical world, extremely relevant to the ethical considerations of the human species. So, it is not surprising that science directly impacts a vast majority of ethical issues like overcoming environmental change that leads to habitat destruction, maintaining health and combating infectious diseases, obtaining sufficient, nutritionally adequate and safe food as well as safe and affordable water, enhancing the ability of future generations to meet their sustainable energy needs and improve energy efficiency, and stimulating emerging technologies and ideas that can increase the number of businesses and grow the economy. Accordingly,

> *Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education—meaning education in science, mathematics, and technology—should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. America's future—its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities—depends more than ever on the character and quality of the education that the nation provides for all of its children.*[74]

To sum up, the business of science is to teach our beliefs to conform themselves to fact, not to try and make facts harmonize with our beliefs.[75] Nor, is science simply just about facts, since to determine whether beliefs themselves conform or not to fact requires that we **evaluate** to select among alternatives. And, that we **evaluate** to select among alternatives suggests that factual premises by themselves cannot establish a value judgment. This mistake is called the *Fact-Value* (or *Is-Ought*) Fallacy—referring to David Hume's distinction found in *A Treatise of Human Nature*, Book III, Part I. Specifically, we cannot get *value* from *facts* because the conclusion of an argument describes something that is not contained in the premises. The premises say nothing about what ought to be the case. But, ethics can come into play, if the conclusion expresses a value related to some value expressed by the premise (or premises) of the argument. The premise (or

---

[72]Huxley, Technical Education. *Science & Education* (adapted).
[73]Easton, *Taking sides: Clashing Views in Science, Technology, and Society*, xvii.
[74]Rutherford and Ahlgren, *Science for all Americans*. American Association for the Advancement of Science.
[75]Lee, *The Scientific Endeavor: A Primer on Scientific Principles and Practice*, 88 (adapted).

premises), then, would say something about being right (or wrong), and, correspondingly, could help establish a conclusion about being right (or wrong). Accordingly, we can take care of the *Fact-Value* problem by adding an explicit value-premise (since it is implied, concealed, or unavailable).[76]

In this sense, it is the systematic attempt of science to get around the limitations of personal experience and belief that focuses on what ought to be done. Accordingly, the means and methods of science demand that we **ought not** ignore, oversimplify, distort, or otherwise unfairly dismiss evidence, sound reasoning, and/or alternative views to evaluate and to select among alternatives—as well as to know when the data do not permit selection. This critical thinking is essential not only in science and technology, but in every other aspect of life as well. It keeps us from fooling ourselves and helps us to curtail the tendency to ignore and misinterpret evidence that conflicts with our own beliefs, to determine whether our beliefs are true and justified (the necessary, but not sufficient conditions for knowledge).

Not surprisingly, then, the largest single contributor to understanding science is not the factual content of the scientific discipline, but rather the ability of students to think, reason, and communicate critically about that content. For, *[t]he purpose which runs through all other educational purposes—the common thread of education—is the development of the ability to think*.[77] And, embedded in the very fabric of any scientific endeavor or training is critical thinking. As Jeffrey Lee notes, *[t]he ability to think critically is crucial for scientists. Scientists must be able to make decisions based primarily on reason, not wholly on emotion….*[78] Accordingly, *science education helps students indirectly by pushing them to develop the critical thinking skills necessary* ***to evaluate all kinds of phenomena****, scientific, pseudoscientific, and other*.[79] In this sense, the means and methods employed in science may be defined and determined by *any procedure* [of critical thinking] *that serves systematically to eliminate reasonable grounds for doubt*.[80] And, by *systematically* eliminating reasonable grounds for doubt, we address skepticism's critical question whether there are reasons to doubt a belief.

In view of that, the higher-cognitive skills of analysis and evaluation necessary for students to secure scientific knowledge and scientific habits of mind may be achieved more **directly** by teaching science as critical thinking. Specifically, as we shall note in **Appendix B** later in this

---

[76]For instance, premise no. 3 below is added to make an argument with just premises no. 1 and no. 2 and conclusion no. 4 an ethical argument, although the soundness of this argument is open to question (The basic argument extracted and formulated from Inquiry no.12 found in Ruggiero, *Thinking Critically about Ethical Issues*, 20.).

1) Zoo officials in California cannot afford to house two healthy bears while a new bear grotto is being built. <FACT>
2) Zoo officials cannot afford the $500 cost to transport the bears to the only zoo that would take them in South Dakota. <FACT>
3) One **ought** to do what is affordable. <VALUE>
----
4) Thus, the zoo officials **ought** to destroy the two adult bears. <VALUE>

[77]Educational Policies Commission, quoted in Bassham, *et al*., *Critical Thinking: A Student's Introduction*, 1.
[78]Lee, *The Scientific Endeavor: A Primer on Scientific Principles and Practice*, 84.
[79]Ibid (136, emphasis mine).
[80]Schick and Vaughn, 173.

treatise, critical thinking may be used to introduce the major themes, processes, and methods common to all scientific disciplines. So, critical thinking may also be applied to statistical and scientific claims so students may develop an understanding about how science works and develop an appreciation for the process by which we gain scientific knowledge. All this suggests that science is not limited to observations, measurements, and experiments (i.e., **empiricism**), but also requires a healthy dose of methodological skepticism, a good deal of logic (providing good reasons and arguments for believing—**rationalism**), and ethical analysis and evaluation (i.e., critical **ethics**).

So although there are many obstacles to the acquisition of knowledge like distorted thinking, biased thinking, pseudoscientific thinking, magical/supernatural thinking,[81] and fallacious thinking, *[t]he careful use of reason leads to the advancement of science and is far superior to the acceptance of ideas based on emotional pleas, one sided arguments, or…force*.[82] We need, therefore, to foment a skeptical attitude in our students so that they do not relinquish their mental capacity to engage the world via analysis and evaluation. Without a skeptical attitude, natural human biases and limitations would inevitably lead a person to hang on to a preferred belief and ignore or resist all other alternatives. This could lead to a gradual hardening of beliefs that would seriously impede scientific inquiry and the attainment of scientific knowledge.

Of course, this gradual hardening of beliefs is more often than not rooted in some form of indoctrination. And, this, has serious implications for the teaching of ethics in science. For, as Richard Paul argues,

> *[w]ithout critical thinking at the heart of ethical instruction, **indoctrination** rather than ethical insight results. Moral principles do not apply themselves, they require a thinking mind to assess facts and interpret situations. Moral agents inevitably bring their perspectives into play in making moral judgments and this, together with the natural tendency of the human mind to self-deception when its interests are involved, is the fundamental impediment to the right use of ethical principles.*[83]

Accordingly, given the biasing influence of upbringing molded by cultures that indoctrinate their children in only one world view, fomenting a skeptical attitude required for critical thinking is not always possible. To be sure, culture also has an important role to play in encouraging critical thinking skills in students. Nevertheless, ideologues (even if suffering from cognitive dissonance) may have expectations of appropriate behavior and obligations from each member of their unique culture or community based on assumptions about what is right and wrong, good and bad that undermines skepticism and the teaching of critical thinking skills. This undercuts, in application, science as critical thinking (i.e., *good* science). So, as Paul goes on further to note,

> *[w]ithout scrupulous care, we merely pass on to students our own moral blindness, moral distortions, and close-mindedness. Certainly many who trumpet most loudly for ethics and morality in the schools merely want students to adopt **their** ethical beliefs and **their** ethical*

[81]Talavera, Science and Religion: Drawing the Line, 1-25.
[82]Lee, *The Scientific Endeavor: A Primer on Scientific Principles and Practice*, 89 (Here Lee means *governmental* force, but this may be reasonably generalized to most applications of force).
[83]Paul, Chapter 12: Ethics Without Indoctrination, 240.

perspectives, regardless of the fusion of insight and prejudice those beliefs and perspectives doubtless represent. They take themselves to have ***the Truth*** *in their pockets. They take their perspective to be exemplary of all morality rightly conceived. On the other hand, what these same people fear most is someone else's moral perspective taught as the truth: conservatives afraid of liberals being in charge, liberals of conservatives, theists of non-theists, non-theists of theists.*[84]

Consider, for example, when religionists claim to support a ***pro-family*** ideology, with a unique set of family values, traditions, and norms. They will have a problem promoting skepticism and the higher-cognitive skills of analysis and evaluation because enculturation is reduced to receiving the *right* education or upbringing (usually following the *right* role models, *right* teachings, or *right* practices). Accordingly, such cultures normally concentrate on the *right* character, *right* values, and/or the *right* rules of a particular code of ethics rather than on ethical analysis and evaluation (i.e., critical ethics). However, this puts the cart before the horse, since this begs the question by relying on the very thing not yet established (i.e., the *right*—an **ethical** matter).

Moreover, the ethical **ABSOLUTISM** usually appealed to by such conservative cultures can never underwrite what is right and wrong, good and bad because it can never hold more than one perspective (given its **dogmatic** approach*: it is my way or the highway*). Furthermore, by itself, the absolutist view would fail to elucidate the *right* view, since we could not show how we are to choose between competing ethical views. Accordingly, there would be no way to convince someone who does not share the privileged view that it is the *right* one. Again, this begs the question by relying on the very thing not yet established (i.e., the *right*—an **ethical** matter). Besides, we would not always be sure of, or in agreement about, the credentials of the prevailing ethical authority appealed to, nor on how its absolutism would rule in ambiguous or new cases. In the end, all of this would trivialize the subject of ethics and serve more to block critical thinking than to promote it.

In contrast, a liberal culture may appeal to ethical **RELATIVISM** to try to overcome the biasing influence of upbringing molded by cultures or communities. But, relativism can never underwrite what is right and wrong, good and bad either because it can never find one perspective to take precedence (given its **pluralistic** approach: *it is relative to the particular context or culture*). So, individuals or groups may differ dramatically in their judgment of what is right and wrong, good and bad. Specifically, since there are many different religions, faiths, or belief systems in the world, the problem is that *what is right and wrong, good and bad* is taken to be relative to the individual or group.

However, this interpretation not only undercuts claims that theistic religion is compatible with critical thinking, but strongly suggests that what is right and wrong, good and bad is personal and subjective. This is because religious authorities espousing competing theistic beliefs differ among themselves on what is right (or good) and what is the conduct that is required by God's will. This not only often leads religious people of good will to opposite positions on ethical matters, but undercuts claims that religion provides a secure, certain, universal, and stable guide to ethics. Accordingly, the problem of relativism is that there can be no objective standards, since

[84]Ibid, 241.

different individuals or groups have different beliefs. Also, the problem is that an individual's or group's judgment is neither better nor worse than that of any other individual or group—it is merely different. And since an individual's or group's judgment has no special status, there can be no individual or group looking down on others as the objective standard.

So, as with the critique of ethical absolutism above, ethical relativism would also not work to overcome the biasing influence of upbringing molded by cultures. This, then, would also trivialize the subject of critical ethics. For if, as relativists have argued, there can be no objective standards and *what is right and wrong, good and bad* just boils down to the personal preference of different individuals with different religions, faiths, or belief systems, then critical thinking (i.e., *analysis* and *evaluation*) has little practical application and science is without genuine consequence. Nevertheless, we can avoid this absurdity by rejecting the claim that *what is right and wrong, good and bad* is always relative to the individual's religion, faith, or belief system.[85] In contrast,

> *[c]ritical thinking does not compel or coerce students to come to any particular substantive moral conclusions or to adopt any particular substantive moral point of view. Neither does it imply moral relativism, for it emphasizes the need for the same high intellectual standards in moral reasoning and judgment at the foundation of any bona fide domain of knowledge*.[86]

Accordingly, science as critical thinking must be based on claims or deduced implications that correspond with objective reality so we can thresh out the good claims or reasoning from the bad—the *good* science from *bad*. And, this, is an ethical matter. For, if we teach only dogmatic beliefs (even if derived from motivated reasoning)—no matter how useful and even inspiring they may be to a particular culture or community—without communicating skepticism and critical thinking, how can the average person possibly distinguish good science from bad? Without a skeptical attitude, ethical analysis and evaluation could not be in play. And, we would believe all kinds of false or inconsistent things and our knowledge would be in conflict with better established background information—there would be no coherency in our knowledge and actions. This would have devastating consequences for the survival of the human species because our knowledge would not align or match with reality. But, as we have seen, key aspects of philosophy (i.e., epistemology, critical thinking, and ethics) characterize *good* science as a natural philosophy relevant to the right conduct, preservation, and non-harmful development of the species. And, because science can be a crucial discipline for improving the human condition, it is, as we have argued, an important expression or part of critical ethics. Therefore, in the sense that science, as a philosophical endeavor, helps us examine the world around us to make it worth living, meaningful, and safe, it is certainly not hostile to human flourishing, dignity, thoughts, feelings, and desires.

---

[85]See Talavera 2011 & 2012 (parts of this paragraph were adapted). See Fleas in a Jar (https://www.youtube.com/watch?v=v-Dn2KEjPuc), Critical Thinking (https://www.youtube.com/watch?v=6OLPL5p0fMg), and Skewed Views of Science (https://www.youtube.com/watch?v=_lQKYhWpwvg). Accessed Jan. 6, 2016.
[86]Paul, Chapter 12: Ethics Without Indoctrination, 243-244.

VIII. Responses to Objections

As we saw in **The Story of the Blind Men and an Elephant** (our metaphor from **Section II** above), the process of getting to know the elephant is, at the very least, an exercise in testing one's belief by means of observation. So the skeptical believer is engaged in the effort to obtain truth about the natural or physical world through observation (enter empiricism). But, scientific knowledge cannot be exclusively based on observable phenomena (i.e., empiricism), since the abstract nature of advanced scientific hypotheses sometimes requires theoretical constructs, objects, principles, or laws that are not accessible to observation. So, for instance, the atomic theory of matter relies on theoretical objects such electrons and protons, which are not accessible to observation. Accordingly, a scientific hypothesis cannot always be based on, and confirmed by, the facts via the senses (observation). And, since a scientific hypothesis cannot always be based on, and confirmed by, the facts via the senses (observation), **inductive thinking** (as a generalization of facts) cannot always be used to generate sophisticated hypotheses in science.

Given this limitation, reason (enter rationalism) is also needed so that the conclusions that should come out on top are the ones that have the best evidence and arguments on their sides. In this sense, truth must matter so that observations correspond with the physical parts of the elephant (enter empiricism) and justification must matter so that good arguments for believing each claim or deduced implications about the elephant are provided (enter rationalism). Accordingly, we can use this example of the story of the blind men and an elephant to address the wider implications of **empirical analysis** (with its emphasis on looking at the **parts** and their possible correspondence with reality) and **rational evaluation** (with its emphasis on looking at the **whole** by using reasoning to connect the dots or parts)—as investigative and corroborative techniques, besides the role these core aspects of critical thinking play in science in general.

To be sure, what we **claim** to **know** about the natural or physical world depends on some **epistemological** view or position arrived at by inquiring whether our corresponding beliefs are **true** (i.e., the beliefs correspond with reality—the philosophical theory of **empiricism** is a factor) *or* the beliefs are **justified** (i.e., there are good reasons and arguments for believing— the philosophical theory of **rationalism** is a factor). But, what the story of the blind men and the elephant shows is that key elements of empiricism like first-hand experience, observations, and facts are not sufficient for scientific knowledge. This is not surprising since empiricism takes its name from *empeiria*, the Greek word for *experience*. And, according to empiricism, the true (or only) *source* of knowledge is found in experience where facts are extracted wholly (or mainly) through one or more of the five senses (sight, hearing, touch, smell, and taste). So, in this account **experiencing is knowing**. But, as we learned in the allegory of the blind men and the elephant, having a correspondence with reality (i.e., true belief) is not sufficient for knowledge.

In contrast, **rationalism** takes its name from *ratio*, the Latin word for *reason*. According to rationalism, the true (or only) *source* of knowledge is found in reason (a faculty or power of the mind commonly referred to as *intellect*). So, in this account **reasoning is knowing**. Reasoning, at its best, calls for sound arguments, which come into play in this interpretation because logic, as a branch of philosophy, studies arguments. Logic is an important factor in science because, as the biologist Thomas H. Huxley once noted, [s]*cience* [must be] *rigidly accurate in observation, and* *merciless to fallacy in logic*.[87] This is so that the **beliefs** that should come out on top are the ones that have the best reasons or evidence on their sides. This is crucial because, as Alfred Tarski notes in his *Introduction to Logic and to the Methodology of the Deductive Sciences*,

> *…logic, by perfecting and by sharpening the tools of thought, makes men and women more critical and thus makes less likely their being misled by all the pseudo-reasonings to which they are incessantly exposed in various parts of the world today*.[88]

But just having good logical reasoning (i.e., justification) is not sufficient for knowledge. As Jacob Bronowski once noted in his book, *The Common Sense of Science*,

> *In order to act in a scientific manner…two things are necessary: fact and thought. Science does not consist only of finding the facts; nor is it enough only to think, however rationally. The processes of science…move by the union of empirical fact and rational thought, in a way which cannot be disentangled.*[89]

To be sure, empiricism and rationalism, as **sources** of scientific knowledge, always go hand in hand; they complement one another. Rational evaluation may be built upon the results of a preceding empirical analysis, and empirical analysis may require a subsequent rational justification to verify and correct its results. But, we **underdetermine** science when we adopt a too narrow vision of what knowledge is and then ignore, oversimplify, distort, or otherwise unfairly dismiss its empirical or rational dimensions.[90] However, with a broader vision of knowledge that incorporates both **empiricism** and **rationalism** as necessary but not sufficient, **science** may get off the ground to obtain (fallible, but self-correcting) knowledge about the physical or natural world through observations, measurements, and experiments (enter **empiricism**) and/or reason (enter **rationalism**).

There are, of course, important situations in which one source of knowledge can be regarded as more *suitable* than the other. But, this concerns the question of which source of knowledge is the most appropriate as the point of departure for scientific inquiry or confirmation. For instance, the atomistic theory of the universe got off the ground, in a very important sense, with the wings of rationalism. For, the ancient pre-Socratic Greek philosopher Democritus (with Leucippus, ca. 460 BC - ca. 370 BC) posited atoms without the benefit of experimental investigation. So, rationalism was crucial to the early scientific endeavors. However, this Ancient Greek metaphysical thesis of the atomistic theory required *…that the nature of the particles and*

[87] *The Crayfish: An Introduction to the Study of Zoology*, 1.
[88] xiii-xiv.
[89] 30.
[90] This **underdetermination** is due to an underlying **bifurcation of knowledge** subject to (a mode or identification of) change or constancy. As the polemic in the history of philosophy about the continuing tension and dialogue between two sharply differing accounts of knowledge, change epistemology (i.e., **empiricism**) has been diametrically opposed to constancy epistemology (i.e., **rationalism**). This is the epistemological version of **the bifurcation of time** discussed in Talavera's The Fallacy of Misplaced Temporality in Western Philosophy, Natural Science and Theistic Religion.

the laws governing them [be] arrived at empirically rather than [just] by a priori philosophical argument.[91] So, empiricism also turned out to be crucial to modern-day atomism.

That a source of knowledge can be regarded as more *suitable* than the other as the most appropriate as the point of departure for scientific inquiry or confirmation also speaks to the point why…*not all scientists do the same kinds of things—some experiment, others don't, some do field observations, others develop theories. Compare what chemists, theoretical physicists, zoologists, and paleontologists do.*[92] Moreover, this may also explain why

> *[h]istorical sciences like cosmology, geology, and evolutionary biology do not fit the naïve view of scientists proposing scientific theories and then carrying out experiments to confirm or falsify them. Experiments are impossible and empirical data is hard to obtain and fragmentary. However, this does not mean that these fields are not scientific, and that their theories do not need to conform to the definition of scientific theories. It does mean that predictions become retrodictions and that a long time may pass between the proposal of a theory and the availability of data to check its retrodictions*.[93]

In this context, then, to regard **empiricism** or **rationalism** as being inherently better than the other is meaningless. Moreover, to regard one source of knowledge as overarching or overbearing results in a self-defeating epistemology. Undermining the objectivity of science and what we can know about the natural world, for instance, is the notion of **theory-laden observations**.[94] These reveal a rationalism-laden empiricism that, in its most radical form, *deeply permeates* the perception of the scientific investigator to prevent the observational testing of scientific theories. That is because in this interpretation scientific rationalism not only may determine what *empirical* facts are appropriate, but may determine what the *empirical* facts *are*. In this case, then, there is no empiricism without rationalism, since all *empirical* facts are theory-laden.

Accordingly, skeptics may **reason** that we cannot facilitate science in this discussion by appealing to impersonal standards and impartial procedures dictated by the **rationalism** of the means and methods of science. This is because we cannot get at ***knowledge* about the natural or physical world**, since we are somehow always filtering what we *know* via theory and evidence so that there simply and literally are no neutral arbiters. But this form of *reasoning* that accepts no independently accessible locus of truth is untenable, since we would be using reason to defeat reason—thus begging the question. For it ultimately trusts on a form of empiricism-laden rationalism that must use an observation or empirical fact-laden rational theory (or variations

---

[91]Chalmers, Atomism from the 17th to the 20th Century, *The Stanford Encyclopedia of Philosophy* (adapted).
[92]See Paul (with Binker), Chapter 38: Critical Thinking and Science, 612.
[93]Ben-Ari, *Just a Theory: Exploring the Nature of Science*, 197.
[94]Many critics of science work within a social constructivist or postmodernist distinction that contrasts the *subjectivity* of theory with the *objectivity* of sensory data to establish the dictum that *sensory data are theory laden*.
It is claimed that this is problematic because the theory-laden character of data implies *subjectivity*, *circularity*, or *rationalization*. This has the goal of minimizing (or denying) the objectivity of science. But such a distinction assumes a naïve understanding of the nature of science and overlooks the possibility that we can overcome this conception of science (Grant, 2011, 20-25; Ben-Ari, 2005, chapters 6-7; Nagel, 1998, 32-38; Rothbart and Slayden, 1994, 25-38).

thereof) to mount its reasoned critique.[95] Moreover, we could not establish the truth of the claim that **there simply and literally are no neutral arbiters**. For if the claim is *itself* derived by reason, then we are using the very thing we are arguing against. On the other hand, if the claim is *itself* derived on the basis that there can be an **outside** position from which to arbitrate and adjudicate, then we are engaged in circular reasoning—where **neutral arbitration** (which is itself in question) is assumed to somehow establish the position against neutral arbitration. Since either result is untenable (each **contradicts** itself without any doubt), we can thus reject the claim that the progress sought in this discussion cannot be achieved by appealing to rationalism.

By also adopting reason as a key source of knowledge, observation (via the senses[96] or calibrated scientific instruments[97]), measurement, and experiment can be kept in check to serve as arbiters between competing hypotheses. Epistemologically, then, whatever light there is, it is revealed in contrast to the darkness. What's more, in important situations in which one source of knowledge can be regarded as more *suitable* than the other (as the most appropriate as the point of departure for scientific inquiry or confirmation), science need not always be exclusively empirical, or empirically based; science may be subject to, or derived from, reason or the application of logic. Because of this, data that is later acquired by means of observation or experimentation need not *always* be influenced by prior beliefs and experiences—contrary to how some read Thomas Kuhn (see *The Structure of Scientific Revolutions*).[98] This is because scientific knowledge can be separated from the beliefs and experiences of the scientist who produces it. So although scientists may at the start disagree on the nature of empirical data, they can, through reason or the application of logic, compensate for theory-dependence of observation (or at least see that observation is affected as little as possible).

Moreover, such scientific rationalism does not require that we be hard pressed to provide good reasons that increase the likelihood to make our scientific propositions absolutely certain, even if possible doubt introduced by the influence of our prior beliefs and experiences cannot always be ruled out. For, the claim to **know** that knowledge requires certainty seems to establish that **nothing** can be *known* (including *knowing* that *observation or experimentation is influenced by prior beliefs and experiences*) while requiring the *certain* knowledge that nothing can be known (i.e., invoking the contradictory notion that **it is known for certain that nothing is known for certain**). Besides, to require that a proposition be certain to be known, would conceivably, in the

[95]This form of self-sabotaging epistemology tends to be antifoundationalist in approach and is avowed (among others) by pragmatism, constructivism, interpretism, or postmodernism. But if this interpretation is taken seriously, empiricism not only may determine what *theoretical* facts are appropriate, but may determine what the *theoretical* facts *are*. In this case, then, one may claim that such self-sabotaging epistemologies really amount to saying that there is no rationalism without empiricism, since all rational theories are (or taken to be) observation or empirical fact-laden.
[96]Philosophers worry that knowledge of the natural or physical world may, in fact, not really be accessible by the senses. That is to say, *sight, hearing, touch, smell, and taste* may be so contaminated by error or distortion (typically introduced or created by the phenomena of perceptual illusion and hallucination) that perception as a source of (factual) knowledge is no longer reliable. This is called *the problem of (sense-) perception*. The *epistemological problem of (sense-) perception*, however, is whether (factual) knowledge generally can be *justified* on the basis of sensory or perceptual experience.
[97]Scientists can *trust the reliability of modern instruments to expose unobservable physical structures* because *the theory-laden character of data will not imply the inherent failure (subjectivity, circularity, or rationalization) of instruments to expose nature's secrets* (Rothbart and Slayden, The Epistemology of a Spectrometer).
[98]Ben-Ari, *Just a Theory: Exploring the Nature of Science*, chapters 6-7.

end, limit the amount of our scientific knowledge to practically nothing. But this is untenable, since it clearly is the case that there is much scientific knowledge. In short, knowledge bifurcated and skewed as (or conflated with) rationalism or empiricism would adopt a too narrow vision of what knowledge is. This would serve to trivialize the subject of science.

IX. Conclusion

The limitations of personal experience (and our judgments about those experiences) create the need for science, which is grounded in common experimental experience and reason. Under this conception, science is the systematic effort to obtain knowledge (i.e., justified true belief) about the natural or physical world through experimentation (enter empiricism) and reason (enter rationalism) so that the beliefs that should come out on top are the ones that not only correspond with reality, but have the best reasons or evidence on their sides. In view of that, critical thinking is required to help us think our way through the limitations of our personal experiences (and our judgments about those experiences) to increase our chances of getting to the truth of the matter and its justification. To keep us from fooling ourselves, then, critical thinking uses analysis and evaluation, rather than personal experience, to hunt for beliefs that correspond with reality and are justified. This is why *...scientific work is largely the business of not taking any one person's word for it*.[99]

Accordingly, the means and methods employed in science may be defined and determined by *any procedure* of critical thinking *that serves systematically to eliminate reasonable grounds for doubt*.[100] This means that doubt is a key factor when it comes to searching for scientific knowledge. So, to help avoid being deceived by means of bogus sciences and extraordinary claims, the means and methods employed in science must also foment a skeptical attitude so that we may use our critical thinking skills to question our hardened beliefs and/or motivated reasoning to overcome biased, distorted, partial, uninformed, or downright prejudiced beliefs. But, since such a charge requires that we choose between alternatives that must be evaluated as **right** or **wrong** (i.e., **good** or **bad**) using critical thinking, the means and methods employed in science must also invoke a form of critical ethics.[101]

The foregoing story of **the blind men and the elephant** (found in **Section II** above) suggests this much, for as scientists or investigators we **ought** to question the dogmatically held belief that the whole elephant is simply just (like) a fan (a wall, a tree, a snake, a spear, etc.). So, using the example of the fan-believer, in order for us to move away from such a strongly held belief, we would have to be skeptical—to question whether what we are observing via touch is really just a fan. This skeptical attitude would require that we think critically about our belief. For, if we simply stopped with the elephant's ear, then the best we could claim is that we had some **description** about a **reality**. But, by their very design **descriptive studies** simply can't provide evidence to determine cause and effect. Applied generally to our lives, this means that we absolutely **ought not** to use these studies to make any changes to our lifestyle and behavior—that's what experimental methods are for.

[99]Schick and Vaughn, 154.
[100]Schick and Vaughn, 173.
[101]For a general examination of the relationship between science and ethics, see the chapter of Science and Values in Boersema's *Philosophy of Science: Text with Readings*.

So we would have to continue the process of critical thinking by analyzing ***how*** the belief is the case. How can, for example, a fan *by itself* just wave to stir up air without something attached to it to make it move? Doesn't this point to a part-whole relation? This analysis would suggest that we are just touching one part of something (i.e., holding onto the *ear*). This would naturally introduce a **correlational/observational study** where a possible association, relationship, or correspondence between different parts of the elephant can be hypothesized (but **not** tested by means of experimentation at this stage). As we have learned, a correlation is a mutual relationship that is thought to exist between two things, events or types of events. Furthermore, we also learned that in correlational studies, correlation must be critically evaluated; for although correlation plays a principal role, it does not necessarily imply causation. So, by their very design **correlational/observational studies** by themselves simply can't provide evidence to determine cause and effect. Applied generally to our lives, this means that we absolutely **ought not** use these studies to make any changes to our lifestyle and behavior—that's what experimental methods are for.

Because a fan waving to stir up air introduces the idea that something must be attached to it **to make it move**, the idea would be invoking the need for an **experimental study** to address the concerns about **what causes what**? What is the causal mechanism? Accordingly, hypotheses may be formulated and tested about what causes what. Therefore, the process of getting to know the **elephant** must also rely on **testing** by means of experimentation. So the skeptical believer must be engaged in the effort to obtain knowledge about the natural or physical world through **experimentation** (enter empiricism).

To be sure, in experimental studies, correlation plays an underlying role. Nevertheless, correlation must be taken as a necessary, but not sufficient, condition for causation. Causation, as the capacity of one variable to directly influence another, is important in experimental studies because it is the bridge that links the independent and dependent variables of the hypothesis (If A, then B)—enabling the experimenter to transcend mere correlation. But, can we be sure that variable A causes variable B, or (as we have seen in an earlier section) is it, in fact, the other way around that variable B causes variable A? Or, is there a hidden third, extraneous, or confounding factor C that can cause one or the other or both? This hidden or lurking third factor (another variable at play/an alternative explanation) is called the extraneous, spurious, or confounding variable. It is important to control the extraneous or confounding variable because if we don't, we will not be able to establish cause and effect. However, because it would be impossible to find everything that could influence one or the other or both variables, a causal relationship cannot be conclusively proven—although a very likely causal relationship between the variables can be established by conducting an experiment.[102]

In short, experimental methods are used to establish whether a causal relationship is the result of an underlying strong correlation so that, in practical terms, we become increasingly

---

[102]The experimental study is the cornerstone of evidence-based research, relying on the statistical method of (double-blind) randomized controlled trial (RCT). Used to determine the effect of a cause, unlike observational studies which find correlations, these trials find causations. Randomized controlled trials begin with a hypothesis and a population. The subjects are randomly separated into groups. Typically, one group is exposed to the cause, while another group serves as a control. Control groups don't receive exposure to the cause—they're used as an objective comparison to see whether the exposure (or dose) actually had an effect on the group being tested.

confident that the relationship was real and not spurious. Accordingly, the experimenter must carefully remove the confounding causes or alternative explanations so that the effect is testable or reproducible. This requires that the experimenter control the extraneous variables or factors that may be lurking in the background. Moreover, experimental methods are used to also show that dumb luck or coincidence (i.e., random variation) is not involved and to seek impartiality, and avoid errors arising from bias. But, although the ideal method for testing cause and effect relationships is through experimental methods, *…fully controlled experiments…* are often *…not possible, not ethical, or of doubtful relevance*."[103] There is a sense, then, that every experimental study is flawed—the results must be considered tentative and limited to the appropriate context.

As we have seen, this **empirical** side of the problem of knowledge points to an underlying possible **underdetermination** of the empirical. (Can we *empirically* know that this is an elephant?) Because **empirical** investigation in science may take the form of an open-ended activity, it will not provide sufficient conditions for knowledge, even if many experiments are carried out with positive outcomes. Accordingly, one cannot rightly claim even after many experiments (i.e., after an accretion of true beliefs) to have **knowledge** unless one had, at the very least, a **justified true belief**. But, even for this, we must proceed with caution with a stronger sense of justification (taken as **good reasons**, not lucky or educated guesses, which properly ground beliefs in reality so that they are highly probable) to prevent the problem that a **justified true belief** may not provide sufficient conditions for knowledge.[104]

Accordingly, the process of critical thinking applied to our story of **the blind men and the elephant** must move from analyzed **true belief** (i.e., correspondence with reality), **to whether that true belief can be justified**. This skeptical attitude would require that we not only think critically about our facts (an empirical matter), but our reasoning (a rational matter). We could continue the process of critical thinking, then, by evaluating ***why*** the belief is the case—on the grounds that a fan waves to stir up air because something must be attached to it to make it move. That is to say, we can ask the fan-believer (as well as the wall-believer, tree-believer, snake-believer, spear-believer, etc.) for a good argument for believing his or her respective claim, in order to see if we can paint a logically consistent and objective picture of the reality sight unseen

[103]Battersby, 139.

[104]For instance, to change the analogy, suppose a person *believes* that a particular propeller airplane is safe to fly across the Atlantic Ocean. Can we say that this person *knows* that the airplane is safe to fly across the Atlantic Ocean? The problem is that although one may *believe* that this particular propeller airplane is safe to fly across the Atlantic Ocean, in a flying attempt (i.e., an experiment) the airplane may, unhappily, break down and crash into the ocean (so belief is necessary, but **not** sufficient for knowledge—science is thus **not** characterized by just belief or faith). However, had the airplane safely flown across the Atlantic Ocean, the belief that the particular propeller airplane is safe to fly would be **true** (i.e., the belief corresponded with reality—an **empirical** matter). Yet, truth also is necessary but **not** sufficient for knowledge—science is **not** characterized by just [the search for] truth. Moreover, even if found together, belief and truth do not constitute knowledge. This is because the true belief that the particular propeller airplane is safe to fly would also have to be **justified** (i.e., at least for a period of time there should exist good reasons to ground the belief in reality—enter **rationalism**). Accordingly, one cannot rightly claim even after many experiments (i.e., after true beliefs of actual completed flights) to have **knowledge** that the airplane was safe to fly across the Atlantic Ocean unless one had, at the very least, a **justified true belief**. But, even for this, we must proceed with caution with a stronger sense of justification (taken as **good reasons**, not lucky or educated guesses, which properly ground beliefs in reality so that they are highly probable) to prevent the problem that a **justified true belief** may not provide sufficient conditions for knowledge. See Gettier's Is Justified True Belief Knowledge?

of the elephant. This **justification** of each claim would require that we look at how ideas are related in the form of a valid argument for the truth of each claim. But, this is just the **rational** side of the problem of knowledge (Can an individual *rationally* know that this is an elephant?). So, we must also try to put together the good arguments for believing each claim or deduced implications about the elephant to help connect the dots (i.e., parts) and introduce some coherence and objectivity into the picture.

As a result, not only can each hypothesis (the elephant is simply a fan, a wall, a tree, a snake, a spear, etc.) now be tested for truth by means of experimentation (enter empiricism), but also justified with good arguments for believing it (enter rationalism)—to try to paint a logically consistent and objective picture of the reality sight unseen of the elephant. We are justified in believing a hypothesis to be true when we *…have adequate evidence, and our evidence is adequate when it puts the proposition in question beyond a reasonable doubt. A proposition is beyond a reasonable doubt when it provides the best explanation of something*.[105] As we noted earlier, one hypothesis explains the evidence and accounts for it better than another hypothesis whenever it has any of the following characteristics: the hypothesis is simpler (i.e., it makes less assumptions), does not raise more questions than it answers, makes testable predictions, fits well with established beliefs, and increases the amount of understanding. Accordingly, we have good reason for doubting that a hypothesis is true when *…it conflicts with other propositions we have good reason to believe* (68), when it conflicts with background information (68), and/or it conflicts with expert opinion (72).[106]

In view of that, it is not enough for each of the blind men in our story to carry out his empirical experiment in isolation. Each experiment in **the story of the blind men and the elephant** suffers from the poverty of empiricism to supply the complete evidence needed to establish the *big-picture*. Every empirical study is flawed—the results must be considered tentative and limited to the appropriate context. **So even if each of the blind men carried out his experimental study in isolation**, **each really would not have science in any sense of the term**. This is because, as we learned, the best each could show is **HOW empirical** claims that typically characterize **experimental studies** arise, but leaving out **WHY**. So if we wanted to connect all the dots, we would need to ask the fan-believer, wall-believer, tree-believer, snake-believer, spear-believer, etc., for a **good argument for believing his claim**, in order to see if we can paint a **logically consistent** and **objective** picture of the reality (sight unseen) of the elephant.

As a practical matter, then, scientists cannot work in isolation from the scientific community. **Independently repeated testing and peer review** would also need to be introduced to help paint this **logically consistent** and **objective** picture of the reality (sight unseen) of the elephant. Because science is a social institution, it relies heavily on the healthy **skepticism** of others to effectively contribute to the advancement of reliable scientific knowledge. So after a **single experiment** is carried out, we would want to know **whether the experimental results are consistent (or converge) with the empirical evidence provided by other independently repeated tests of the results of the original experiment**.

---

[105]Schick and Vaughn, 67.
[106]Ibid, 68; 72.

We would also want to know, after each **single experiment** is carried out, **whether the experimental results are consistent (or converge) with the entire body of our knowledge of the natural or physical world**. This not only requires that other *outside* experimenters **aggregate further evidence by reproducing the experiment to help corroborate the causal claim in question** (to help expose and remove further threats to the internal and external validity of the experiment),[107] but that members of the scientific community determine whether the experimental research carried out fits well with **established science, trustworthy observations, known natural laws, and/or with well-established theories of science** (enter the Criteria of Adequacy). To be sure, the problems that threaten the internal and external validity of an experiment cannot always be overcome with independently repeated testing and peer review. There is always the possibility that some **empirical** matter may slip through the cracks of the experimental design or the review of the community of scientists. As a result, **rationalism** must continue to play its important role as researchers or reviewers critically evaluate the scientific claim to help deal with the possible **underdetermination** of the empirical.

To be sure, this **independently repeated testing and peer review** is just the **rational** side of the problem of knowledge. (Can we ***rationally*** **know** that this is an elephant?) The acquisition of scientific knowledge seeks **justification of truth**, looking **at how ideas are related** in the form of **established science, trustworthy observations, known natural laws, and/or with well-established theories of science**. That means that **reason** (enter rationalism) is also needed so that the conclusions that come out on top are the ones that have the best evidence and arguments on their sides to help connect the dots (i.e., parts)—introducing some **formal reasoning and inference** to help **justify** the **true belief**.

Accordingly, each hypothesis (the elephant is simply a fan, a wall, a tree, a snake, a spear, etc.) can be tested for truth by means of experimentation (enter empiricism), but also justified with good arguments for believing it (enter rationalism), to paint a logically consistent and objective theory of the reality (sight unseen) of the elephant. In this sense, **truth** must matter (the observations made must **correspond** with the physical parts of the elephant—enter **empiricism**) and **justification** must matter (as the **good arguments for believing each claim or deduced implication** about the elephant—enter **rationalism**). In short, **science** may get off the ground to obtain (fallible, but self-correcting) knowledge about the natural or physical world through **the union of empirical fact and rational thought**. But, **critical thinking** is needed in order to close the gap between underdetermined theory and the empirical evidence brought in its support. And, **critical ethics** is also needed so that the characteristic **values** scientists have come to expect a

[107]We can put together the possible problems with experimental studies into two general categories: problems that threaten **internal validity** and **external validity** of the experiment. **Internal validity** concerns the quality of, and the confidence we have in, the **cause-effect relationship** after doing an experiment. What is crucial here is whether **the experimenter** can manipulate the independent variable, measure the dependent variable, set-up equivalent groups, and experimental control. **External validity** refers to the extent that the results of an experiment carried out in **an artificial**, **sanitized**, **and/or controlled laboratory setting** can be generalized from the sample to the real world (to provide real-world meaning), across populations, times, and settings. What is crucial here is whether in **a real-world context** internal validity is maintained, the sample is big enough for generalization to arise, the sample is representative of a target population, the experience of the independent variable in the study is representative, and the measurement of the dependent variable is representative (in a meaningful way) of the changes or differences. For a list of these possible problems with experimental studies, see **Appendix A**.

theory to embody in its appraisal, its truth-like character and justification, may play their roles in the effort to attain objectivity and consistency.

In short, the peer review process makes science stronger by ensuring that experimental results will be tested, studied, reviewed, and examined in light of their internal and external validity. And the knowledge that they will be reviewed prevents overreaching and checks the accretion of flawed, biased, or unethical results. Parallelly, whenever flawed, biased, or unethical results are unchecked and the experimenter held unaccountable, it almost inevitably leads to mistakes and abuses. In the absence of critical ethics in the acquisition of scientific knowledge, then, incompetence, dishonesty, and exploitation flourishes. For rigorous accountability is discouraged and unethical behavior is rewarded in the absence of critical thinking that is indispensable when choosing between alternatives that must be evaluated as **right** or **wrong**.[108]

So, to keep members of the scientific community from fooling themselves and engaging in unethical behavior, and help curtail the tendency of some to ignore and misinterpret the main body of reliable research in each scientific discipline, science seeks ***further*** **analysis** and **evaluation** in the form of **peer review**, rather than **single experiments**, to justify new causal claims. **This typically requires *formal* argumentation by members of the scientific community that re-evaluates the methods used and evidence obtained to establish the causal claim**. Given the open-ended nature of research, this mutual criticism and intellectual cooperation, makes it **less likely** for scientists to mislead others by unjustified and/or false claims passing for new knowledge or research. But, researchers and peer reviewers must **continuously** be on the look-out for flaws (and/or, fraud) in the experimental study. This is because some flaws (and/or, fraud) may be so great that the results are worthless, while other results may be valuable in spite of the flaws (and/or, fraud). Thus, scientific claims must be systematically and continuously threshed by means of **analysis** (to determine **how** the belief is the case) and **evaluation** (to determine **why** the belief is the case).

This suggests that whether we are researchers and peer reviewers or not, we may participate in the process of refining the acquisition of **scientific** knowledge by engaging in a form of methodological skepticism that systematically and continuously asks **Critical Questions**.[109] In the following, we summarize this methodological approach to critical thinking.[110]

---

[108]Students may be made aware of this problem by reading, for example, The Belmont Report (which outlines ethical principles and guidelines for research involving human subjects) in light of the infamous clinical biomedical research study, the Tuskegee Syphilis Experiment, conducted between 1932 and 1972 by the U.S. Public Health Service in Alabama. Under the pretext of providing free health care from the United States government, researchers knowingly failed to treat the natural progression of untreated syphilis in rural African-American men. These syphilis experiments were later moved to Guatemala were United States-led human experiments were conducted on the vulnerable Guatemalan population.

[109]Here we have significantly modified and fleshed out Battersby's four basic questions from this philosopher's excellent book: *Is that a Fact? A Field Guide to Statistical and Scientific Information*: 1. **What is being claimed?** 2. **How good is the evidence?** 3. **What other information is relevant?** 4. **Are relevant fallacies avoided?** For an application showing how students may develop an understanding about how science works and how students may develop an appreciation for the process by which we gain scientific knowledge, see **Appendix B**.

[110]**Appendix B** highlights the point that critical thinking may be used to introduce the major themes, processes, and methods common to all scientific disciplines applying the critical questions to statistical and scientific claims.

CRITICAL QUESTIONS

I. BELIEF:

What is the belief? (What is being claimed? What is the conclusion? What is the hypothesis?)

II. SKEPTICISM:

Are there reasons to doubt the belief?

III. CRITICAL THINKING (ANALYSIS + EVALUATION):

A. ANALYSIS:

1. What is the argument for the belief?

2. What is the conclusion? (What is being claimed?)

3. What are the premise(s)? (What is the evidence?)

4. TRUTH: Are the premises true?

B. EVALUATION:

1. How good is the argument?

a. Is it inductive (strong, cogent)?

b. Is it deductive (valid, sound)?

2. How good is the conclusion? (How good is the claim?)

a. JUSTIFICATION: Does the conclusion logically follow from the premise(s)? (Does the claim logically follow from the evidence?)

3. How good are the premise(s)? (How good is the evidence?)

a. Is the evidence credible? Plausible? (Are the premises known by personal experience, do not contradict personal experience, do not contradict other statements we know to be true, are made by an honest and reputable authority, journal, reference source, or media source we know and trust?)

b. Is each premise reliable, uses language that is concrete and concise, avoids loaded language, uses consistent terms, and sticks to one meaning for each term?[111]

c. Assuming the premise(s) are true, how much support do these premise(s) provide for the claim? (Assuming the evidence is true, how much support does this evidence provide for the claim?)

4. Does the argument meet the burden of proof?

a. Is the argument consistent with the direction of previous (or other) research or evidence?

b. If in conflict with previous (or other) research, does the argument deal effectively with opposing evidence or

[111]Adapted from Weston, *A Rulebook for Arguments.*

arguments? Is it strong enough to counter this previous (or other) research?

5. Is there relevant information that is missing?

a. Is there any context or background information of the argument missing? Any assumptions missing? Any ignored or actively suppressed premises? Any hidden third, extraneous, lurking, spurious, or confounding factor or variable omitted?

6. Is the argument fallacious? Are relevant fallacies avoided?

In conclusion, the foregoing critical questions suggest how the educator might help science students bridge the gap between the facts learned in a science course and the critical thinking skills of analysis and evaluation so that they may secure scientific knowledge and scientific habits of mind. For teaching science is not just about how we do science (i.e., focusing on just accumulating undigested facts and scientific definitions and procedures), but why (i.e., focusing on helping students learn to think scientifically). So although select subject matter is important, the largest single contributor to understanding science is not the factual content of the scientific discipline, but rather the ability of students to think, reason, and communicate critically about that content. When…*teaching scientific facts is emphasized, while individuals are not given the skills with which to critically evaluate the claims that are presented to them [,p]eople are placed in the position of accepting or rejecting claims based on what they are told to believe, rather than being able to critically evaluate the evidence.*[112]

This, as we have argued, may be dealt with by a science education that helps students directly by encouraging them to analyze and evaluate all kinds of phenomena, scientific, pseudoscientific, and other. Accordingly, this science education should focus on analyzing and evaluating arguments typically marshaled for and against alleged sources of knowledge (e.g., ordinary belief and pseudoscience, etc.) in order to help the learner avoid being deceived by means of bogus sciences and extraordinary claims. For,

> *Scientific habits of mind can help people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems.*[113]

In short, we have seen that the acquisition of scientific knowledge via critical thinking foments a skeptical attitude in our students so that they do not relinquish their mental capacity to engage the world critically and ethically. This is important because students, as future citizens or scientists, must develop the critical thinking skills necessary to overcome obstacles to reliable reasoning and clear thinking to deal effectively with ethical issues. We live in a time when people throughout the world need analytical and evaluation skills more than ever to address crucial issues such as maintaining health and combating infectious diseases, obtaining sufficient, nutritionally

[112]Walker, *et al.*, Science education is no guarantee of skepticism.
[113]Rutherford and Ahlgren, *Science for all Americans*.

adequate and safe food as well as safe and affordable water, enhancing the ability of future generations to meet their sustainable energy needs and improve energy efficiency, dealing with potential environmental change that leads to habitat destruction, and stimulating emerging technologies and ideas that can increase the number of businesses and grow the economy.

There is no such thing as philosophy-free science; there is only science whose philosophical baggage is taken on board without examination.[114] Accordingly, philosophy has a unique and essential role in science education that must be examined—to strengthen critical thinking, help in the evaluation of arguments, help introduce standards of evidence to advance human knowledge, and help improve the student's capacity to articulate his or her own ethical views to frame and assess the important scientific issues he or she may be challenged with. This is consistent with the aim of the philosophical approach to science education presented in this treatise, which is not simply to help the student to acquire content but to enable and empower the student to grasp, interpret, and extend the content ***outside the box***—beyond the limits of upbringing, hardened beliefs, dogmatic values, motivated reasoning, and different worldviews that arise from social or political contexts[115]—to help the student develop as a well-rounded, autonomous, rational, and ethical human being.

APPENDIX A: Possible Problems with Experimental Studies

I. Internal validity

An experiment may be characterized as **internally valid** when:

1. The experimenter's conclusion is correct based on the evidence provided (statistical validity);
2. The changes seen or measured in the dependent variable (i.e., the differences in the dependent variable) are actually a result of the manipulation of the independent variable (where the independent variable comes before the dependent variable);

---

[114]Dennett, *Darwin's Dangerous Idea*, 21.

[115]The challenge is to recognize that in social or political contexts, in approach and/or application, **every belief system is conservative to itself, but liberal to others**. Accordingly, a social or political belief system is caught between a rock and a hard place: ***conservatism*** (interpreted as the *dogmatism* of the particular social or political position so that *it is my way or the highway*) and ***liberalism*** (interpreted as the *plurality* of social or political positions where the belief systems espouse competing moral codes and/or differ among themselves on what is right and what is the conduct that is required). Consider, for instance, the one dimensional battle being fought today in politics (i.e., the *culture* wars)—the *right* versus *left*, which for the Christian fundamentalist really is the *spiritual* battle (Eph. 6:10-20) of theism versus atheism. Although this black and white thinking has no real connection to science (science is neither conservative nor liberal), science nevertheless is caught-up in this battle (i.e., the *science* wars—see Grant, 20-25) when characterized by the religionist as an *atheistic* religion, faith, and/or just a theory or belief system. In short, this simplistic reduction clearly makes Christian fundamentalism and modern science incompatible. Moreover, because an appeal to critical thinking itself may be considered subversive to religiously socialized (or indoctrinated) followers, it is an important underlying reason why modern science may be taken as a threat by some religionists (See Heitin, Colbert, and Talavera 2012). Nevertheless, a religion can encourage critical thinking and because of this not be hostile to science. An example of this is Buddhism (See Jayatunge).

3. And, there are no other confounding, or omitted, variables that actually caused the change in the dependent variable.

Depending on the kind of experimental method carried out, **internal validity** may be **threatened** by any of the following (this is not an exhaustive list):

1. **Confounding Variable** (change in the dependent variable caused by a variable not included in the experimental study);
2. **Placebo effect** (a non-active treatment that (for possibly psychological or unknown reasons) seems to be causing a change like an active treatment);
3. **Contamination** (participants from one group communicate with participants of the other group and find out what the experiment or treatment is all about);
4. **Compensatory Behavior** (participants from one group find out that the participants of the other group were given something of value and try to reduce (or compensate for) the differences);
5. **Experimenter Bias** (participants change their behavior after the experimenter carelessly or unconsciously communicates (through subtle clues or nonverbal behavior) the outcome that s/he wants);
6. **Selection Bias** (assignment bias, self-selection, existing groups);
7. **Demand Characteristics** (participants discover what the hypothesis is and work to confirm it in order to please the experimenter);
8. **Selection by Maturation Interaction** (a dependent variable at one point of testing isn't always the same at all points in time—e.g., IQ matching of two existing groups measured or sampled to be equivalent on the dependent variable at one point of testing);
9. **Statistical Regression**—given time, an extreme measure/score will move to the average/mean (e.g., a sample of subjects with either very high or low measures of depression);
10. **Mortality** (differential attrition/unequal group drop-out of a study);
11. **Biological Maturation** (e.g., infants mature faster than adults);
12. **History Effects** (some factor out in the world that effects the dependent variable—e.g., collective anxiety produced by the 9/11 historical disaster);
13. **Testing** (practice effects—experience makes the participant perform better), fatigue effects—repeated experience makes the participant tired or bored, *catching on* effects—experience helps the participant figure out the hypothesis);
14. **Instrumentation** (measurement bias or error is introduced by instrumentation effects).

II. External validity

Depending on the kind of experimental method carried out, **external validity** may be threatened by the following (this is not an exhaustive list):

1. **Population Validity** (small unrepresentative sample);

2. **Change over Time** (treatment will not work when applied to a later time period; or, treatment may work later than expected);
3. **Multiple-Treatment Interference** (multiple-treatments given to participants make it difficult to separate the change associated with a single treatment);
4. **Experimenter Effect** (a treatment may not work if a different experimenter delivers it);
5. **Hawthorne Effect** (participants may behave differently because they are being watched);
6. **Novelty Effect** (participants may or may not react to the novel nature of a treatment, rather than the actual treatment);
7. **Measurement** (a treatment effect may only be observable with specific measures or types of measures).

APPENDIX B: Application of the Critical Questions to a Specific Example

To further highlight that critical thinking may be used to introduce the major themes, processes, and methods common to all scientific disciplines, the critical questions will be applied below to a claim as an example of how students may develop an understanding about how science works and how students may develop an appreciation for the process by which we gain scientific knowledge. Let's try using the critical questions on a **made-up** poll report. Let's suppose that on a specific date, a national poll report is published in the **National Enquirer** (a popular tabloid newspaper). The headline states: ***Support for flu-vaccinations plunges (RESULTS: DON'T VACCINATE: 75%; VACCINATE: 25%)***.

But, after some extensive research, you (the investigator) find out that the *national* poll was based on a street survey carried out in Rodeo Drive (a street in Beverly Hills, California, where the very rich and famous shop, live, and eat). Moreover, you find out that the street survey (claiming a margin of error ± 5 percentage points) asked five-hundred rich celebrities who are very influential political activists: ***Which of the following 4 options do you support?***

1. Vaccinate at the risk of getting the flu from the vaccine (3%).
2. Seek an alternative (less dangerous) medical approach (27%).
3. Do nothing (48%).
4. Vaccinate (22%).

Furthermore, you find out that the poll was taken just after a major news report about how some influential celebrities fear inoculating their children against childhood diseases because of the link between vaccines and autism.

CRITICAL QUESTIONS APPLIED

I. BELIEF:

What is the belief? (What is being claimed? What is the hypothesis?)

(National) support for flu-vaccinations plunges.

II. SKEPTICISM:

Are there reasons to doubt the belief?
We may doubt the belief because of the following reasons.

1. We may question whether the sponsor of the poll is biased and whether this bias affected the poll. The reason for this is that throughout the years, the National Enquirer has developed an unsavory reputation of promoting scandals and fabrications. To be sure, these scandals and fabrications are sought by the general public for their entertainment value. But, as a tabloid newspaper in the business of drawing in readers to increase circulation and income, it is almost certain that their polling was biased and this bias affected the poll.

2. The people involved do not appear to understand the issue. Those that are answering to promote a particular hidden agenda are individuals who refuse to think critically about an issue and fall prey to hardened beliefs, a *my-way-or-the highway* or *self-serving* belief system, and have a hard time understanding any issue. As noted by Battersby, the sad reality is that *...it is the unreflective and uninformed beliefs of many people that determine how they vote* (37). So, people who have already made-up their minds (in the dogmatic sense) do not think critically. This is because it takes a lot of work and resolution

> *...to discover and overcome personal prejudices and biases; to formulate and present convincing reasons in support of conclusions; and to make reasonable, intelligent decisions about what to believe and what to do* (Bassham, et al).

3. There appears to be self-selection involved by the respondents. Accordingly, we may question whether the respondents of the poll are biased and whether this bias affected the poll. For, if a person refuses, because of a self-interested nature, to discover and overcome personal prejudices and biases, he or she will have a hard time trying to think critically about the issue—closed-minded and locked in his/her personal prejudices and biases. For any such person, what is true (or false) really does not matter in a *my-way-or-the highway* belief system.

4. Does the claim made by the poll report about a population base itself on a sample involving a margin of error? The actual poll did not mention a margin of error. But, after some extensive research, the investigator found out that the street survey poll claimed a margin of error ± 5 percentage points.

5. Does the poll report mistake the information about the sample, for the claim about the population? The poll report definitely mistakes the information about the sample for the claim about the population. Where is the lack of support coming from? Since the poll report does not mention which population was being sampled, it appears to have intentionally mistaken the information about the sample of five-hundred rich celebrities who are very influential political activists for the claim about the population. Shouldn't the headline say **Support for flu-vaccinations plunges for most rich celebrities sampled**?

6. Does the poll report really reflect the questions asked? The poll report cannot really reflect the question asked, if crucial factors that make up the question are not reported in this poll report.

7. The claim in question (***National*** **support for flu-vaccinations plunges.**) is not beyond a **reasonable** doubt, since there exists a **hypothesis** that explains the evidence and accounts for it **better** than any other competing explanation—**a best explanation**. A hypothesis $\mathbf{h_2}$ explains the evidence and accounts for it **better** than $\mathbf{h_1}$ whenever it is simpler (i.e., it makes less assumptions), does not raise more questions than it answers, makes testable predictions, fits well with established beliefs, and/or increases the amount of understanding (since it systematizes and unifies well our knowledge). This way of rating or evaluating which hypothesis (claim or belief) is best is called **the Criteria of Adequacy**.[116] Accordingly, hypothesis h_2 (**Support for flu-vaccinations among five-hundred rich celebrities who are very influential political activists plunges.**) explains the evidence and accounts for it better than hypothesis h_1 (***National*** **support for flu-vaccinations plunges.**).

III. CRITICAL THINKING (ANALYSIS + EVALUATION):

A. ANALYSIS:

1. What is the argument for the belief?

1) Five-hundred rich celebrities who are very influential political activists do not support flu-vaccinations.

---

2) Thus, (national) support for flu-vaccinations plunges.

2. What is the conclusion of this argument? (What is being claimed? What is the hypothesis?)

(National) support for flu-vaccinations plunges.

3. What are the premise(s) of this argument? (What is the evidence?)

The evidence consists of the respondents' answer to the question surveyed: *Support for flu-vaccinations plunges (RESULTS: DON'T VACCINATE: 75%; VACCINATE: 25%).*

PREMISE: Five-hundred rich celebrities who are very influential political activists do not support flu-vaccinations.

[116] Schick and Vaughn, 179-190.

4. Are the premise(s) true?

Yes.

B. EVALUATION:

1. How good is the argument?

When we look at the form of the argument above, we can see that the derived conclusion need not always follow from the premise. This is a WEAK **inductive** argument because it has the following form.

1. Sample
----
2. Thus, population

2. How good is the conclusion? (How good is the claim? Is the belief true? Does the belief correspond with reality? Is the belief justified?)

A WEAK inductive argument form means that the reason provided as evidence for the conclusion is inadequate for accepting the conclusion **(*National* support for flu-vaccinations plunges.**).

3. How good are the premise(s)? (How good is the evidence?)

The evidence is not good because assuming the evidence is true, it does not provide much support for the claim. Given that the survey asked only five-hundred rich celebrities who are very influential political activists, the reasoning appears to really go from observations about some of this group's characteristics to a claim about an entire (much bigger) group (i.e., the population on a *national* level).

The evidence is not credible because of the following reasons.

a. The sampling method (known as CONVENIENCE SAMPLING) **was biased** because not only was it not random, but the sampling method was also not geographically and economically representative. The sampling method involved self-selection bias because the subjects (rich celebrities who are very influential political activists) were allowed to choose whether to respond. So, those who went to the trouble of responding tended to be those who overwhelmingly DO NOT approve of vaccinations. It involved other inevitable sampling biases, for instance, consider the bias resulting from non-response attributable to **minority languages**. Since the poll was not geographically and economically representative, the poll was clearly biased in favor of those who frequently visit Rodeo Drive (a street in Beverly Hills, California, where the very rich and famous shop, live, and eat) and speak the dominant language (English). Most likely, thousands of very low-income people and/or thousands of people who do not speak the dominant language could benefit from the flu-vaccine. But, based on the poll's poor sampling, the poll excludes them.

b. The sample was not large enough because of the following reasons.

i. Does the poll report provide a sample large enough to generate the kind of margin of error and confidence level as a reasonable basis for claims about national issues (1,200 people, ±3 percentage points; Battersby, TABLE 1, 28)? For a *national poll*, the 500 sample was not large enough to establish the claim. Hence, the margin of error of ±5 percentage points they claim should not be allowed.

ii. Does the poll report provide a sample large enough to generate the kind of margin of error and confidence level as a reasonable basis for claims about local issues (500 people, ±5 percentage points; Battersby, TABLE 1, 28)? The poll report provides a sample large enough to generate the kind of margin of error and confidence level as a reasonable basis for claims about LOCAL issues, since the survey asked 500 people from California. But, they claim it was a *national* poll.

c. The margin of error was not allowed for and credible. A random sample of 500 people would require a margin of error of about ±5 percent (Battersby, TABLE 1, 28). But, since the respondents were self-selected, the notion of randomness was left out. So, the concept of the margin of error for such a *national* poll is certainly not credible and should not be allowed. As Battersby notes, *[t]he results of polls like this one should never be relied on* (51). Is it reasonable to assume that the actual margin of error is greater? The margin of error, when reported accurately, is the mathematical ideal. As Battersby notes (50), *[t]he practical constraints of everyday polling mean that the margin of error is undoubtedly greater than the theoretical ideal. Don't let reporters slip misleadingly precise sample percentages by you as if that was the true figure for the population of the country*.

d. There were non-sampling biases. The questions, question order, survey introduction, or interviewer invited biased answers. There was non-sampling bias that directly invited a ***DON'T VACCINATE*** response, since the question wording and order affected the respondent's answers. It appears that the sponsor of the poll was able to easily manipulate the survey's results by providing options that remind respondents of issues critical to any form of vaccination. So, by providing option 4 last (see below), the specific alternatives stated before option 4 may have actually caused people to decrease their support level for vaccination. This results in QUESTION ORDER BIAS (Battersby, 47).

Which of the following 4 options do you support?

1. Vaccinate at the risk of getting the flu from the vaccine (3%).
2. Seek an alternative (less dangerous) medical approach (27%).
3. Do nothing (48%).
4. Vaccinate (22%).

4. Does the argument meet the burden of proof?

a. The argument is not consistent with the direction of research on vaccinations or evidence about the risk of getting the flu from the vaccine. To be sure, there are competing polls or competing evidence contrary to the poll's claims. Consider the following competing evidence contrary to the poll's claims found online (Accessed Aug. 6, 2016).

Science Behind The News: Influenza & Flu Vaccines
(https://www.youtube.com/watch?v=gCkiNMYnmw0)

Flu shots: Why in the world would I get one?
(https://www.youtube.com/watch?v=ky7rqA0-Y_M)

You Should Get a Flu Shot
(https://www.youtube.com/watch?v=9_npl3A3KHQ)

b. It is clear that the argument does not meet the burden of proof because it is in conflict with present scientific/medical research. Moreover, since the argument doesn't make any attempts to deal effectively with opposing evidence or arguments, it is not strong enough to counter this previous (or other) research.

5. Is there relevant information that is missing?
Other relevant information is as follows.

a. The poll was taken just after a major news report about how some influential celebrities fear inoculating their children against childhood diseases because of the perceived link/correlation between vaccines and autism. Hence, because the poll was taken just after a major news event, it could have easily temporarily influenced people's views. For, unfortunately, this leads some to reason incorrectly that correlation is the same thing as causation (i.e., some commit the fallacy of false or questionable cause).

b. These type of questions require thought and information for credible answers. But, it is clear that the respondents lacked thought and information, particularly about such crucial scientific issues. Unfortunately, non-credible answers such as these sooner or later influence public policy. It is a sad reality indeed that *...it is the unreflective and uninformed beliefs of many people that determine how they vote* (Battersby, 37).

6. Is the argument fallacious? Are relevant fallacies avoided?

The argument is fallacious because it attempts to generalize properties by drawing conclusions from the sample (part) to the population (whole). This is known as **the part-whole fallacy.**

Relevant fallacies were not avoided. As reviewed above, the value of the poll is undermined by:

a. Reporting sample statistics as if they were population statistics
Since the poll report does not mention which *population* was being sampled, it appears to have intentionally mistaken the information about the sample of five-hundred rich celebrities who are very influential political activists for the claim about the population.

b. Committing selection bias, self-selection bias, and non-response bias
The sampling method involved self-selection bias because the subjects (rich celebrities who are very influential political activists) were allowed to choose whether to respond. So, those who went to the trouble of responding tended to be those who overwhelmingly DO NOT approve of vaccinations.

c. Non-sampling bias created by question phrasing, question order, or poll introduction
It appears that the sponsor of the poll was able to easily manipulate the survey's results by providing options that remind respondents of issues of which are critical of any form of vaccination. So, by providing option 4 last (i.e., *Vaccinate*), the specific alternatives stated before option 4 may have actually caused people to decrease their support level for vaccination. This results in QUESTION ORDER BIAS (Battersby, 47).

References

Alberts, B. 2005. A wakeup call for science faculty. *Cell* 123: 739-741.

Alberts, B. 2009. Redefining science education. *Science* 323: 437.

Alters, B. J., and C. E. Nelson. 2002. Perspective: teaching evolution in higher education. *Evolution* 56: 1891-1901.

Aristotle. 1941. *The basic works of Aristotle*. Edited by R. McKeon. New York: Random House.

Arum, R., and J. Roksa. 2010. *Academically adrift: Limited learning on college campuses.* Chicago: University of Chicago Press.

Arum, R., J. Roksa, and E. Cho. 2011. *Improving undergraduate learning: Findings and policy recommendations from the SSRC-CLA longitudinal project*. Brooklyn, NY: Social Science Research Council.

Arum, R., and J. Roksa. 2014. *Aspiring adults adrift: Tentative transitions of college graduates.* Chicago: University of Chicago Press.

Bassham, G., W. Irwin, H. Nardone, and J. M. Wallace. 2008. *Critical thinking: A student's introduction.* 3rd ed. New York: McGraw-Hill.

Battersby, M. 2010. *Is that a fact? A field guide to statistical and scientific information*. Ontario: Broadview Press.

Ben-Ari, M. 2005. *Just a theory: Exploring the nature of science*. Amherst: Prometheus Books.

Boersema, D. 2009. *Philosophy of science: Text with readings*. New York: Pearson Prentice Hall.

Bok, D. 2006. *Our underachieving colleges: A candid look at how much students learn and why they should be learning more*. Princeton, N.J.: Princeton University Press.

Bricker, L., and P. Bell. 2009. Conceptualizations of argumentation from science studies and the learning sciences and their implications for the practices of science education. *Science Education* 92: 473-498.

Bronowski, J. 1978. *The common sense of science*. Cambridge: Harvard University Press.

Bunge, M. 2009. *Causality and modern science.* 4th rev. ed. New Jersey: Transaction Publishers.

Campbell, S. K. 2002. *Flaws and fallacies in statistical thinking*. Mineola: Dover Publications, Inc.

Caste, N. J., and J. H. Kiersky. 1995. *Thinking critically: Techniques for logical reasoning*. St. Paul: West Publishing Co.

Chalmers, A. 2014. Atomism from the 17th to the 20th Century. *The Stanford Encyclopedia of Philosophy*. Edited by Edward N. Zalta. http://plato.stanford.edu/archives/win2014/entries/atomismmodern/ (Accessed Nov. 27, 2015).

Colbert, S. 2012. The word: On the straight & narrow-minded. *Colbert Nation: The Colbert Report*, July 17. http://www.colbertnation.com/the-colbert-report-videos/416535/july-17-2012/the-word---on-the-straight---narrow-minded (Accessed July 22, 2012).

Colodny, R. G., ed. 1965. *Beyond the edge of certainty: Essays in contemporary science and philosophy*, The ethical dimension of scientific research. New Jersey: Prentice-Hall.

Cools, A. 2015. Science & philosophy: A beautiful friendship. *Philosophy Now* 109: 6-9.

Davies, P., and J. Gribbin. 1992. *The matter myth: Dramatic discoveries that challenge our understanding of physical reality*. New York: Simon & Schuster.

Dennett, D. 1995. *Darwin's dangerous idea: Evolution and the meanings of life*. New York: Simon & Schuster.

Easton, T. A., ed. 2009. *Taking sides: Clashing views in science, technology, and society*. 8th ed. New York: McGraw-Hill.

Ebert-May, D., T. L. Derting, J. Hodder, J. L. Momsen, T. M. Long, and S. E. Jardeleza. 2011. What we say is not what we do: effective evaluation of faculty professional development programs. *BioScience* 61 (7): 550-558.

Ede, A. 2000. Has science education become an enemy of scientific rationality? *Skeptical Inquirer* 24: 48-51.

Epstein, R. L., and C. Kernberger. 2006. *The pocket guide to critical thinking*. Belmont: Wadsworth.

Eve, R. A., and D. Dunn. 1990. Psychic powers, astrology & creationism in the classroom? Evidence of pseudoscientific beliefs among high school biology & life science teachers. *The American Biology Teacher* 52 (1): 10-21.

Facione, P. A., C. A. Sánchez, N.C. Facione, and J. Gainen. 1995. The disposition toward critical thinking. *The Journal of General Education* 44 (1): 1-25.

Feyerabend, P. 2011. *The tyranny of science*. Cambridge: Polity Press.

Gettier, E. L. 1963. Is justified true belief knowledge? *Analysis* 23 (June): 121-123.

Goldfarb, T., and M. Pritchard. 1999. Ethics in the science classroom: An instructional guide for secondary school science teachers. *ENC Focus: A Magazine for Classroom Innovators* 8(3), Online Ethics Center for Engineering. http://www.onlineethics.org/Resources/precollege/scienceclass.aspx (Accessed: July 13, 2016).

Goldstein, R. 2014. *Plato at the googleplex: Why philosophy won't go away*. New York: Random House.

Grant, J. 2011. *Denying science: Conspiracy theories, media distortions, and the war against reality.* Amherst: Prometheus Books.

Gross, P. R., and N. Levitt. 1994. *Higher superstition: The academic left and its quarrels with science*. Baltimore: The John Hopkins University Press.

Heitin, L. 2012. Texas GOP: No more critical thinking in schools. *Education Week Teacher: Teaching Now*, June 28. http://blogs.edweek.org/teachers/teaching_now/ 2012/06/texas_gop_no_more_critical_thinking.html (Accessed July 22, 2012).

Henry, J. 2006. The rise of the new scientific priesthood. *Creation Concepts: Exploring Biblical Origins and its Applications for Today.* http://creationconcepts.org/resources/PRIESTS.pdf/ (Accessed July 6, 2012).

Hume, D. 1978. *A treatise of human nature*. 2nd ed. Edited by L. A. Selby-Bigge and P. H. Nidditch. Oxford: Oxford University Press.

Hume, D. 1988. *An enquiry concerning human understanding*. Edited by A. Flew. La Salle: Open Court Publishing.

Huxley, T. H. 1877. Technical education. *Science & Education*: *Collected Essays*: Vol. III. http://aleph0.clarku.edu/huxley/CE3/TechEd.html (Accessed Dec. 31, 2015).

Huxley, T. H. 1880. *The crayfish: An introduction to the study of zoology*. New York: D. Appleton.

Impey, C., S. Buxner, and J. Antonellis. 2012. Non-scientific beliefs among undergraduate students. *Astronomy Education Review*: 010111-1–010111-12.

Jayatunge, R. M. 2011. Buddhist philosophy and critical thinking. *Sri Lanka Guardian,* February 26. http://www.srilankaguardian.org/2011/02/buddhist-philosophy-and-critical.html (Accessed July 22, 2012).

Johnson, A. C. 2007. Unintended consequences: how science professors discourage women of color. *Science Education* 91 (5): 805-821.

Johnson, M., and M. Pigliucci. 2004. Is knowledge of science associated with higher skepticism of pseudoscientific claims? *The American Biology Teacher* 66 (8): 536-548.

Kuhn, D. 1993. Science as argument: implications for teaching and learning scientific thinking. *Science Education* 77 (3): 319-337.

Kuhn, D. 2010. Teaching and learning science as argument. *Science Education* 94: 810-824.

Kuhn, T. 1996. *The structure of scientific revolutions*. 3rd ed. Chicago: The University of Chicago Press.

Lambert, K., and G. G. Brittan, Jr. 1992. *An introduction to the philosophy of science*. 4th ed. Atascadero: Ridgeview Publishing Co.

Lee, J. A. 2000. *The scientific endeavor: A primer on scientific principles and practice.* San Francisco: Addison Wesley Longman.

Levine, S., and F. F. Elzey. 1968. *A programmed introduction to research.* Belmont: Wadsworth Publishing Company, Inc.

Mayfield, M. 2001. *Thinking for yourself: Developing critical thinking skills through reading and writing*. USA: Thomson Learning, Inc.

Momsen, J. L., T. M. Long, S. A. Wyse, and D. Ebert-May. 2010. Just the facts? Introductory undergraduate biology courses focus on low-level cognitive skills. *CBE—Life Sciences Education* 9: 435-440.

Moore, B. N., and R. Parker. 2015. *Critical thinking*. New York: McGraw-Hill, Inc.

Moore, J. A. 1999. *Science as a way of knowing.* Cambridge, MA: Harvard Univ. Press.

Nagel, T. 1998. The sleep of reason. *The New Republic* (October 12): 32–38.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2010. *Rising above the gathering storm, revisited: Rapidly approaching category 5.* Washington, DC: National Academies Press.

Nelson, C. E. 2008. Teaching evolution (and all of biology) more effectively: strategies for engagement, critical reasoning, and confronting misconceptions. *Integrative and Comparative Biology* 48 (2): 213-225.

Nolt, J., and D. Rohatyn. 1988. *Schaum's outline of theory and problems of logic*. New York: McGraw-Hill, Inc.

Norton, J. D. 1998. *How Science Works*. New York: McGraw-Hill, Inc.

Pascarella, E. T., C. Blaich, G. L. Martin, and J. M. Hanson. 2011. How robust are the findings of academically adrift. *Change* 43: 20-24.

Paul, R. W. 2012. *Critical thinking: What every person needs to survive in a rapidly changing world.* Tomales: Foundation for Critical Thinking.

Pecorino, P. A. 1987. Critical thinking and philosophy. *Informal Logic: A Journal of Queensborough Community College, CUNY* IX. 2 & 3 (Spring & Fall): 141-145.

Popper, K. R. 1963. *Conjectures and refutations: The growth of scientific knowledge*. London: Routledge.

Rothbart, D., and S. W. Slayden. 1994. The epistemology of a spectrometer. *Philosophy of Science* 61 (March): 25-38.

Rowe, M. P., B. M. Gillespie, K. R. Harris, S. D. Koether, L. Y. Shannon, and L. A. Rose. 2015. Redesigning a general education science course to promote critical thinking. *CBE—Life Sciences Education* 14 (Fall): 1-12.

Ruggiero, V. R. 2008. *Thinking critically about ethical issues*. 7th ed. New York: McGraw-Hill.

Rutherford, F. J., and A. Ahlgren. 1990. *Science for all Americans*. New York: Oxford University Press.

Sagan, C. 1996. *The demon-haunted world: Science as a candle in the dark*. New York: Ballantine.

Schick Jr., T., and L. Vaughn. 2008. *How to think about weird things: Critical thinking for a new age*. 5th ed. New York: McGraw-Hill.

Seymour, E., and N. M. Hewitt. 1997. *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview.

Smolin, L. 2006. *The trouble with physics: The rise of string theory, the fall of a science, and what comes next*. New York: Houghton Mifflin.

Suresh, A. 2015. Genetic literacy project: Autism increase mystery solved: No, it's not vaccines, GMOs glyphosate–or organic foods. https://www.geneticliteracyproject.org/2015/10/13/autism-increase-mystery-solved-no-its-not-vaccines-gmos-glyphosate-or-organic-foods/ (Accessed August 5, 2016).

Talavera, I. 2006. The problem of teaching critical thinking: Three approaches. *NADE Digest* 2 (1) (Spring): 63-69.

Talavera, I. 2011. Beyond ethical codes: A call for critical thinking in religious culture. *The Forum on Public Policy: A Journal of the Oxford Round Table* 2011 (November): 1-14.

Talavera, I. 2012. Science and religion: Drawing the line. *The Forum on Public Policy: A Journal of the Oxford Round Table* 2012 (November): 1-25.

Talavera, I. 2013. The fallacy of misplaced temporality in western philosophy, natural science and theistic religion. *The Forum on Public Policy: A Journal of the Oxford Round Table* 2013: 1-46.

Tarski, A. 1994. *Introduction to logic and to the methodology of deductive sciences*. 4th ed. Edited by J. Tarski. New York: Oxford University Press.

U.S. Department of Health & Human Services. 1979. *The Belmont Report: Ethical principles and guidelines for the protection of human subjects of research.* http://www.hhs.gov/ohrp/regulations-and-policy/belmont-report/ (Accessed July 4, 2016).

Van Gelder, T. 2005. Teaching critical thinking: Some lessons from cognitive science. *College Teaching* 45: 41-46.

Verhey, S. D. 2005. The effect of engaging prior learning on student attitudes toward creationism and evolution. *BioScience* 55 (11): 996-1003.

Walker, W. R., S. J. Hoekstra, and R. J. Vogl. 2002. Science education is no guarantee of skepticism. *Skeptic* 9: 24-27.

Weston, A. 2000. *A rulebook for arguments.* 3rd ed. Indianapolis: Hackett Publishing Co., Inc.

Published by the Forum on Public Policy