Subverting Common Sense: Textbooks and Scientific Theory[1]

E.P. Brandon

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Abstract

Science has advanced by replacing existing ideas with new, often counter-intuitive theories. Science education has recently stressed ways of getting close to the learner. These points conflict. The ways various textbooks present two ideas - the earth's shape; the atomic theory of matter - are examined. The books mistake the cognitive situation (no attempt is made to explain away first impressions; no alternative accounts are evaluated; there is no mention of difficulties and only occasional recognition of the epistemological status of the theories involved). A possible disagreement between practitioners and philosophers over the nature of support is also noted.

I

It is a commonplace of reflective writing on science that the western scientific tradition has mainly advanced through the replacement of apparently commonsensical views by theoretical accounts of the nature of things. These theories often give a very different, sometimes counter-intuitive, picture of reality. Of course, given the permeability of common sense by what at one time were conjectures going beyond appearances, one man's counter-intuitive mystery is the next man's, or generation's, common sense observation. But such developments do not impugn the general and pedagogically central point that learners are faced with grasping concepts and understanding claims which are often very different from anything already a part of their intellectual make up, or that of their local environment (cf. Brandon, 1987, ch. 3).

While it is impossible to enter here into the controversies surrounding the critical evaluation of science, it is important to note that the same tradition of reflection on science overwhelmingly sees the permanent revolution of concepts and theories as cognitively progressive, at least in the main. Common sense is not only overturned, but deserves to be.

In reflection on the teaching of science, there has been tremendous enthusiasm, "probably unprecedented in the history of pedagogy" (Nadeau and D�sautels, 1984, p. 47), for assorted ideas under the capacious umbrella of science as inquiry. Given, among other things, the lack of clarity about the content of this ideology (cf. Brandon, 1981; Martin, 1985, ch. 1), it is perhaps not surprising that it appears not to have been quite the success that had been hoped for. After twenty odd years, writers still complain of unimaginative, fact-besotted students, unaware of the fluidity of our conjectural theorizing. If secondary schools had taught a less rigid view of theory, "students entering university would be prepared to anticipate novel and more refined models" (Munby, 1982, p. 30).

More recently integrated science has become fashionable, not least in the Caribbean, where the local Examinations Council provided Integrated Science before offering the traditional separate sciences. More recently still, science educators have paid attention to the views of the nature of things and how they work that the learners bring to the interaction, "street science" as some of my colleagues have labelled it (cf. Driver et al., 1985; George & Glasgow, 1988). As with other subjects in the curriculum, there is here and elsewhere a wish to get as close as possible to the learner and his or her preconceptions, to provide "relevant" or "meaningful" learning. With all this concern for rapprochement, it is refreshing to hear Harlen remark that "there is a danger that children's use of process skills will be limited by these existing ideas, so inhibiting the collection of evidence which will challenge these ideas" (1986, p. 33).

While perhaps laudable in themselves, these pedagogical emphases tend to conflict with the initial point: worthwhile ideas in science do not in general lie to the untutored (or uninspired) hand; the content we want grasped is not continuous with what the rest of society accepts but often subverts it. It may not be particularly "meaningful": Gellner remarked that "a bundle of conjectures is not a habitable world" (1985, p. 126) but he has also suggested (1987, ch. 10) that we need more rather than less of that disenchantment of the world that Weber claimed to be integral to modernity.

Despite, or in part because of, this challenge, these revolutionary changes in our view of the world are also (potentially) among the most exciting things schools have to offer their pupils. We may follow Healey (1984, p. 59) in characterizing the particular sort of issue I am examining as one in which our initial inclination is to conceptualize our experience as of *p*; we are then faced with a theory *T* that redescribes that experience as of *q*, where *p* and the conjunction of *T* and *q* are incompatible, or at least generate "epistemological tension". One problem is to explain away the initial characterization; we need at least an outline account of why a world in which *T* and *q* hold should seem like *p*; we need, also, of course, some independent reasons for thinking that *T* is preferable to whatever we had before.

This paper reports an initial inquiry into the ways we do in fact teach such challenging ideas in schools. Are they presented as radical changes? Are they presented as rational responses to problems, or as articles of yet another faith? Quarks and black holes do not feature in the schools I am dealing with, but there is sufficient in what does get into the curriculum to show the power and the novelty of scientific thinking. I have chosen to look at how some secondary school textbooks deal with a couple of basic points in the scientific world view that go against (or certainly do not obviously flow from) our everyday perception of things. The issues to be examined are (i) the roughly spherical shape of the earth, as presented in geography, and (ii) the idea of atomism. The books constitute a small sample from among those in use in the English-speaking Caribbean to prepare students for their first public examination by the Caribbean Examinations Council (CXC) at around age 15 or 16; the topics chosen are found near the beginning of what is usually a two-year course of study.

Of the many limitations of this study one might note explicitly now that I am deliberately discounting whatever teachers may add orally to the textbook account, and am also being somewhat unfair to the authors by focussing solely on what they say in presenting the specific issue - I have not taken into account the atmosphere created by their other comments, later use of the ideas, or what have you.

II

Although many writers for an adult audience have stressed the fact that the earth on which we live need not strike anyone as even roughly spherical - Whewell, for instance, claims that its shape is "directly opposed to the apparent evidence of the senses" (1857, Book III, section 9, p. 115) - Waters begins his school textbook, under the heading "the shape of the planet earth", by assuring his readers that "we all know the world is round. We are probably all familiar with the various ways in which it can be proved" (1984, p. 1). Unfortunately it is more likely that his readers' earlier experience is better captured by Rogers' remark "the picture of the Earth as a round ball is hard to believe. You accept it very easily because you were indoctrinated when very young" (1960, p. 224). In any case, Waters goes on to offer five "ways in which it can be proved", which I shall give in his order with any noteworthy variations offered by other books:

> (a) If we look at other planets and the sun, they are round "and therefore we may assume that our world too is round" (Waters, 1984, p. 1). Preece and Wood (1968, ch. II, p. 45) give a more extended argument: spheres are the only shapes that appear round from any point of view; the sun, moon, and stars always appear circular in outline, so we can conclude that they are spherical in shape; why should the earth be the only exception?
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> (b) If we watch a ship, we first see smoke and then more and more of the vessel. Other texts reverse the direction: ships disappear bottom first (London (1983); Preece and Wood (1968)). Burnett (1988) offers a hypothetical situation in which there are two ships at sea, only one of which is visible to an observer on land.
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> (c) When the earth comes between the sun and the moon, its shadow is a black circle on the moon. Burnett adds the false claim that "only a sphere can cast a shadow which is circular" (1988, p. 3) while Preece and Wood tell us more cautiously that if the earth were a disc then at times its shadow might be oval.
>
> (d) From the experience of many travellers we know we can go right round the world moving in the same direction all the time, "as proven by Magellan in 1522" (London, 1983, p. 1). Burnett and Preece and Wood also give this argument.
>
> (e) Cosmonauts have taken photos which show the earth with a ball-like shape. Burnett and Preece and Wood give this argument too.

Before commenting on these points, let us gather up the other arguments offered elsewhere.

> (f) London and Preece and Wood both note that as one goes higher the visible expanse increases and the horizon remains circular.
>
> (g) Burnett argues from the fact that the horizon appears curved; if the earth were not spherical there would not be a circular horizon (he gives what I find to be an unintelligible diagram of what the horizon on a flat surface would look like).
>
> (h) Burnett and Preece and Wood both argue that different parts of the world see the sun at different times; if the earth were flat we would all see the sun at the same time.
>
> (i) Preece and Wood (a textbook of an older generation) give an account of experiments on Bedford Level Canal: the surface of the water provided the horizontal; 3 vertical stakes rising to equal heights above water were set in the ground at intervals of three miles, labelled ACB. An observer looked through a telescope so that the top of A appeared level with the top of B; it was found that the AB line of vision did not pass through the top of C but cut it 6 feet below. This could not happen if the surface were flat. They note that similar experiments have been performed elsewhere.

To begin, we might quibble over Waters' begging of part of the question in his heading by assimilating the earth to the planets (about which his learners have virtually no evidence or information). But I suspect a more serious semantic fault lies in his use of the word "round" without any immediate clarification regarding the number of dimensions. All the other books begin with talk either of spheres or of round balls, for instance. If Bishop Isidore of Seville "quotes ancient writers on the globe ... but fails to understand that they are talking of a globe and not a circle" (Thomson, 1948, p. 389) we might forgive some of Waters' readers for similarly misinterpreting his intent.

Waters shares with the other writers the careless everyday sense of the word "prove", although it must be admitted that Preece and Wood use "reasons for the belief" as apparently synonymous with "proofs" (1968, p. 45). While writers in the natural sciences seem to have grasped the elementary distinction between logical proof and the offering of supporting evidence, these passages show that it has not yet impinged on the writers of geography textbooks. Yet, the consumers of these books can be expected to be studying not only clearly evidential subjects such as history or chemistry but also mathematics, where even now they might be learning something of what constitutes demonstrative proof of a claim. To offer as "proofs" three or eight points that, whatever else can be said for them, could clearly never demonstrate the desired conclusion does not seem likely to promote the intellectual virtues.

But what can be said for the reasons offered? Taking the arguments in the same order:

> (a) Neither book offers any guidance on the applicability of this sort of analogical reasoning.
>
> (b) A theory of a flat earth must assume either a limit to sight or odd behaviour of light, but given those so what? To put it another way, none of the authors allows us to see the way in which we are accepting not just the shape of the earth but a whole bundle of views.
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> (c) This again assumes background knowledge of how eclipses happen, which perhaps one ought not to take for granted: Toulmin and Goodfield report that generations of Byzantine scholars and potentates ridiculed such views (1963, p. 170-71). Commentators (on Aristotle, d*e Caelo*, since he offered this argument too) are somewhat hesitant about the worth of the eclipse argument: Dreyer says it is a "weighty" argument (1953, p. 172); Dicks (1970, p. 260) says the shadow only proves curvature so we need other reasons for sphericity; but I am pleased to find that Neugebauer (1975, p. 1094) says an unlimited number of shapes could give such shadows and anyway no one tells us how to find the exact shape of the shadow.
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> (d) To be harsh, if we are only learning what we all know already, we may well give credence to travellers' tales.
>
> (e) One could object that we need to put these photos together to get beyond a disc, but it seems much more significant to me to note that sphericity is so deeply embedded in all the work that got the cosmonauts there that there is little to be gained from a photo.
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> Arguments (f) to (i) exemplify the same sort of point as (b): that one simple explanation for various facts is a roughly spherical earth plus our other current pre-scientific beliefs about light, our eyes, etc., but these facts do not force a spherical earth upon us. Personally I find (i) rather nice, since it presents something that would seem to require very odd behaviour of light on a flat surface, but the general point

remains.

More generally one can say that there is virtually no explicit recognition of how any of these reasons supports the conclusion about the shape of the earth. As noted already, most of the time the writers speak of proofs rather than a good explanation of various facts, which leads them to restrict the facts cited to what may appear "existence" proofs. (Note, however, that most of them are not really accessible directly to most children; they are yet more reports to be taken on trust.) But even when, as in Preece and Wood, the presentation suggests the idea of a conjecture or argues by excluding a rival flat surface hypothesis, these strategies are not made explicit.

There is anyway no elaboration of alternative possibilities beyond some sort of flat earth. Stories about ships disappearing are not likely to impress any lingering adherents or young rediscoverers of the Kai Thien account of the universe as two hemispherical domes inside one another (Needham and Wang Ling, 1959, section 20, p. 210 et seq.), for instance.

Again, as already noted, there is no explicit acknowledgement of having to make further assumptions, e.g. about what causes an eclipse of the moon (cf. Martin, 1985, p. 37).

Pedagogically, the topic is not presented as containing problems to be solved; since we all know the right answer anyway, the "proofs" are offered perfunctorily. Far from acknowledging a gap between the claim and common sense, only Preece and Wood even mention that people have thought anything different. There is, then, no attempt to solve the problem Healey describes: why is it that things generally appear non-spherical? What the books do is simply offer a few recondite cases where things do not appear non-spherical; students are left then with the official evidence against flatness and their own evidence against sphericity; and little more than an appeal to authority to settle the matter.

Nor is the answer itself used to make further possibly unexpected predictions which can then be examined (cf. Neugebauer's (1975, p. 576) supposition that a certain Bion, mentioned by Diogenes Laertius, deduced what he certainly asserted, that there would be places where day and night lasted for six months). I have already had occasion to mention that none of the books insists on the deeply entrenched position of a globular earth in our whole understanding of physical geography, our astronomy, our technologies, and much else.

Bunbury's comment on the argument from circumnavigation - "a conclusive proof indeed, but one that was never known to the Greeks" (1959, p. 126 ftn) - can be taken as suggesting that scientifically literate people should be able to defend a spherical earth without reliance on such journalistic evidence. It is but one of the sad consequences of the virtual absence of astronomy from our school curricula that the empirical data that gave rise to most early reflection on the shape of the earth are simply not mentioned in our texts, though, as Saunders (1955, p. 27) argues, they are in fact more readily available to many students than ships disappearing over the horizon. Another is the absence from all our textbooks of the kind of theoretical cosmogonic argument used by Aristotle which Toulmin and Goodfield (1963, p. 120) at least regard as fundamentally sound on more modern views of the origin of the earth - of course such an argument would now rely on gravitation, which might not have occurred in the syllabus, but what of the spiral curriculum and integrated science?

III

In the previous section we have found that the dubiously scientific school subject of geography does not acquit itself very well in teaching one elementary item of knowledge. In this section we shall look very briefly at how texts aimed at similar students deal with the idea that matter is composed of atoms and molecules. I shall restrict attention simply to the initial introduction of the idea and so will not consider how it may later be used in more detailed work in chemistry or physics.

One's impression, unchecked, is that in the "bad old days" this idea was simply announced to students as a view to be accepted in the science classroom. "For many reasons which we cannot discuss here, scientists are almost certain that each element is made up of tiny particles called atoms" (Painter and Skewes, 1961, p. 46), an approach repeated with even less linkage to problems, findings, or explananda in a more recent "low reading level" General Science text from the U.S. discovered in our library (Heimler & Neal, 1979, p. 38).

This blatantly unargued presentation is fortunately quite rare in the local texts sampled. Lambert and Mohammed begin their chemistry text (1986, p. 1) by saying that the evidence for atomism is indirect and they give none. They then present an account of something called "Dalton's atomic theory" in four propositions but again with none of his evidence, and add that we have now modified it considerably, but they do not specify how. They then move on immediately to recounting stories about subatomic particles. In a later section they discuss various properties of gases and claim that they can all be explained by the atomic model (p. 16). (Perhaps it is worth noting that they are liable to mislead when discussing Brownian motion by saying that the "same haphazard motion" (p. 17) can be seen when a beam of light illuminates dust particles in a darkened room.)

The one physics text sampled (Duncan & �na�, 1985) also introduces atoms and molecules as facts to be accepted, which can then be used to explain the three states of matter, diffusion, the gas laws and so on. There is no consideration of alternatives or of the status of the theory.

Another dogmatic statement of the atomic theory of matter without any subatomic trappings is to be found in Mitchelmore et al. (1986, p. 8), a text aimed at the Integrated Science market. But in an earlier book for the same students atomism is offered as the only reasonable way to explain various diffusion phenomena that are discussed and exemplified in experiments (Commissiong et al., 1976), though these authors make the grotesquely untrue claim that "scientists have used the idea of particles to predict what would happen when they carry out certain experiments. These predictions have always been right" (p. 66).

A similar but somewhat more advanced treatment is given in another chemistry text: Atherton and Lawrence tell us that many results are "best explained by using the idea that all materials are made out of very small particles" (1986, ch. 5, p. 15). Later (in chapter 19) they give by way of experiments to be performed in the laboratory various pieces of evidence that can all be explained by atomism: the dilution of fluorescein; regular crystal growth; the diffusion of gases; Brownian motion; the mixing of certain substances with a reduction in volume. They insist that none of these prove atomism (p. 54). But the only hint of there being alternative explanations is their challenge to students to come up with some. Nor is there here any recognition or discussion of the data that prompt non-atomistic views of the nature of things.

A similar list of explananda, but not presented as experiments to be performed, is given by Ferguson and Hart who start their account of atoms by saying "we believe they exist, because with them we can explain the results of many experiments" (1985, p. 6). Since they are not tied to chemistry experiments they add osmosis and the existence of three different states of matter, as well as the fact that crystals dissolve (though here they forget to specify the quantifier "some").

It may be of some interest to compare these explananda with what was urged some time ago by Saunders (1955) who wanted teachers not to ignore requests for reasons, even if they could not elaborate on them. His words are certainly still pertinent for the geographers we have encountered: "the 'proofs' of many theories do not depend upon direct demonstration. They are built on an accumulation of evidence all pointing in the same direction... The more nearly conclusions reached by different methods agree with one another, the more confident is the scientist in the accuracy of his final figures and the theories he advances" (p. 75). For atomism, Saunders suggests (p. 76) that a teacher might mention (i) Brownian motion; (ii) osmosis and diffusion; (iii) conduction of heat; (iv) gas pressure, including deviations from Boyle's Law; (v) chemical proportions; (vi) magnetism, electrolysis, and the existence of helium particles in radio-activity. Of course, Saunders was not working within the constraints of someone else's syllabus.

As with the shape of the earth, these accounts fail to develop alternatives. It is not likely to help anyone grasp what makes a view tenable just to be told to try to construct an alternative explanation. The explanations offered in the texts considered here are, of course, all qualitative; no guidance is offered on what might be wrong with other qualitative views. Of course, nothing might be, when restricting attention to one particular finding; our students might be in the position of Toulmin and Goodfield's seventeenth century corpuscular theorists: "their experimental work on air did not, by itself, provide compelling evidence of the truth of the atomistic doctrines" (1965, p. 199). It is, I think, unfortunate that even with all the remarks about atomism not being proved, the texts do not stop to mention the continuing problems it creates. At the level we are dealing with it may be difficult even to gesture at quantum mechanics but one could, I should think, mention irreversibility and the second law of thermodynamics as continuing irritants (for some discussion of nineteenth century difficulties for atomism, see Clark, 1976, versus Strong, 1976, and Nyhof, 1988, who both remind us of the influence of philosophically grounded objections; for now, Sklar, 1987).

Again we do not find much explicit recognition that atomism must be combined with other possibly controversial views even to produce the qualitative explanations we are offered. For instance, as Toulmin and Goodfield note, liquids are a problem for Greek atomism; we need a force of attraction (1965, p. 73), and the same goes for magnetism. It is revealing that Feynman's one sentence that contains the most information in fewest words - "all things are made of atoms - little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another" (1963, p. 1-2) - is a statement of atomism plus forces. This is even more obvious if we were to move on to quantitative statements of atomic theory which would crucially require such things as Avogadro's hypothesis (cf. Frick, 1976, for a version of the history of this particular suggestion). When explanations in our texts mention forces they are just left as ad hoc devices to make a difference, say, between liquids and solids.

Saunders' remark about "final figures" suggests another failing of these purely qualitative explanations: that they cannot reproduce the sort of "boot-strapping" that Glymour has argued to underlie much of the actual history of the adoption of atomic theory in chemistry:

> When the fundamental hypotheses of a theory cannot be tested but, for whatever reasons, the theory is appealing anyway, a reasonable requirement is that the properties the theory ascribes be determinable, and, if other hypotheses must be used in making such determinations, that these hypotheses be testable with respect to the theory in question. ...I believe a great deal of it [controversy over atomic theory] can and should be understood to have been about whether or not the atomic theory could meet the requirement just stated. So long as that requirement remained unfulfilled, many responsible scientists found the hypothetico-deductive argument for the theory

unconvincing (1980, pp. 227-8).

Whatever the historical situation, it would seem appropriate to get students to realize the importance of Glymour's general point even if they cannot at this stage reproduce the calculations themselves.

IV

To answer the questions I asked earlier: in neither area do the textbook writers confront the counter-intuitive aspect of what they are teaching. They try to find a few cases which intuitively support their position, but that on its own can hardly satisfy the intellectual demands of anyone seriously wishing to be convinced of the issue.

Nor are the theories presented explicitly as solutions to problems, though it would be easy so to restructure a lot of the material. Alternative accounts of the data are not in general examined (apart from gestures at some sort of flat earth view), nor are difficulties with the view or the often abundant prima facie evidence against it.

The structure of reasoning involved in the discussion remains, as almost always in school teaching, implicit. As we saw, in the case of the earth's shape most writers fail to distinguish deductive proof from non-deductive support; the atomists can perhaps be forgiven for not saying anything illuminating about the latter, but they might at least have tried to give more of a "feel" for it by discussing alternatives and difficulties.

Our own discussion raises one general issue for anyone concerned for a more self-conscious, philosophical approach to science. Of course, there is no consensus about that approach itself, but one widely accepted belief is that a central value of theory "lies in its capacity to unite phenomena which, without the theory, are either surprising, anomalous, or wholly unnoticed" (Hanson, 1965, p. 121). Along with this goes the view that support accrues from a place in a wide-ranging and stringently tested theory as much, if not more, than from particular experiments to isolate entities. As Post says of elementary particles, "the distinction between evidence derived from such experiments ['isolation' of elementary particles] and the vast body of confirmatory evidence involving the particle in other ways by way of synthesis is hard to maintain or justify" (1975, p. 25). But these philosophical views come up against a strong tradition among (experimental) scientists in favour of such "existence proofs", a tendency which it is often tempting to see as positivistic excess, although Glymour's point above may allow for a sympathetic reinterpretation of some such cases. The problem for pedagogy is whether to present the theories supported as one's philosophical approach sees them (which would in these cases lead to much greater integration) or whether to initiate people into what might very well be a blinkered view of what constitutes support. Of course, had one but time enough, one might try both approaches.

It is hardly news that initiation into science fails to give a fair hearing to rejected theories, or that it encourages uncritical allegiance as a base for future allowable criticism, or that for the majority who drop out very little seeps through. Still, one would like to believe that something else is possible (certainly some of the presentations of atomism make a start in that direction). It seems to me that one avenue worth exploring would be to focus on the confrontation between science and common sense, and to try to teach the former as a progressive, explanatory move that can also explain away the latter. As things stand, the science remains isolated from everyday thinking; it ought at least to be alienating.

Footnote

1. The author wishes to thank Peter Whiteley for comments on a draft of this paper. He is, of course, not to be taken to be in agreement with any of it. Return to text.

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Common Sense and Artificial Intelligence. As computer scientists have been forced, by degrees, to acknowledge, it is everyday knowledge that is hardest to convey to a computer. Such knowledge is, however, of tremendous importance. For it seems on the face of it that our commonsensical belief-systems enjoy not merely a remarkable efficiency when it comes to solving the problems raised in our everyday passage through the world, but also a no less remarkable adaptability, a capacity to maintain themselves in functioning order from situation to situation and from generation to generation, even in >Volume 67 Issue 2. >Common-sense Constructivism and Hegemony in World Politics. English FranÃ§ais. International Organization.Â 1998. The Rocky Road Toward Peace: Beliefs on Conflict in Israeli Textbooks. Journal of Peace Research 35 (6):723â€“42.CrossRef Google Scholar. Berger, Thomas U. 1998.Â 2005. Towards an Intellectual Reformation: The Critique of Common Sense and the Forgotten Revolutionary Project of Gramscian Theory. Critical Review of International Social and Political Philosophy 8 (4):469â€“81.CrossRef Google Scholar. Scott, James. Common sense and science are two words that are often confused when it comes to their meanings when strictly speaking, there is a difference between the two words. Common sense is our usual understanding of practical issues. The word common sense is used in the sense of natural instinct.Â An academic has both common sense and scientific knowledge. Connection: Science goes a step beyond common sense and explores why an incident occurs in that particular way. Science versus common sense. Science, as a way of thinking, possesses many vital qualities for true understanding that common sense does not. Based on observations we make, science operates under theories, constantly revised and checked by experiment. Common Sense, Science and has been added to your Cart. Add to Cart. Buy Now.Â Unlike most introductory texts or short histories, which merely summarize the conclusions of great philosophers, "Common Sense, Science, and Scepticism" focuses on the arguments of the philosophers. Thus, the book is an excellent introduction to what it means to "do" philosophy. The text is rewarding, and anyone interested in philosophy can read it with profit. Scientific theories are hypotheses which have stood up to repeated attempts at falsification and are thus supported by a great deal of data and evidence. Some well known biological theories include the theory of evolution by natural selection , the cell theory (the idea that all organisms are made of cells), and the germ theory of disease (the idea that certain microbes cause certain diseases). The scientific community holds that a greater amount of evidence supports these ideas than contradicts them, and so they are referred to as theories.Â For example, â€œI have a theory as to why the light bulb is not working.â€ When used in this common way, â€œtheoryâ€ does not have to be based on facts. It does not have to be based on a true description of reality.