

Paradigms and Barriers¹

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Having for thirty years believed and taught the doctrine of phlogiston... I for a long time felt inimical to the new system, which represented as absurd that which I hitherto regarded as sound doctrine; but this enmity... springs only from force of habit... [Black to Lavoisier, 1791]

1. Introduction

This paper is abstracted from a forthcoming book which defends a particular answer to the question of just what it is that shifts when a paradigm shifts. The claim is that what shifts are habits of mind. And in particular the claim is that the most striking cases of paradigm shift will characteristically turn on a shift in some single, uniquely critical, habit of mind: the barrier. An account of a radical discovery — discovery that prompts the Kuhnian symptoms of incommensurability, so that intuitions that seem irresistible to some seem perverse to their rivals — then characteristically turns on how some individual got past the barrier (escaped the critical habit of mind), while at least for a while others could not do so.

The study spells out the argument in detail and supports and illustrates it with a series of historical cases. But since the basic claims strike first hearers more readily as obviously wrong than as probably right, I can't hope to persuade many readers with the brief summary here. However, I will sketch out the main lines of the argument, and indicate the sort of historical applications developed in the full study: perhaps enough to make the idea seem at least possibly right.

The argument is an extension of the account of persuasion and belief in my *Patterns, Thinking & Cognition* (1988), where I try to show that a remarkable range of cognitive features (and in principle all cognition) can be accounted for in terms of sequences of pattern-recognition. The new work provides a stronger version of the argument about paradigm shifts worked out in that earlier book. There the argument is applied (in particular) to give an account of how the heliocentric idea could lay on the table, waiting to be noticed, for 14 centuries before someone finally was able to see it. For as Neugebauer (1968) and others have pointed out, everything needed for the heliocentric argument is in Ptolemy's *Almagest*. In the new work summarized here and

in other work in press, I elaborate on the Copernican account, and add new accounts of two further memorable episodes: the overthrow of phlogiston and the emergence of probability.

2. Habits of mind

The central notion of habits of mind refers to scenarios or templates or patterns that guide intuitions in the automatic, non-conscious, hard-to-change way characteristic of physical habits. I had a good deal to say about that in *Patterns*. The new study begins with detailed discussions of why (in terms of their neural character) habits of mind can reasonably be taken to be essentially identical to physical habits, and hence why it makes sense to suppose that the way habits of mind operate, their resistance to change, and the conditions under which they nevertheless sometimes do change closely parallels what we know about physical habits. I must treat the notion of habits of mind with properties akin to those of physical habits as something the reader is already familiar with, which in a rough sense at least is surely true.

Our special concern is with what binds a community in the special way that yields the Kuhnian symptoms of incommensurability across the beliefs of rival communities. Suppose for a moment that the relation between habits of mind and paradigms were actually something like the relation between physical habits (and as a reviewer has suggested, also habits that characterize a style of play) and games. On that view, we could think of people operating within a paradigm as developing certain characteristic habits of mind that fit with and ordinarily facilitate their work. The situation (on this kind of view) is like that of someone who plays tennis or squash, and accordingly develops habits that facilitate play in those games. Theories and descriptions of equipment and procedures in a science would be the analog of rules and descriptions of the equipment and layouts for the games.

Changes in habits of mind (if this view were sound) would go along with a paradigm shift, as some habits would change if a person switches from squash to tennis. But for paradigms as for sports a change in habits of itself could not change the activity. Nor would it make sense (if the parallel with games were sound) to say that habits of mind are constitutive of a paradigm. That would be like saying that the habits characteristic of people expert in squash or tennis are constitutive of the games themselves.

In contrast to all that, on the view here habits in fact are constitutive of paradigms. To put the point in the most extreme way, on this view shared habits of mind are the only *essential* constituents tying together a community in the way that makes talk of sharing a paradigm fruitful. Talk of a paradigm without particular habits of mind (I want to argue) is like talk of a square without a perimeter.

Entrenchment in certain habits grows out of intense, specialized experience with certain kinds of activity, as entrenchment in the physical habits that make an expert tennis player or violinist grow out of the practice of those activities. Further, as is stressed in the full study though I will not have space to develop the point here, what prove to be particularly potent barriers turn out to be *entangled* in several different ways in the thinking and practice of members of the expert community. See the detailed discussion of the "nested spheres" sense of the world in Chapters 11 and 12 of *Patterns*. Hence on the view here the central puzzle for understanding what bound together a certain community (made communication easy within the community and made it hard to communicate with a rival community when that appeared) would be identification of habits of mind which tacitly guide various critical intuitions.

A paradigm shift then is a special sort of shift in habits of mind. In particular, we are interested in just those cases where the shift is in some way essential for emergence of a new idea in science. We expect to find that the more striking the Kuhnian symptoms of incommensurability, the more effective an account focussed on some shift in habits of mind will prove to be.

So sometimes new ideas appear which create a marked sense of cognitive shock in the first audience, and which eventually yield (when successful) the Kuhnian sense of conversion among those convinced (apparent, for example, in Black's remark to Lavoisier quoted at the outset), and of being swept aside by something that does not really make sense among those who are not. What marks such cases, on the argument here, is that a shift — ordinarily entirely tacit and unconscious — in some critical habit of mind is required to see the new idea in a way that makes it look insightful rather than illusory.

The argument here might seem more congenial if I spoke of a paradigm as defined by a "point of view" rather than habits of mind. But there is good reason not to do that. A person is ordinarily conscious of a point of view. But unless specifically and effectively prompted, a person is ordinarily unconscious of the operation of habits, and indeed is to a large extent unaware of the existence of habits. A person ordinarily can try a different point of view, and certainly understands what is being asked when someone proposes a look at things from another point of view. But we can't try out a different habit, and the claim that a person has a habit is something that usually needs to be backed up by much more than an appeal to introspection.

So while the habits of mind claim pressed here overlaps some of what is meant by the more familiar comment that people within a paradigm share a point of view, it is not merely another way of stating such a claim. A person can be highly expert in a formal theory, able to give an elegant presentation of how observations can be interpreted from that point of view, but not be operating in the paradigm at all. For example, modern writers like Neugebauer 1968 and Price 1959 can take a Ptolemaic point of view, but no modern writer can be entrenched in Ptolemaic habits of mind — we all inescapably see the Ptolemaic models in relation to Copernican beliefs. This easily yields striking divergences from the intuitions of an actual Ptolemaic astronomer. From the time of Ptolemy to the time of Copernicus, no astronomer left even a hint of seeing the heliocentric possibility. But on Neugebauer's or Price's account that was easy to do, hence their unflattering judgments on the Copernican achievement. And indeed, logically, the transformation from Ptolemaic to Copernican astronomy is easy. But cognitively it was enormously difficult, as discussed in detail in the full study.

Since habits of mind characteristically are unnoticed, how do we ferret them out? Certainly an attempt to specify the complete set of habits of mind characteristic of a paradigm is not plausible. But we never need undertake that impossible task. We only need to identify those habits of minds which are critical for distinguishing a paradigm from some historically conspicuous rival. Pragmatically, habits can only be made visible by setting them against the background of some alternative. We can become aware of our own habits of walking by comparing our some other gait we observe, as we can become aware of our own habits of speech by comparing our habits of speech to those of some other community which shares the language but with differences of accent and lingo. In our context, if we can identify an at least implicit alternative, we could try to say something about habits that would facilitate one way of doing things (for habits of mind, some sorts of intuitions) and that would act as a barrier to the alternative. But we need never undertake the impractical task of providing some total ac-

count of habits of mind characteristic of a paradigm. There is not some in-principle unbounded scope to the enterprise.

A subtle but essential point here concerns the distinction between a rule or axiom (such as that heavenly motions must be circular, or compounded of circles) and the habit of mind that makes that rule seem beyond questioning. The latter, I try to show, is always linked to experience in the world, allowing that experience in the world includes work with the computations, diagrams, and other intellectual and physical apparatus peculiar to the theory at issue. It is important to distinguish between the intuitive sense that grows out of experience and the merely verbal (however useful and unavoidable) approximation of that habitual sense of things.

But relative to physical habits, habits of mind are particularly likely to go unnoticed. What we can observe are only reports of intuitions, which ordinarily do not directly reveal the habits of mind that prompt them. The socially-shared habits of mind with which we are particularly concerned here may be even harder to discover. To people within the community, what will prove to be critical for the barrier analysis may be intuitions that seem too obviously right to prompt discussion. They are in the realm of what "everybody knows" and takes for granted. The important role that thought experiments have played in the history of science — always proposed by individuals who wish to challenge prevailing views — is as a device for prompting people to notice that something totally taken for granted could be wrong (Kuhn 1977).

But this shows that the critical habits of mind are unlikely to be superficially obvious, hence routinely discussed in accounts of the events. But it is not hard to see how to proceed: namely by close examination of what was being taken for granted, what persistently ignored prior to the paradigm shift but not so afterward: in particular, where did good arguments or evidence seem to be missed or dismissed; where did bad arguments seemed to go unchallenged?

Summing up: Entrenchment in particular habits of mind shared across an expert community is (on the argument here) exactly what defines operating within some paradigm, tacitly guiding key intuitions within the community, facilitating communication and many aspects of constructive work, but also constraining what can be seen as making sense.

3. Gap versus barrier views

The barrier argument (as against what is at least implicit in more familiar views) suggests a parallel with views of adaptation before and after Darwin. The most natural intuition is that what looks like a set of arrangements to serve some function implies some agent or pressure which intends or forces that set of arrangements. Before Darwin, no naturalist had ever really escaped that sense of things, usually made explicit in the intuition that good design implies a designer. But on the Darwinian account good design can emerge by a process of natural selection in which there is no design. Design can appear as the result of a process which itself intends nothing.

The parallel I want to suggest for paradigm shifts takes the extremely natural view that the cause of difficulty in understanding a new position, or difficulty in reaching it, is some logical distance between the two positions: what I will call the gap. On that view, we could think of a revolutionary paradigm shift as a shift requiring an intrinsically large logical discontinuity between the theories or practices characteristic of the new and old paradigms.

Alternatively, though, we can consider the quasi-Darwinian possibility that paradigm changes which provoke the symptoms of a Kuhnian revolutionary episode are just those where there happens to be an important cognitive *barrier* between the new and old paradigms. If that is the right story, then we can get a cognitive crisis even if there is no intrinsically difficult logical distance between the two. Contrariwise (on this view) even when there is a substantial logical distance, the transition can go smoothly (the discovery occurs soon after the knowledge needed is available, and its contagion across the relevant community is rapid) because there happens to be no habit of mind sufficiently robust in the context to constitute a strong barrier. We get what can be articulated as a “normal revolution”, in contrast to the cognitively stressful characteristics of a Kuhnian revolution.

In the full study, this point is particularly evident in an analysis of the overthrow of phlogiston. Logically Lavoisier’s initiative can be seen as merely an episode in the larger story of the rise of pneumatic chemistry. The latter required that what had always been a substance (air) now be seen as a category (today, gases), and that the varied substances within this category play just as essential a role in chemical processes as until then been allowed only for solids and liquids. In contrast, as has often been pointed out, Lavoisier’s new theory of combustion can be assimilated to Stahl’s phlogiston theory by simply defining phlogiston to be negative oxygen. Logically, consequently, the former transition involves a conceptual shift far more drastic than the latter. But in the view of not only Lavoisier but of Priestley and other adversaries, it was the overthrow of phlogiston that was revolutionary, while the radical conceptual shifts of that came with the rise of pneumatic chemistry were absorbed with remarkably little controversy.

This distinction between “normal” and “Kuhnian” revolutions (those which reveal the symptoms of a cognitive crisis vs. those which do not) relates to the more general distinction I am drawing of *gap vs. barrier* views of paradigm shifts. In terms of the gap view, the question of whether a scientific development is worth describing as a paradigm shift depends on the extent of the conceptual change required for its assimilation. But on the barrier view, major conceptual change is only a correlate, not a defining or necessary feature, of the cognitively stressful developments Kuhn has taught us to think of as involving paradigm shifts.

On the gap view, the logical distance separating a prevailing view and some conflicting new proposal may be comfortably narrow, so that a person can just step across it. But wide gaps require a leap. Very wide gaps require an exceptional good jumper and exceptionally favorable conditions for the leap to be feasible. Wider gaps still are beyond the reach of any plausible human leap. If the new idea is reachable at all it will only be later in the history of the science, when a paradigm has developed which does not require so forbidding a leap. On this view, once we know the prevailing theories before and after a paradigm shift, a judgment about the size of the logical gap will explain why a dramatic transition (a leap) was required to get across in some cases, but only a normal science evolution from earlier ideas in others. Although simplified, I think this is close to the implicit picture usually held. Thagard (1990) provides a particularly explicit ‘gap’ account of the overthrow of phlogiston as a remapping of networks of rules, taxonomies, and so on. This turns on a very different (and more familiar) view of how the overthrow proceeded than I am led to on the barrier view. And the record, I try to show, supports the barrier view, not the “usual story” of secondary accounts.

In a ‘gap’ account, habits of mind play no essential role. Whether a particular transition is revolutionary or not depends on how different the rival theories are, how ex-

tensive a remapping is required to go from one formal network to another, and so on. From the 'gap' view, there may not be much in Kuhn's notion of paradigms beyond a single word for the complex of theories, equipment, and procedures as described in a textbook. Talk of incommensurability is likely to seem just puzzling.

But now consider an alternative which more congenial to the habits of mind claim. Here the critical problem for a revolutionary paradigm shift is not some necessarily difficult logical gap that needs to be leaped (though that might be present), but the robustness of the most severe cognitive barrier that blocks the path to discovery. Ordinarily, on this view, anyone who can get over the barrier can get across the gap. Hence the critical focus is not on a comparison of theories *ex ante* vs. *ex post*, and from that to judge the size of the logical gap. Rather, the critical focus is within the gap, where the primary question concerns identifying the critical barrier within that gap. Of course the bigger the gap, the more room for a really forbidding barrier somewhere along the discovery path. But here the size of the gap is only a correlate of the cognitive difficulty of the transition, not the cause of it, nor necessarily even a well-marked correlate. The psychological character of the barrier turns essentially on the difficulty of breaking an entrenched habit of mind.

Of course a person might also have difficulty related to habits because he is missing some critical facilitating habit as well as by entrenchment in an incompatible habit. Correspondingly, therefore, a paradigm shift might turn on the emergence of a new habit of mind rather than on the breaking of a deeply entrenched one. So although the argument here is framed in terms of the latter case, it implies the converse case as well. I may be unable to hit a certain kind of tennis shot, or to see the point of a particular sort of argument, for either reason. Hence the barrier might take the inverse form of a missing facilitating habit. I give a number of concrete applications in the full study, but the main one for a positive barrier is the new account of the overthrow of phlogiston, the main illustration of a missing facilitating habit concerns the emergence of probability.

In either case when we see a shift which shows the Kuhnian symptoms (delays in seeing a possibility that is logically available, incomprehension or indifference among its first audience to arguments that eventually come to seem hard to resist) we expect to be able to identify a particularly important habit of mind, and to be able to give an account of how it came to arise and how it came to be overcome. We are prepared to find that even when the symptoms of delay or incomprehension are striking that nevertheless the steps necessary to get from one the old theory to the new might be logically easy. That was true for the transition from Ptolemaic to Copernican mathematical astronomy, as Neugebauer and Price have argued, and as I try to show in a more transparent way in the study. The same holds even more transparently for the two other major cases in the new study (concerning phlogiston and probability).

Hence, summing up the barrier claim: There may exist a habit of mind (or several such) which yield intuitions incompatible with some novel idea, where the novel idea is one that once grasped, turns out to be very powerful. Call that a strategically located habit of mind. And occasionally, for some subset of strategically located habits, the relevant habit could not only be strategic but also highly robust, so that escaping it is difficult even after some striking anomaly challenging that habit had come on the scene.

A habit of mind that meets these conditions for a particular case (that is: a habit of mind that is both robust and strategically located) I will call a barrier for that case. Of course habits of mind far more often block ideas which would not only look worthless or perverse to someone entrenched in those habits, but would in fact be worthless or

perverse. Once again, as with physical habits, ordinarily habits are the key to fluent and effective expert performance. It requires peculiar circumstances for the reverse to hold. The whole point of the Darwinian parallel is to notice that the reverse cases, like favorable mutations, though rare, must occasionally occur. And like favorable mutations, habits of mind that are at once both adversely stubborn and strategic, even though rare, will play a major role in how things develop.

4. The uniqueness argument

The stronger claim I will finally introduce is that characteristically, the barrier is *unique*, which readily prompts objections along these lines:

Even if habits of mind in fact play the constitutive role urged here, why should it follow that some particular habit of mind will ordinarily be critical for a particular paradigm shift? For it must be a network of interacting habits of mind that characterizes a paradigm, hence a network of habits that must change. So why not suppose that the empirical anomalies or whatever else serves to challenge what had been taken for granted might develop at a number of different points in the network, or in several more or less at once, with no particular habit of mind playing a uniquely critical role?

And even if we are only concerned with what happened in some particular historical case (not with abstract might-have-beens), why not even then multiple points on which the discovery proceeded? And yet again, even if there was a single point of initial escape from the commitments of the prior paradigm, might that not be something merely idiosyncratic for the particular discoverer in particular circumstances: hence something which even if identifiable might be of no real significance for understanding the development of science, or for understanding more generally the emergence of radically novel ideas?

Summing up these objections using an analogy from *Patterns*: If discovery is like finding a path to the top of a mountain, why suppose that any feasible route would encounter a certain barrier, or that one particular point of difficulty on the path actually taken (even if that was somehow the only path that might have been taken) was uniquely the barrier that was critical?

As usual in such a situation, the complimentary components of an answer are a conceptual argument for the plausibility of the claim, then an attempt to show successful application of the argument. The full study, of course, seeks to provide both. But here I can give only a shortened version of the conceptual argument.

Any anomaly must weaken a theory, and make further challenges to the theory easier, and perhaps make previously invincible intuitions visibly problematical. But in the language I used in *Patterns*, ordinarily anomalies are tamed and after a period are no longer capable of prompting serious doubts about the basic theory. Consequently, even what logically seems to be a striking anomaly will still have only a limited window of opportunity in which it might be fruitfully exploited. It is not hard to find striking illustrations of this propensity in the historical record, as with various tamed anomalies for Ptolemaic astronomy mentioned in *Patterns*, p. 263, or as I show holds for the increase of weight of calxes in the forthcoming Lavoisier analysis. It is that powerful propensity to tame anomalies that makes it plausible to suppose there is one identifiable habit of mind newly challenged (or in the converse case, some facilitating habit of mind which emerges just prior to this discovery) which is ordinarily critical for putting a radical novelty within reach.

For phlogiston — a particularly easy case for exposition, since the relevant habit of mind is rooted in everyday experience (not expert knowledge) — we are all familiar with seeing flames emerge from the burning fuel, and with the gradual disappearance of the fuel as this process continues. If we look to the history of ideas about combustion (as in Gregory 1934) it is clear that this “phlogistic” intuition — under other names of course — long predates Stahl’s elaboration of that idea, and indeed can be traced back to the earliest recorded speculations about the nature of fire. Somehow fire is congealed in combustible substances, and the flames we see leaping up during combustion reveal the escape of this congealed matter of fire.

In other cases (for example, the Copernican case, as developed in detail in *Patterns*), the critical habit of mind is not so obvious. Nevertheless, examination of the history can be expected to reveal a plausible candidate. For if such a barrier exists, it must leave evidence of its presence in a puzzling inability of those involved to see possibilities that are logically easily available, and which (after the transition) no one seemed to be capable of missing.

But when the tendency to tame anomalies and the possibility of strategic and stubborn habits of mind are considered together, the conjecture that a barrier will ordinarily be unique becomes hard to avoid. Since habits are rarely either quickly made or quickly broken, much repetition is characteristically required to displace an entrenched habit. But anomalies eventually lose their bite. If beyond a momentary escape from the barrier habit of mind, there is only a further barrier — not a striking novelty that motivates the repeated effort required to break a deeply entrenched habit — then the opportunity to go further will ordinarily be lost. The anomaly will be tamed, rather than the habit broken. But given that point, it becomes almost tautological that, if the barrier argument in general is correct, then the stronger claim will also be true: that a characteristic of revolutionary discovery is that there will ordinarily be some unique critical barrier.

Putting this argument in another way: Just what we mean when we say a habit of mind was a barrier in some context is that if given a chance (if not blocked by that barrier) some idea incompatible with that habit of mind would work in strikingly effective ways. An anomaly creates a window of opportunity for established ideas to be challenged. But over time anomalies are ordinarily tamed. And habits are not broken abruptly, any more than they are made abruptly: repeated experience is required to break a habit even after some transient circumstances has allowed a momentary departure from the habitual intuition. Hence unless an escape from some habit of mind quickly reveals further ideas or observations sufficiently remarkable to assure that the individual will be highly motivated to repeat the experience (to try to glimpse whatever was striking again, ponder its significance, think about how it might make sense), then the episode is likely to be transient, so that nothing deep happens until some new anomaly arises, or new circumstances bring renewed salience to what had become a tamed anomaly.

So suppose we have a case in which we can point to more than one candidate for barrier: the Copernican case treated in detail in *Patterns* provides a splendid example. For here the obvious candidate for barrier — the profound intuitive sense of the Earth as fixed and stable — does not in fact turn out to be the barrier. Instead the critical habitual sense of things turns on a way of seeing the structure of the world that could be acquired in the deeply entrenched and entangled way we need only through the practice of a thoroughly expert Ptolemaic astronomer: what I called in *Patterns* the “nested-spheres” sense of the structure of the world. But when multiple potential barriers are involved on the way to some discovery, they will always be to some extent inter-

dependent: if one were broken or even weakened the other would become more vulnerable. Hence (for two salient candidates for barrier) the main possibilities following a breach of the first barrier become these:

If there are breakthrough effects, the second apparent barrier *may* now have lost much of its potential to block the new idea. On the account worked out in *Patterns*, that occurs in the Copernican case. Or if there are no breakthrough effects, the anomaly will be tamed. Then both barriers would remain in place. Or (the final main possibility) if there are breakthrough effects but the second barrier remains strong, then the breakthrough effects are themselves remembered as a revolutionary discovery, with the eventual fall of the second barrier seen as a second revolutionary episode. In Kuhnian language, we would have a striking paradigm shift with the first breakthrough, and another later on with the second — as with the fall of Ptolemaic astronomy after Copernicus, then decades later, the replacement of the Ptolemaic technical apparatus by Kepler's ellipses.

But for all three possibilities, although multiple habits of mind may be critical for some idea to fully emerge, we still have, for each episode of cognitively radical discovery, one critical barrier

Summing up in Lakatosian language, but with a meaning substantially different from the rational reconstructionist sense Lakatos had in mind: The normal response to anomalies is some change in the protective belt not a disruption of the hard core. For anomalies are fragile, gradually losing their power to shock, hence to incite interest in radical alternatives to what has become the accepted view of things. The dynamics of the process consequently almost assure that to the extent that an episode is well-marked by Kuhnian symptoms of incommensurability, then some particular habit of mind is likely to be uniquely crucial for that episode. The extension of the Copernican analysis and the additional case material developed in the new study, I try to show, demonstrates a striking capacity of this line of argument to yield fresh insight into some of the most intensely studied episodes in the history of science.

Note

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