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There has been considerable controversy in recent years about the "logic" of scientific discovery. Much of that controversy is due to the lack of clarity in the concept of "a discovery." Consider T. S. Kuhn's comment:[[1]](#footnote-1)

Clearly we need a new vocabulary and concepts for analyzing events like the discovery of oxygen. Though undoubtedly correct, the sentence "oxygen was discovered," misleads by suggesting that discovering something is a single, simple act assimilable to our usual (and also questionable) concept of seeing. That is why we so readily assume that discovering, like seeing or touching, should be unequivocally attributable to an individual and to a moment in time. But the latter attribution is always impossible, and the former is as well. Ignoring Scheele, we can safely say that oxygen had not been discovered before 1774, and we would probably also say it had been discovered by 1777 or shortly thereafter. But within those limits or others like them, any attempt to date the discovery must inevitably be arbitrary because discovering a new sort of phenomenon is necessarily a complete event, one which involves recognizing *that* something is and *what* it is. Note, for example, that if oxygen were dephlogisticated air for us, we had discovered it, though we would still not know quite when. But if both observation and conceptualization, fact and assimilation to theory, are inseparably linked in discovery, then discovery is a process that must take time.

Kuhn hits upon several very important points; however, much of the problem in figuring out the conceptual development of a discovery, the "process" of discovery, lies in the ambiguity and vagueness of claims about attributions of discovery.

In this article, I will give a preliminary analysis of the concept of “a discovery;” a complete analysis of this epistemologically important concept would require much more than an article. My analysis will concentrate on the ambiguities implicit in locutions used to express attributions of discovery.

Let's begin by considering the claim that the act of discovery is the act of somebody discovering something. The inadequacy of that claim is apparent if we consider these statements:

* 1. John discovered his wife's body.
	2. John discovered that his wife had been murdered.
	3. John discovered the law of displacement.
	4. John discovered how to open his father's safe.
	5. John discovered the cause of her death.

Note that (1) involves (minimally) some person being the first to see some object (a body). But if we naively try to assimilate (2)-(5) with (1) if we are deceived by their grammatical similarity to (1) we wind up thinking that propositions, laws, theories, facts, techniques (methods), and causes are all objects which the discoverer stumbles across. Actually, (2) and (3) are eases in which John discovered *that* something is the ease; (4) is a ease in which John discovered *how* to do something; and (5) is a ease in which John discovered *why* something is the case. (These rough assertions will be amplified upon below.)

In picking our way through the types of discovery (discovering-how, discovering-that, discovering-why, etc.), we must critically examine examples of attributions of discovery, avoiding being misled by the surface grammatical structure. We must remember that we are operating on two levels in our analysis: we are working with examples sentences which are all locutions using the verb "discover," and we are directing our attention to the concept of discovery, inquiring into the types of discovery. We are operating on the syntactic, the semantic, and even the pragmatic levels simultaneously.

*DISCOVERING-IT AND DISCOVERING-THAT*

I indicated above that "the" concept of discovering something is really a cluster of concepts. Let me elaborate upon this point by distinguishing two elements of the cluster. Compare sentences (6), (7), and (8) with (9) and (10).

(6) Scheele discovered oxygen.

(7) Fleming discovered penicillin.

 (8) Le Verrier discovered Neptune.

 (9) Scheele discovered that oxygen is an element.

(10) Fleming discovered that penicillium mold gives off a substance which lyses bacteria.

Note that all the examples given so far, (1)-(10), are locutions with "discover" as the main verb. I shall call all such declarative sentences *discover-locutions.* If we look at (1), (6), (7), and (8), we see, on the one hand, that this type has the form [subject noun] + “discover” + <tense> + [object noun]. Let me call locutions of that form *discovering-it* locutions. On the other hand, examples like (2), (9), and (10) are complex declarative sentences of the form [subject noun] + “discover” + <tense> + “that” + [declarative sentence]. Let me call these *discovering-that* locutions.

Now let's look at what is being asserted by someone who utters (1), (6), (7), or (8). Clearly, the statement of any of them involves the notion that someone John, Scheele, Fleming, Le Verrier has observed (or detected) an object (or substance), and has been the first to do so. On the other hand, the statement of (2), (9), or (10) involves the notion that someone has learned the truth-value of some proposition, and has been the first to do so. The first concept, the concept of *discovering-it,* involves observation, whereas the second concept, the concept of *discovering- that,* does not necessarily involve observation. *Discovering-that* merely involves learning (method unspecified) the truth-value of a proposition. Thus the notion of A discovering X is at least two-fold ambiguous. If X is an object, we have in mind *discovering-it.* If X is a proposition, we have in mind *discovering that.*

Before looking more closely at the concepts of *discovering-that* and *discovering-it,* some remarks must be made about the use of locutions to express concepts. We generally use *discovering-that* locutions for attributions of the discovery that a certain state of affairs obtains, and *discovering-it* locutions for attributions of the observation (for the first time) of an object or substance.

But things are not always so pat. Reconsider (3), as well as:

 (11) John discovered the fact of her death.

 (12) John discovered the theory of natural selection.

While (3), (11), and (12) are all *discovering-it* locutions, we do not (as we have seen) use them to describe cases of *discovering-it.* After all, laws, theories, facts, and such like are propositional entities, not objects which John, stumbles across. What *do* we use the locutions to say? Well, (3) can be paraphrased as "John discovered that an object in water is buoyed up by a force equal to the weight of the water it displaces;" (11) as "John discovered that his wife had died;" (12) as "John discovered that species evolve via the mechanism of Natural Selection."

Thus, on the one hand, in many cases, we use a *discovering-it* locution to describe *discovering-that.* (Syntax may lead one into reification of all sorts of things laws, theories, facts, etc.) On the other hand however, the situation in which a *discovering-that* locution is used to talk about a case of *discovering-it* seems not to arise.

Turning now to the concept of *discovering that,* we note that it includes as special cases *discovering-where, discovering-what, discovering-when,* and *discovering-why.* To discover where something is simply is to discover that it is in a certain location. To discover who did such and such is to discover that person P did it. To discover what object X is simply is to discover that X fits a certain category. To discover when some event occurred is to discover that the event occurred at time T. *(Discovering-why* will be examined in a separate section.)

Another thing to note about *discovering-that* is the complication caused by the nature of propositions.

Saying "A discovered that P" involves expressing P in your own language, or (if A speaks your language) in your own theoretical terms. A may not express P the way you do. Putting this point in terms of *discovering-that* locutions, one might say that *discovering that* locutions are referentially tricky. To say "John discovered that the carburetor was dirty" is not to say the John would himself say "I discovered that the carburetor was dirty." He may know little about cars, and may refer to carburetors as "gas goodies." More importantly, he may not know he is referring to the carburetor at all. This is a special case of the ambiguity of sentences involving definite descriptions. John may have said "The person who did this is a bum," thinking that Fred is the one who did it, whereas Ted is in fact the culprit. Depending on whether John is using the definite description "the man who did this" referentially or descriptively, he means either "Fred is a bum" or "Ted is a bum." I do not want to get bogged down in the confusing topic of reference; I want merely to point out that *discover-locutions* in general, and *discovering-that* locutions in particular, can be referentially tricky.

Putting this comment pragmatically, let me speak of the *preferred case of discovering that P* as being the case in which the discoverer would state P in the same way as our community would.[[2]](#footnote-2) The upshot then is this: in considering cases of *discovering-that,* we must keep in mind that a state of affairs is one thing, a fact (a description of a state of affairs) is quite another. This is a misleading way of putting the point, in that it sounds as if there were theory-neutral states of affairs. I merely suggest that very few cases of *discovering-that* are preferred cases. (The question whether there is such a thing as theory-neutral observation is quite beyond the scope of this paper.)

 Let's return to the concept of *discovering-it.* Reconsider example (1). What do we usually mean when we attribute the discovery of his wife's body to John? This sort of scenario comes to mind: John returns home from work, and smells gas. Running into his house, he finds his wife's body, and (perhaps) mourns. Discovering a body is not merely being the first to see it, but (in the usual case) to recognize it as a body, to see that the person is dead. *Discovering-it* typically involves *discovering-that.* Putting the point pragmatically, for our community to claim that a discovered object X generally involves our believing that A saw/observed/detected X, and was the first to do so, and further that A had knowledge about X. The recognition of this epistemic dimension of *discovering-it* is the basis of Kuhn's claim in the passage cited earlier, that discovering a new phenomenon "involves recognizing both that something is and what it is." What he should say instead is that discovering a thing generally involves possessing some knowledge which allows you to categorize that thing. This holds for even mundane discovery, and is not limited to cases of scientific discovery.

However, suppose again thinking of example (1) that John saw his wife's body, but erroneously supposed that she was asleep. Suppose, that is, that John saw the body without seeing that she was dead. It still seems quite correct to say John discovered his wife's body -- although we are tempted to add that he didn't recognize it. It won't do to insist that John must have had some knowledge of the matter that he must at least have recognized it as his wife, say, or at least as a woman. We can imagine John erroneously believing it to be an old rug (supposing his eyesight to be poor). Even here it seems correct to say that John discovered his wife's body. The point is, though, that John would use a different description to refer to the object from the one we would use. Thus, we might say that *discovering-it* locutions are also referentially tricky. To say that A discovered object X is not necessarily to say that A would refer to X by "X."

We can shed light on the relation between *discovering-it* and *discovering-that* by considering the claim that Scheele discovered oxygen. Kuhn's remarks lead one to view this claim as unambiguous, yet hard to assess, because of the complexity of the historical process. But the historical process is really quite simple.[[3]](#footnote-3)

Scheele was a proponent of the phlogiston theory, which held that combustion involves the release of a substance "phlogiston" (denoted by the symbol ) into the air. For example, modern science views the change of a heated metal into calx as the combination of the metal with oxygen (combustion of the metal), producing its oxide:

Metal + Oxygen heat Oxide

 

But a phlogistonist would view this change as a decomposition of the metal (presumed to be a compound) into calx plus the hypothetical substance phlogiston:

Metal heat + calx



Guided by this theory, Scheele was investigating the release of phlogiston from various substances in confined volumes of air. He knew that when a substance burns in air, the volume of air decreases, leaving "foul air." He reasoned that the phlogiston released in the combustion must therefore combine with part of ordinary air and escape as heat. He called this hypothetical part of air "fire air." Thus air was a mixture of foul air and fire air, and he set out to isolate fire air by decomposing heat (fire air + ).

Scheele decided that to isolate fire air from heat he would have to absorb the phlogiston with a *better* receptor than fire air. He picked nitric acid, since it would separate the phlogiston from metals thus:

Metal (Calx + ) + Nitric Acid Calx + red fumes (taken to be nitric acid + ) So Scheele felt that heating nitric acid would give fire air via this reaction:

Heat (fire air + ) + Nitric Acid Red fumes + Fire Air

Scheele fixed the nitric acid with potash, heated it, and absorbed the red fumes with slaked lime. He indeed isolated a gas, fire air, which we know to be oxygen. Scheele investigated the properties of "fire air," and found that it behaved just as he expected it would it restored foul air to breathability, enabled a candle to burn brightly, and so on. But Scheele never abandoned the phlogiston theory, and always viewed "fire air" in those terms.

our difficulty in assessing the claim "Scheele discovered oxygen" lies *not* in the complexity of the historical process that Scheele underwent, i.e., his conceptual evolution. The facts are clear, and common in the history of science. A researcher, possessing what we believe is a mistaken theory, carries out a line of research obviously suggested by that theory, and discovers an entity which we would refer to in one way, he another. It is the *claim* itself which is ambiguous. Do we mean that Scheele discovered the substance known to us as oxygen? Clearly true. Does it mean that Scheele discovered the substance (known to us as oxygen) and recognized that it is a separate element? Also true, although he did not have the modern concept of an "element."

The point is that *discovering-it* claims are vague, especially when (as in the case of scientific discovery) there are changes in terminology and conceptual schemes, leading to problems of reference. The attribution of discovery is an honor bestowed by a community, and the members of that community rarely state explicitly what concepts the putative discoverer must have possessed in order to receive the credit.

*DISCOVERING-HOW*

In our discussion of Scheele's case, we can pick out yet another interpretation of the claim "Scheele discovered oxygen," viz., that Scheele discovered how to separate a substance, now known as oxygen. Under this possible construal, we have in mind that Scheele discovered a technique *without having the correct conceptual rationale for it.* The histories of medicine and engineering are replete with similar cases where a technique, the knowledge *how* to do something, is discovered without the discoverer being able to say why that technique works. Discovering a technique, learning a skill and being the first to do so, is what I mean when I speak of *discovering how.*

 Now, aswe have seen before, the same concept may be expressed by different (and often misleading) locutions. Consider:

* 1. Some primitive man discovered fire.

Note that (13) uses a *discovering-it* locution, which may mislead one to view it as one views (1). But clearly, in saying (13) I don't mean that some early man stumbled across a fire. Rather, I mean that some early man mastered the art of starting, maintaining, and controlling fire for his purposes (such as cooking). In other words, discovering fire is really discovering how to start a fire and use it for various purposes. (13) is conceptually similar to (5), as well as:

1. Paracelsus discovered how to treat syphilis with mercury.
2. Carnegie discovered how to make inexpensive steel.

Let's define a *discovering-how* locution as being one of the form: [subject noun] + “discover” +< tense> + “how to” + [transitive verb] + [object noun]. The point of the foregoing is that not every case of discovering-how is described using a *discovering-how* locution. (The question whether *knowing how* practical knowledge is reducible to or equivalent to *knowing that* propositional knowledge is irrelevant here.)

*DISCOVERING-WHY*

Consider yet more examples:

1. John discovered why his car was idling poorly.
2. Freud discovered why people stammer.
3. Pasteur discovered why juice ferments.

Asserting (16), (17), or (18) involves describing someone's discovery of why some proposition P is true, or more accurately, of his finding an explanation of its truth. *Discovering-why* is usually, but not always, expressed using a locution of the form: [subject noun] + discover + tense + why

+ [declarative sentence], which I will call *discovering-why* locutions. Cases where discovering- why is not expressed using a *discovering-why* locution are:

1. Freud discovered the cause of stammering.
2. Pasteur discovered the explanation of fermentation.

Clearly, if we credit a person A with discovering why p, we are presupposing that p is true. More pragmatically put, for a community to honor A by saying that A discovered why p, that community must believe p is true. More importantly, discovering why p involves discovering that q is true, where q explains p. Thus *discovering- why* is really a special case of *discovering-that.* This being so, we must be prepared for the usual referential trickiness.

Note that we generally mean, by saying that A discovered why p, that A not only discovered that q, where q explains p, *but also realized that q explains p.* This is not always true. Looking at (16), suppose John's car is idling poorly, and he sets out to discover why. He finds that the valve cover is dented, and replaces it under the misapprehension that this is the cause of the rough idling. At the same time he notices that the carburetor is dirty, and cleans it as well. Of course, the actual explanation of the rough idling is the dirty carburetor, but John doesn't recognize that fact. We (a community of auto mechanics) would say that John discovered (without realizing it) why his car was idling roughly.

Yet such cases are deviant. In general, discovering the explanation of a phenomenon involves recognizing that it is the explanation.

Let me conclude with a few remarks about the applicability of any logic of discovery (if one there be) to the history of science. We should not assume that the difficulty of assessing a historical claim arises from the difficulty in rationally reconstructing the past. Rather, the impreciseness and misleading structure of *discovering locutions,* and the cluster nature of the concept of discovery, make such historical claims ambiguous. Consider Kuhn's statement:

Was it Priestley or Lavoisier, if either, who first discovered oxygen? In any case, when was oxygen discovered? In that form the question could be asked even if only one claimant had existed. As a ruling about priority and date, an answer does not at all concern us. Nevertheless, an attempt to produce one will illuminate the nature of discovery, because there is no answer of the kind which is sought. Discovery is not the sort of process about which the question is appropriately asked. The fact that it is asked is a symptom of something askew in the image of science that gives discovery so fundamental a role.[4](#bookmark40)

It seems to be misleading because questions such as "Who discovered oxygen?" are inherently ambiguous. But a precise question (such as "Who first isolated the substance we know as oxygen?" "Who first recognized that that substance is consumed in combustion?” and the like) does admit of straightforward historical treatment, especially if one keeps the niceties of reference clearly in mind.

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1. T. S. Kuhn, *The Structure* of *Scientific Revolutions* (Chicago: University of Chicago Press, 1962), p. 117. [↑](#footnote-ref-1)
2. This definition can be easily generalized to arbitrary linguistic/epistemic communities. [↑](#footnote-ref-2)
3. For a fuller account, see Aaron Ihide, *The Development of Modern Chemistry* New York: Harper & Row, 1964 [↑](#footnote-ref-3)