18 The Baby in the Lab-Coat: Why Child Development Is Not an Adequate Model for Understanding the Development of Science

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Alison Gopnik and her collaborators have recently proposed a bold and intriguing hypothesis about the relationship between scientific cognition and cognitive development in childhood. According to this view, the processes underlying cognitive development in infants and children and the processes underlying scientific cognition are *identical*. We argue that Gopnik's bold hypothesis is untenable because it, along with much of cognitive science, neglects the many important ways in which human minds are designed to operate within a social environment. This leads to a neglect of *norms* and the processes of *social transmission* which have an important effect on scientific cognition and cognition more generally.

1 Introduction

In two recent books and a number of articles, Alison Gopnik and her collaborators have proposed a bold and intriguing hypothesis about the relationship between scientific cognition and cognitive development in early childhood.[1] In this paper we will argue that Gopnik's bold hypothesis is untenable. More specifically, we will argue that even if Gopnik and her collaborators are right about cognitive development in early childhood they are wrong about science.[2] The minds of normal adults and of older children are more complex than the minds of young children, as Gopnik portrays them, and some of the mechanisms that play no role in Gopnik's account of cognitive development in early childhood play an essential role in scientific cognition. A central theme in our critique of Gopnik's account will be that it ignores the many important ways in which human minds are designed to operate within a social environment – a phenomenon that we'll sometimes refer to as *the interpenetration of minds and culture*. One aspect of the interpenetration of mind and culture that will loom large in our argument is the human capacity to identify and internalize the *norms* of the surrounding culture. We will argue that the cultural transmission of norms, which has been largely neglected in the cognitive sciences, has a major impact on theoretical reasoning and thus has an essential role to play in explaining the emergence of science. Cultural transmission also plays a central role in learning science and, remarkably, in shaping some quite basic cognitive processes that make science possible. These phenomena have been given little attention in the cognitive sciences and they play no role in Gopnik account.

2 Gopnik's Bold Hypothesis

Gopnik reports, with obvious relish, that her theory often provokes "shocked incredulity."(Gopnik 1996a, p. 486) In this section, we'll set out some of the central components of that shocking theory.

According to Gopnik and her colleagues, infants are born with a rich endowment of theoretical information. (Gopnik 1996a, p. 510) They often describe this innate endowment as "knowledge," though it is clear that they are using that term in a way that is importantly different from the way that philosophers use it, since a fair amount of the innate theory turns out not to be true, and is ultimately replaced as the child develops. It is the thesis that infants are born with lots of theoretical knowledge, Gopnik suggests, that generates much of the shocked incredulity. Gopnik and her colleagues have quite a lot to say about the nature of this innate knowledge and why they believe it should be regarded as "theoretical". For our purposes, the crucial point is that theories are "defeasible" – they can be and often are replaced when they are not well supported by the evidence that a cognitive agent (child or scientist) encounters. (Gopnik & Meltzoff 1997, p. 39)

Cognitive development in infancy and early childhood, Gopnik maintains, consists in the adoption (and subsequent abandoning) of a sequence of theories. Subserving this process of theory revision is a "powerful and flexible set of cognitive devices" which are also innate. These devices, unlike the infant's innate theories, remain largely unchanged throughout childhood and beyond. The reason that Gopnik and her colleagues think that there are important connections between scientific cognition and cognitive development in infancy is that, on their view, the psychological processes subserving cognitive development in children, from early infancy onward, are *identical* to those that underlie theory change in science. (Gopnik & Meltzoff 1997, p. 3; Gopnik 1996a, p. 486) We will call this claim the *Continuity Thesis*, and much of what follows is devoted to arguing that it is false.

On Gopnik's account, scientific cognition is just a continuation of the very same processes of theory revision that children have been engaged in from earliest infancy:

> [T]he moral of [the] story is not that children are little scientists but that scientists are big children. (Gopnik 1996a, p. 486)

> [E]veryday cognition, on this view, is simply the theory that most of us most of the time have arrived at when we get too old and stupid to do more theorizing…. We might think of our enterprise as scientists as the further revision of the theory by the fortunate, or possibly just childish, few who are given leisure to collect evidence and think about it. (Gopnik & Meltzoff 1997, p. 214)

Indeed, Gopnik goes on to suggest that the greatness of many important figures in the history of science can be traced to their "childishness." (Gopnik 1996b, p. 561) One of the attractions of Gopnik's bold hypothesis is that, if it is correct, it will unify two fields of investigation – the study of early cognitive development and the study of scientific cognition – that have hitherto been thought quite distinct, with the result that advances in either domain will further our understanding of the other.

Figures A & B are our attempt to capture the fundamental aspects of Gopnik's theory.

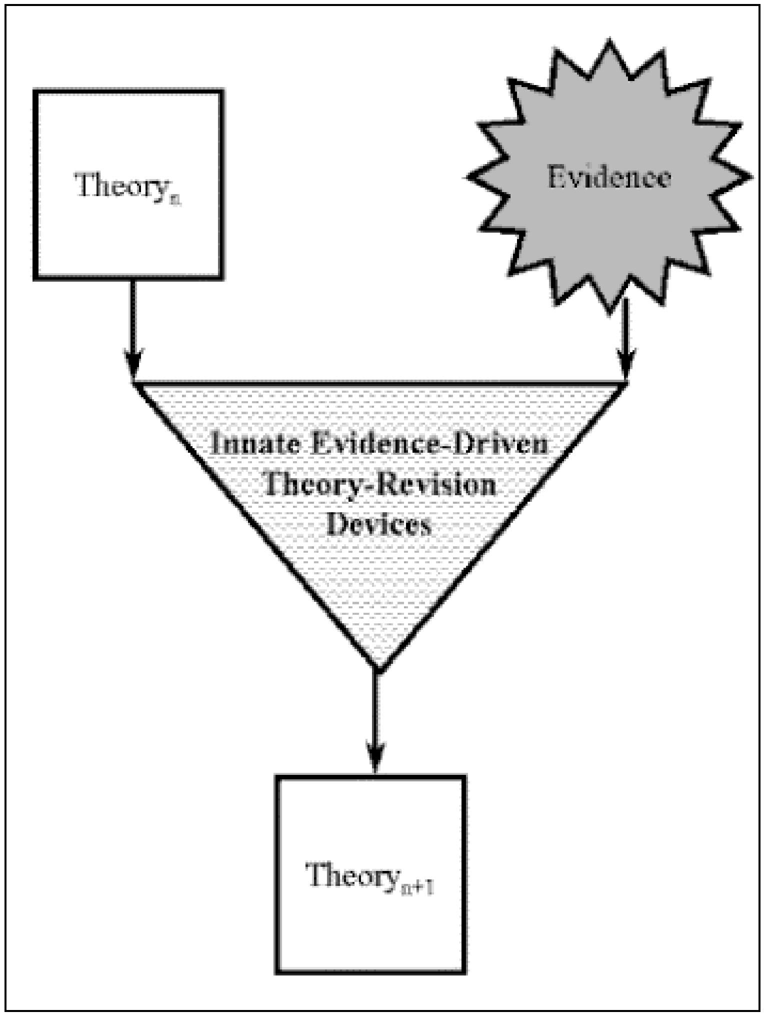

Figure A

Figure A depicts the basic components in Gopnik's account of theory change, and Figure B, our attempt to capture the Continuity Thesis, shows that, for Gopnik, the same theory revision process is at work in early childhood, later childhood and science.

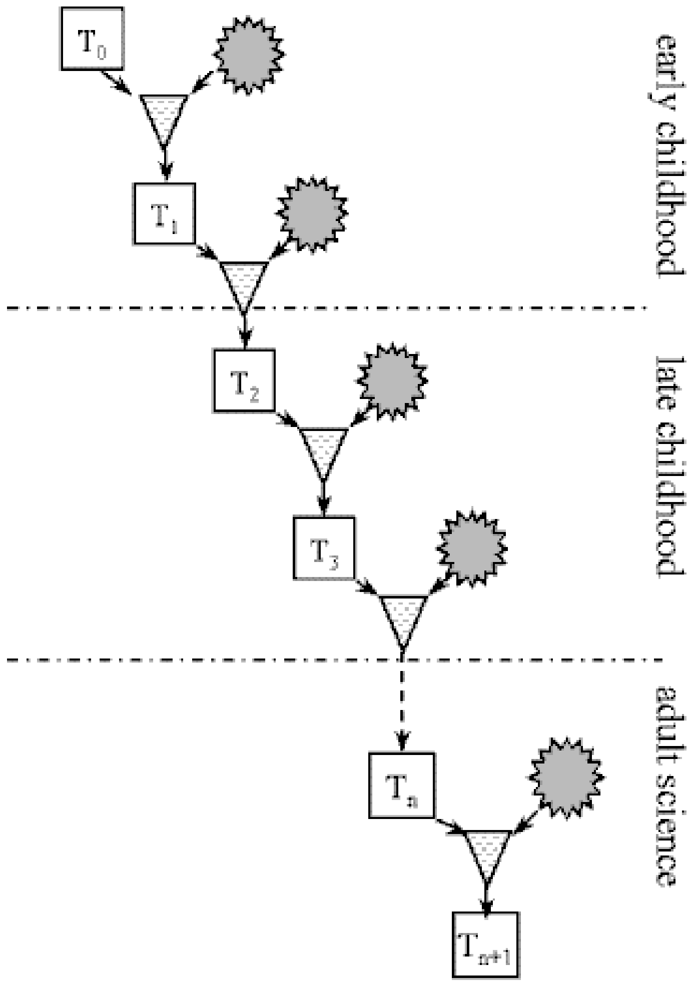

Figure B

3 Why Do People Have The Capacity to Do Science? An Old Puzzle "Solved" and a New One Created

One virtue that Gopnik and her colleagues claim for their theory is that it solves "an interesting evolutionary puzzle." Everyone agrees that at least some humans have the capacity to do science. And few would challenge the claim that in doing science people use a flexible and powerful set of cognitive abilities. But, Gopnik & Meltzoff ask, "Where did the particularly powerful and flexible devices of science come from? After all, we have only been doing science in an organized way for the last 500 years or so; presumably they didn't evolve so that we could do that." (Gopnik & Meltzoff 1997, p. 18 & Gopnik 1996a, p. 489) The answer they suggest is that many of the cognitive devices that subserve scientific reasoning and theory change evolved because they facilitate "the staggering amount of learning that goes on in infancy and early childhood." ((Gopnik & Meltzoff 1997, p. 18 & Gopnik 1996a, p. 489) So, according to Gopnik, "*science is a kind of spandrel, an epiphenomenon of childhood*." (Gopnik 1996a, p. 490; emphasis added)

This proposed solution immediately suggests another problem, which Giere (1996, p. 539) has dubbed "the 1492 problem." "Science as we know it," Giere notes, "did not exist in 1492." But if Gopnik and her colleagues are right, then the cognitive devices that give rise to science have been part of our heritage since the Pleistocene. *So why have humans only been doing science for the last 500 years*? The solution that Gopnik proposes turns on the availability of relevant evidence.

My guess is that children, as well as ordinary adults, do not … systematically search for evidence

> that falsifies their hypotheses, though … they do revise their theories when a sufficient amount of falsifying evidence is presented to them. In a very evidentially rich situation, the sort of situation in which children find themselves, there is no point in such a search; falsifying evidence will batter you over the head soon enough. (Gopnik 1996b, p. 554)

Now what happened about 500 years ago, Gopnik maintains, is that as a result of various historical and social factors a few thinkers found themselves confronted with unprecedented amounts of new evidence, some of which falsified venerable answers to questions like: Why do the stars and planets move as they do? New technology was one reason for the availability of new evidence; telescopes, microscopes and devices like the air pump were invented. Other technological and social changes greatly facilitated communication allowing "a mathematician in Italy to know what an astronomer has seen in Denmark." (Gopnik 1996b, p. 554) Greater leisure (at least for a few) was yet another factor. All of this, and perhaps other factors as well, Gopnik suggests, created an environment in which the theory revision mechanisms that natural selection had designed to enable children to cope with "the staggering amount of learning that goes on in infancy and childhood" might begin functioning actively in adulthood, long past the stage in life in which they would have made their principal contribution to fitness in the environment in which our ancestors evolved.

Though in an earlier paper two of the current authors expressed some enthusiasm for this solution, (Stich & Nichols, 1998) the work of others in the current group of authors has made us all quite skeptical. The problem, as we see it, is that just about all the factors cited in Gopnik's explanation of the emergence of science in the West were present at that time – and indeed much earlier – in China. Well before science emerged in the West, the Chinese had much sophisticated technology that generated vast amounts of information, which they collected systematically for various practical purposes. So there was *lots* of data. They also had a tradition of strong unified government and a centralized bureaucracy that built and maintained systems of transportation and communication far superior to those in the West. Compared with the situation in the West, it was relatively easy for scholars in one part of the country to learn about information generated in another part of the country. Moreover, there was no shortage of scholars with ample leisure. A substantial number of astronomers and other collectors of useful information were employed by rich aristocrats, and there was a substantial class of wealthy individuals who had access to the highly developed system of communication and who were well enough educated to be aware of the large amounts of data being generated in their society by sophisticated equipment and instruments. Despite all this, however, *science as we know it did not emerge in China*. (Needham, 1954; Guantao et al., 1996) So something in addition to the availability of new data is needed to explain why science emerged in the West. In Sections 6-9 we will offer an account of some of the additional factors that played an important role.

4 The Very Limited Role that Culture Plays in Gopnik's Account

One feature of Gopnik's account that will play a central role in our critique is that it is fundamentally individualistic or asocial. According to Gopnik, as children develop they proceed from one theory to another and, as indicated in Figure A, their trajectory – the path they follow through this space of theories – is determined by only three factors: (i) the nature of the Innate Theory Revision Devices; (ii) their current theory in the domain in question; (iii) the evidence that they have available. Since, on Gopnik's view, theory change in science is entirely parallel to theory change in infancy, the same three factors, and *only* these, determine the process of theory revision in science.

Gopnik would, of course, allow that the culture in which a cognitive agent (whether she is a child or a scientist) is embedded can be a source of evidence for *theories about that culture*. And, for both older children and scientists, the culture can also be an indirect source of evidence about the world, when one person reports his observations to another, either in person or in writing. (Recall the example of the astronomer in Denmark who wrote a letter to a mathematician in Italy describing what he had seen.) But apart from using other people as an indirect means of gathering evidence, the social surround is largely irrelevant.

The fundamental *un*importance of culture in Gopnik's account of theory change can be seen particularly clearly in a passage in which Gopnik predicts that *all* cognitive agents – *regardless of the culture in which they are embedded* – would end up with "precisely" the same theory, provided they start with the same initial theory and get the same evidence:

> [Our] theory proposes that there are powerful cognitive processes that revise existing theories in response to evidence. If cognitive agents began with the same initial theory, tried to solve the same problems, and were presented with similar patterns of evidence over the same period of time they should, precisely, converge on the same theories at about the same time. (Gopnik, 1996a, p. 494)

Gopnik and her colleagues are hardly alone in offering an individualistic and fundamentally asocial account of the processes subserving cognitive development in childhood. As Paul Harris notes in his contribution to this volume, most of the leading figures in developmental psychology from Piaget onward have viewed the child as "a stubborn autodidact." Arguably, this tradition of "intellectual individualism" can be traced all the way back to Galileo, Descartes and other central figures in the Scientific Revolution. (Shapin 1996, Ch. 2) As we will see in Section 6, there is a certain irony in the fact that Gopnik treats intellectual individualism as a descriptive claim, since for the founding fathers of modern science the individualistic approach to belief formation and theory revision was intended not as a description but as a *pre*scription – a *norm* that specified how inquiry *ought* to proceed.

5 The Interpenetration of Minds and Cultures

What we propose to argue in this Section is that Gopnik's account of the cognitive mechanisms subserving theory revision, sketched in Figure A, provides an importantly incomplete picture of cognition in adults. The inadequacy on which we will focus is that this highly individualistic picture neglects the important ways in which cultural or social phenomena affect cognition. Of course, this *by itself* is hardly a criticism of Gopnik and her colleagues, since they do not claim to be offering a *complete* account of the processes involved in adult cognition. However, in Sections 6-9 we will argue that some of the social aspects of cognition that Gopnik and most other cognitive scientists neglect have had (and continue to have) a profound effect on scientific cognition.

A central theme underlying our critique is a cluster of interrelated theses which we'll refer to collectively as the *Interpenetration of Minds and Culture*. Among the more important claims included in this cluster are the following:

(1) The minds of contemporary humans were designed by natural selection to operate within a cultural environment.

(2) Humans have mental mechanisms that are designed to exploit culturally local beliefs and theories as well as culturally local information about norms, social roles, local practices and prevailing conditions. In some cases, these mechanisms cannot work *at all* unless this culturally local information has been provided. In other cases, when the culturally local information is not provided the mechanisms will do only a part (often a small part) of what they are supposed to do, and an individual who lacks the culturally local information will be significantly impaired.

(3) In addition to acquiring culturally local *content* (like beliefs, norms, and information about social roles), the cultures in which people are embedded also have a profound effect on many cognitive *processes* including perception, attention, categorization and reasoning.

(4) The cultural transmission of both content and cognitive processes is subserved by a variety of mechanisms, most of which are quite different from the sorts of theory revision processes emphasized by Gopnik and her colleagues.

(5) Minds contain a variety of mechanisms and interconnected caches of information, some innate and some acquired from the surrounding culture, that impose important constraints on the ways in

which cultures can develop. However, these constraints do not fully determine the ways in which cultural systems evolve. The evolution of culture is *partially autonomous*.

5.1 An example of the Interpenetration of Minds and Culture: The Emotions

One of the clearest examples of a system that exhibits the interpenetration of mind and culture is to be found in the work on the psychological mechanisms underlying the emotions done over the last 25 years by Paul Ekman, Richard Lazarus, Robert Levenson and a number of other researchers. On the account that has been emerging from that research, the emotions are produced by a complex system which includes the following elements:

A set of "*affect programs*" (one for each basic emotion). These can be thought of as universal and largely automated or involuntary suites of coordinated emotional responses that are subserved by evolved, psychological and physiological mechanisms present in all normal members of the species.

Several sets of *triggering conditions*. Associated with each affect program is a set of abstractly characterized conditions specifying the circumstances under which it is appropriate to have the emotion. Like the affect programs, these triggering conditions (which Ekman calls "appraisal mechanisms" and Levenson calls "emotion prototypes") are innate and present in all normal members of the species. Lazarus (1994) offers the following examples of triggering conditions:

For Anger: A demeaning offense against me and mine

For Fright: An immediate, concrete, and overwhelming physical danger

For our purposes, what is important about these innate triggering conditions is that they are designed to work in conjunction with a substantial cache of information about culturally local norms, values, beliefs and circumstances. It is the job of this culturally local information to specify what counts as a demeaning offense, for example, or what sorts of situations pose overwhelming physical danger. And without information of this sort, the emotion triggering system cannot function.

Display rules and other downstream processes. On the "downstream" side of the affect program, the theory maintains that there is another set of mechanisms that serve to filter and fine tune emotional responses. Perhaps the most famous example of these are the culturally local "display rules" which, Ekman demonstrated, lead Japanese subjects, but not Americans, to repress certain emotional responses after they have begun when (but apparently only when) the subjects are in the presence of an authority figure. (Ekman 1972) In this case, the culturally local display rules must interact with a body of information about prevailing norms and social roles that enables the subject to assess who counts as a person of sufficient authority. Local norms also often play an important role in determining the downstream reactions after an affect program has been triggered. So, for example, Catherine Lutz (1988) reports that the Ifaluk people (inhabitants of a Micronesian atoll) have a term, *song*, for a special sort of justified anger. In a dispute, only one party can have a legitimate claim to feeling *song*, and according to the norms of the Ifaluk both the aggrieved party and other members of the community can apply sanctions against the person who has provoked *song*. Similarly, Daly & Wilson (1988) note that in many cultures the prevailing norms specify that if a man is angry because another man has had sex with his wife, the aggrieved party has a right to call on others in the community to aid him in punishing the offender.

Figure C is Robert Levenson's (1994) sketch of some of the main elements of this "biocultural" model of the emotions.

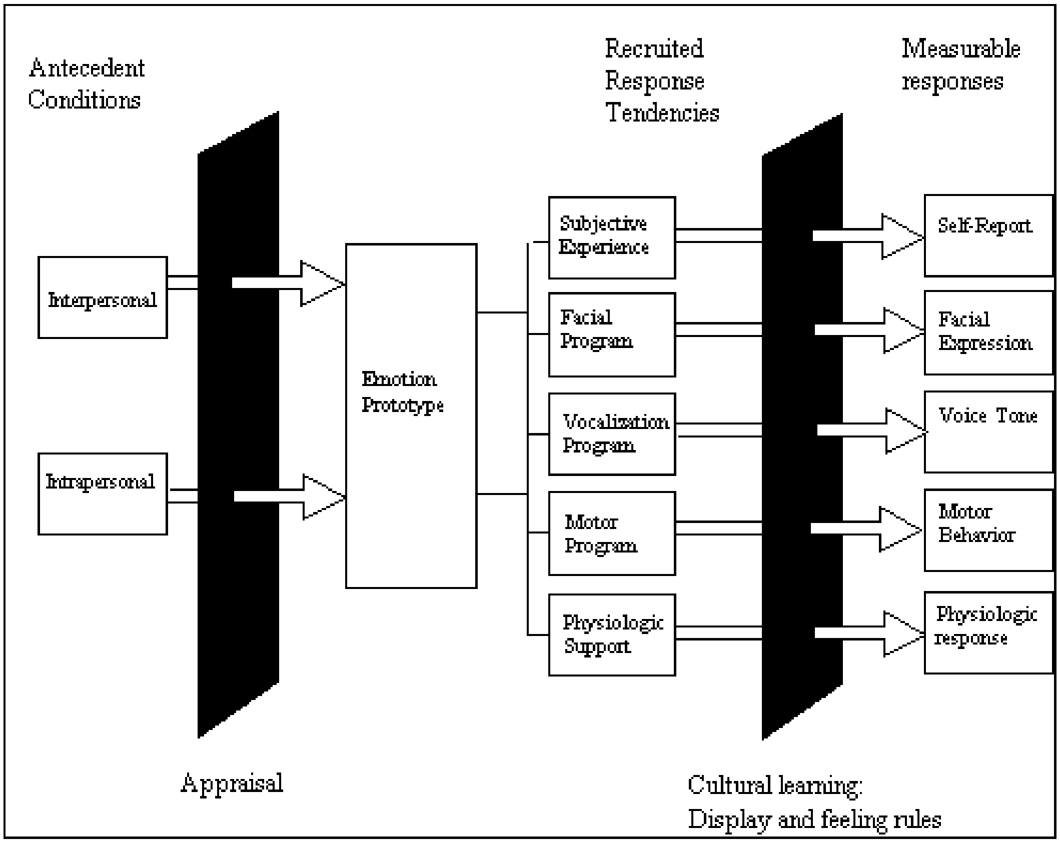

Figure C. Robert Levenson's Biocultural Model of the Emotions (1994, p. 126)

5.2 The Importance of Norms

The psychological processes underlying the emotions are, of course, importantly different from those underlying scientific cognition. For our purposes, the example of the emotions is important for two reasons. First, it illustrates one well studied domain in which the interpenetration of minds and culture has been explored in some detail. Second, it highlights the fact that the *norms* that obtain in a culture can have an important effect on cognition. In a full account of the role of norms in cognition, there are many important questions that would need to be addressed, including questions about the nature of norms and about the psychological mechanisms that subserve them, questions about how norms are transmitted, how they change, and what their evolutionary function may have been. In this paper, we can offer only a few brief remarks on these issues.

- Norms typically characterize a range of actions or behaviors that are appropriate or required or prohibited in various circumstances.

- Norms are typically "common knowledge" in the relevant community. More or less everyone knows them and more or less everyone knows that everyone knows them.

- Norms typically include an *affective component.* Doing an appropriate or required action typically generates positive affect in others which may be accompanied by praise, admiration or support. Doing inappropriate or prohibited actions typically generates negative affect in those who know about it, and this will often be accompanied by sanctions. It is important to note that norm violations (in contrast with actions which merely provoke anger but do not violate norms) typically provoke negative affect and an inclination to sanction or punish among members of the community who are not directly involved or harmed.

- Along with Axelrod (1986), Boyd & Richerson (1992), and Sober & Wilson (1998), we think that norms and the psychological mechanisms subserving them may have evolved because they give communities a powerful and relatively inexpensive way of altering the "payoffs" for various sorts of behaviors that may benefit an individual to the detriment of the group (or vice versa).

6 Science Is A Norm Governed Activity

What makes the preceding discussion of norms relevant to our current topic is that science is a norm governed activity. It is a commonplace that norms govern many aspects of science, including the sorts of evidence that must be offered in support of a claim, the sorts of arguments that may (and may not) be offered in support of a claim, the sorts of information that scientists are expected to report (and the sorts they are allowed or expected *not* to report), the procedures required for getting work accepted for presentation at scientific meetings and for publication in scientific publications, the ways in which researchers claim credit for work and the ways in which they share credit with other researchers and with their own collaborators and students. These norms not only affect what scientists do, they also affect what scientists *believe* – they affect which theories are accepted, which theories are taken seriously, and which theories are rejected. Moreover, while it is possible that *some* of the norms that play a role in science are innate, many others certainly are not. Most scientific norms are neither universal nor unchanging; they are not a fixed or permanent feature of human minds or of human cultures. Quite the opposite. The norms of science have a history (indeed, in most cases a relatively short history) and they are subject to ongoing modification.

6.1 Some Examples of the Role of Changing Norms in the History of Science

This is not the place to attempt a systematic survey of the role that norms have played in the history of science. However, a few examples should serve to make the point that they have been of enormous importance.

Nullius in verba

Nullius in verba ("On no man's word") was the motto of the Royal Society, founded in 1660, and it captures a fundamental norm that early scientists saw as setting them apart from the university based 'schoolmen' on whom they regularly poured scorn. The norm that the slogan reflected was that in order to understand how the world works, one ought to look at the 'testimony' of nature rather than reading and interpreting Aristotle and other ancient authors. The spread of this new norm marked a sea change in the intellectual history of the West – a change without which the emergence of science would obviously have been impossible.

Why did the norm emerge and spread? As in most cases of transformations in prevailing norms, the reasons were many and complex. We will mention just two parts of the story that historians of science have stressed. The first is that fathers of modern science were hardly alone in rebelling against established authorities. In the two centuries prior to the founding of the Royal Society, the questioning of intellectual and political authorities was becoming far more common in many areas of society. In religion, for example, Martin Luther famously asked people to focus on scripture rather than church doctrine. Second, as a number of historians have emphasized, some of the earliest advocates of looking at nature were not saying "give up copying and look at the facts," rather, they were actually saying that we should study better books namely "those which [God] wrote with his own fingers" which are found everywhere (Nicholas of Cusa (1401-1464) quoted in Hacking, 1975, p. 41.) It may seem that such claims are only metaphorical, but Ian Hacking argues that many claims like this one were meant literally. One piece of evidence that Hacking cites is the 'doctrine of signatures' that suggested that physicians should attempt to find natural signs which were considered to be like linguistic testimony. (Hacking 1975, pp. 41-43). While there is much more to be said about the emergence of the new norm according to which scientists (or natural philosophers as they preferred to be called) should ignore the Ancients and look at nature, we think these two fragments of the story provide a nice illustration of fact that the evolution of culture is *partially autonomous*. Though the structure of the mind may impose important constraints on the evolution of norms, local and surprisingly idiosyncratic historical factors also play a crucial role in the process.

The Management of Testimony

Though their motto discouraged relying on the testimony of the Ancients, the members of the Royal Society relied heavily on testimony from each other, from scientists in other countries and from travelers who had been to distant lands and seen things that could not be seen in England. The members of the Society actively debated which principles they ought to apply in accepting such testimony. They wanted to avoid excessive skepticism toward strange tales from afar,[3] but they also did not want to give uncritical credence to stories from travelers.

In *A Social History of Truth*, Steven Shapin (1994) offers an extended discussion of how the Royal Society "managed" testimony. On Shapin's account, 17th century beliefs and norms regarding truthfulness had a major effect on the standards that these early scientists adopted. One belief that played a central role was that "gentlemen" were more trustworthy than artisans, servants, merchants and other folk. This belief was intertwined with the prevailing norm according to which a gentleman's reputation for truthfulness was a matter of major importance. "Giving the lie" or accusing someone of dishonesty was a very serious matter.[4] Shapin argues that these attitudes had important effects on the members of the Royal Society, and thus on the development of science in the 17th century. One rather curious consequence was that quite different standards were applied in deciding whether to trust testimony from people of different social status. Thus, for example, Boyle refused to accept the testimony of "common" divers when it contradicted his theories about water pressure. At the same time Boyle attempted to accommodate testimony from gentlemen travelers to the arctic even when their testimony regarding icebergs contradicted his theories. (Shapin, 1994, pp. 253-266). Testimony from non-gentlemen was sometimes accepted but it needed to be vouched for by someone of good standing. When Leeuwenhoek, a haberdasher by trade and a chamberlain for the sheriffs of Delft, provided the Society with strange reports of the abundance of microscopic creatures, he felt the need to have no less than eight "local worthies" vouch for his claims, even though none had any relevant technical experience (Shapin, 1994, pp. 305-307.) For our purposes, a more important consequence was that members of the Royal Society typically took great pains to avoid being seen as anything other than disinterested investigators. They wished to avoid appearing like merchants or tradespeople for then they would suffer a considerable drop in credibility. (Shapin, 1994, pp. 175-192) As a result, the "gentlemen scientists" of the Royal Society tended to focus on what we would describe as "pure science" rather than on potential applications or the development of technology. This stands in stark contrast to the pattern of inquiry to be found in China at that time and earlier. In China, inquiry was almost always conducted with some practical goal in mind; the ideals of pure inquiry and theory for its own sake were never embraced. The importance of this fact will emerge more clearly in Sections 8 and 9.

Contemporary Debates about Scientific Norms

The emergence of new norms regulating the conduct of inquiry is not a phenomenon restricted to the early history of science. Quite the opposite, it is a process that has operated throughout the history of science and continues in contemporary science. In experimental psychology, for example, there has recently been a heated debate about experimental designs in which the participants are deceived about some aspect of the experimental situation. Some of those who urge that the use of deceptions should be curtailed are motivated by moral concerns, but others have argued that deception should be avoided because of the "methodological consequences of the use of deception on participants' attitudes, expectations, and in particular, on participants' behavior in experiments." (Hertwig & Ortmann, forthcoming a). The behavior revealed in experiments involving deception, these critics maintain, particularly when it is widely known that psychologists practice deception, may not give us reliable information about how participants would behave outside an experimental setting. (Hertwig & Ortmann, forthcoming b) One fact that has come to play an important role in this debate is that the norms that obtain in experimental psychology are quite different from the norms that prevail in the closely related field of experimental economics. In the latter discipline the use of deception is strongly discouraged, and the use of financial incentives – which are rarely used in psychology – is mandatory. "Experimental economists who do not use them at all can count on not getting their work published." (Hertwig & Ortmann, forthcoming a)

6.2 A First Modification to Gopnik's Picture

The conclusion that we want to draw from the discussion in this Section is that Gopnik's picture of scientific cognition is in an important way incomplete. While it *may* be the case that the pattern of theory revision in early childhood is entirely determined by the three factors mentioned earlier – the nature of the Innate Theory Revision Devices, the current theory and the available evidence – there is another factor that plays a crucial role in theory revision in adults: *norms* – more specifically norms governing how one ought to go about the process of inquiry and how one ought to revise one's beliefs about the natural world. Moreover, the emergence of new norms played a crucial role in the emergence of science. So, while Figure A *may* offer a plausible picture of theory revision in early childhood, something more along the lines of Figure A* does a better job of capturing theory revision in science.

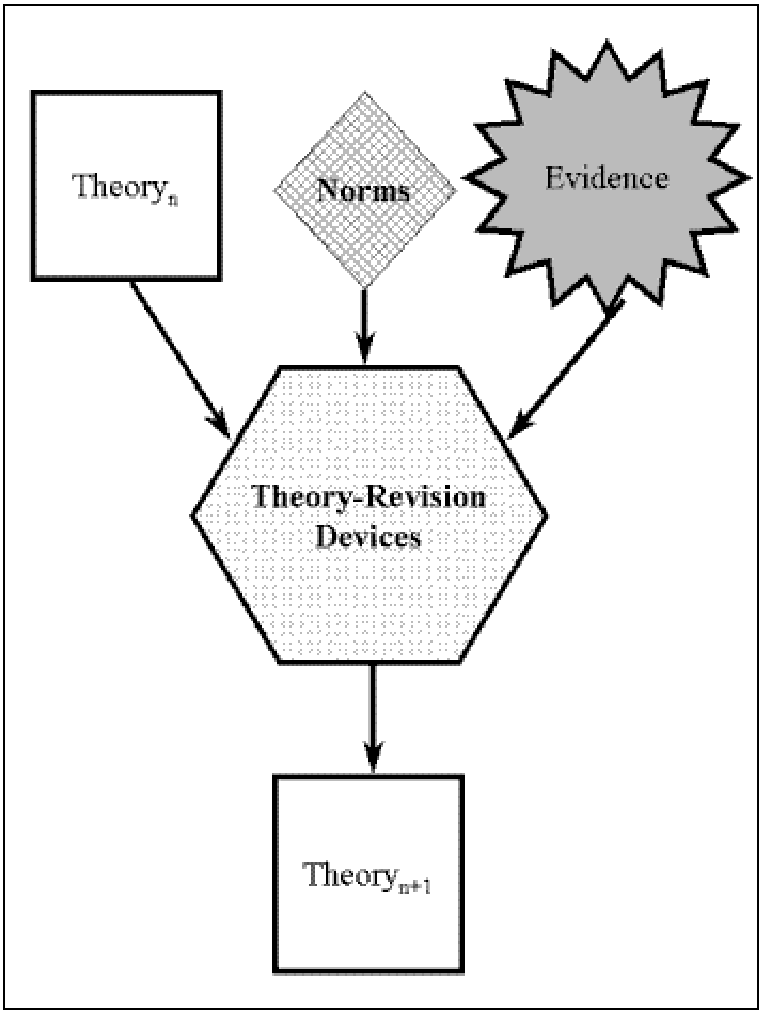

Figure A*

And thus Gopnik's Continuity Thesis, depicted in Figure B must be replaced by something more like Figure B*.

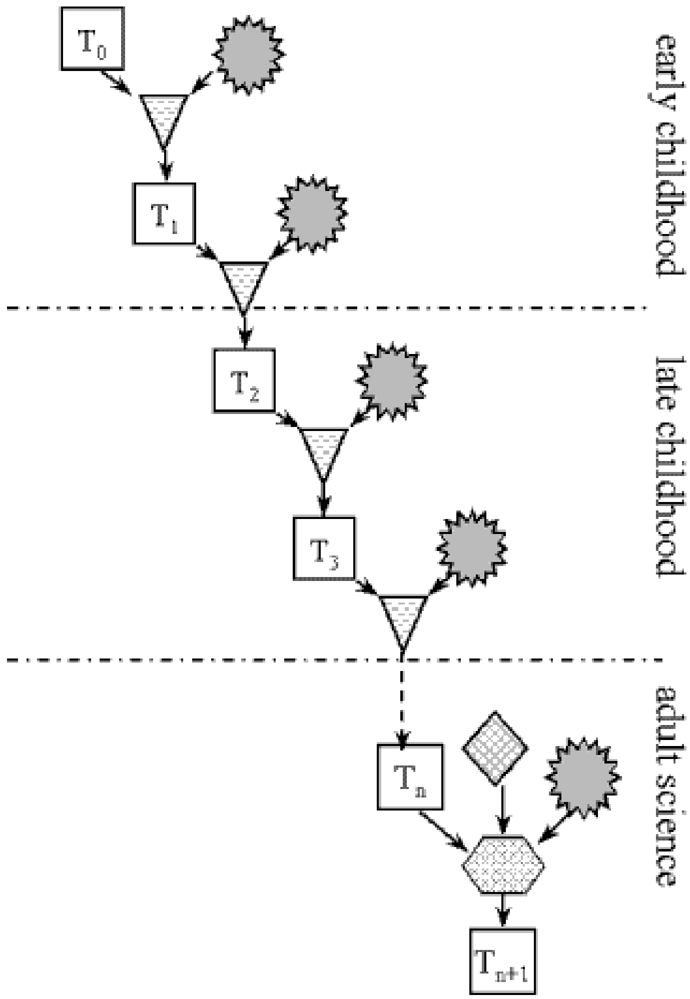

Figure B*

7 The Cultural Transmission of Norms and Theories (and Two More Modifications to Gopnik's Picture)

In the previous section we argued that norms play an important role in science and we emphasized the emergence of new norms and the role that these new norms played in making science possible. But, as the literature in anthropology and social psychology makes abundantly clear, though norms do change they are also often remarkably stable. Within a culture, the norms governing many aspects of behavior can be highly resistant to change. In traditional societies with relatively homogenous norms, children and adolescents almost always end up sharing the norms of their culture.

To the best of our knowledge, relatively little is known about the details of the cognitive processes subserving the acquisition of norms, and even less is known about the processes that result in the emergence of new norms. However, a bit of reflection on familiar experience suggest that norm transmission *cannot* be subserved by the sort of evidence driven theory revision process that, according to Gopnik, subserves cognitive development in infants. (Figure A) Rather, norm transmission is a process of *cultural transmission*. Children acquire their norms from older members of their society and this process is not plausibly viewed as a matter of accumulating evidence indicating that one set of norms is better than another. Our point here is not that evidence is irrelevant to norm acquisition, but rather that to the extent that it is relevant it plays a very different role from the one suggested in Figure A. An anthropologist will use evidence of various sorts to discover the norms that obtain in a culture. And it is entirely possible that children in that culture will use some of the same evidence to discover what norms their cultural parents embrace.[5] But this alone is not enough to explain the *transmission* of norms. For it does not explain the crucial fact that children typically *adopt* the norms of their cultural parents while anthropologists do not typically adopt the norms of the culture they are studying. Much the same, of course, is true for the acquisition of scientific norms which (we would speculate) typically occurs somewhat later in life. Evidence of various sorts may be necessary to figure out what norms of inquiry obtain in a given branch of science. But *knowing what the norms are* and *accepting them* are important different phenomena.

If this is right, it indicates that there is yet another mental mechanism (or cluster of mental mechanisms) that must be added to our evolving sketch of the cognitive underpinnings of scientific cognition. In addition to the mechanisms in Figure A*, we need a mechanism (or cluster of mechanisms) whose function it is to subserve the process of cultural transmission via which norms are acquired. Adding this to Figure A* gives us Figure A**.

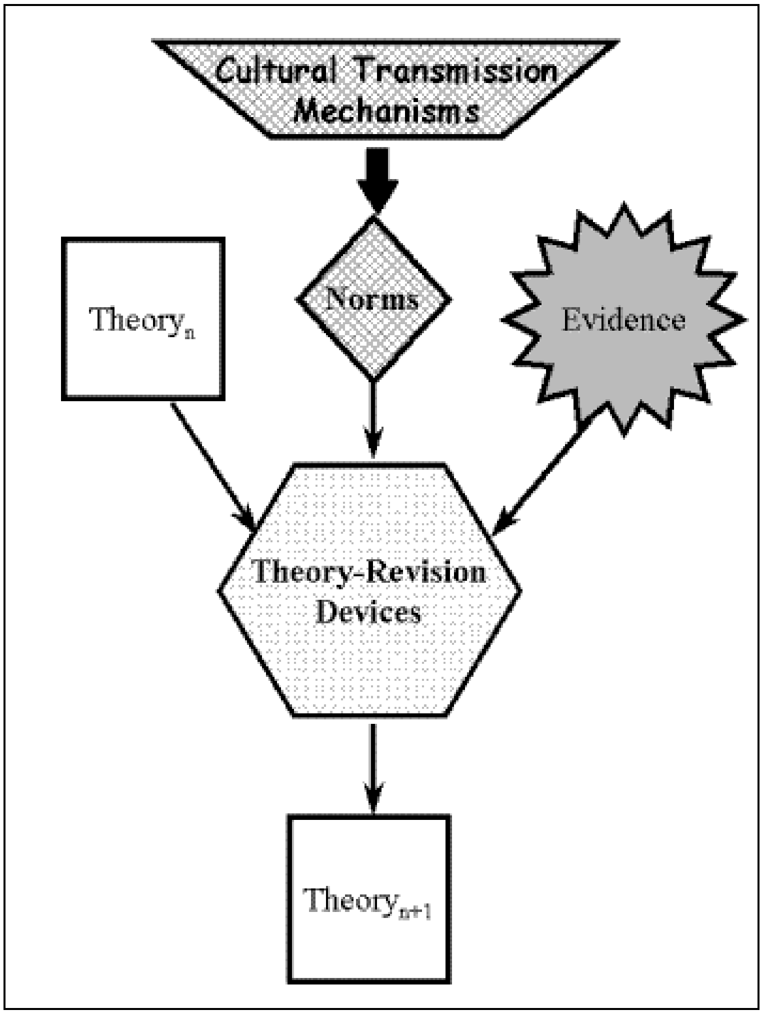

Figure A**

Once mechanisms subserving social transmission have been added to the picture, a natural question to ask is whether these mechanisms might play any other role in helping to explain scientific cognition. And the answer, we think, is yes. For there is an interesting *prima facie* parallel between the process by which norms are transmitted and the process by which children and adolescents acquire much of their basic knowledge of science. Learning science, like learning norms, appears to be largely a process of cultural transmission in which younger members of a culture are instructed and indoctrinated by appropriate senior members. In the case of science, of course, teachers are among the more important "cultural parents." What makes this analogy important for our current concerns is that in the cultural transmission of both norms and science, evidence takes a backseat to *authority*. When children are taught the basics of the heliocentric theory of the solar system, Newtonian physics, the atomic theory of matter or Watson & Crick's theory about the structure of DNA, the challenge is to get them to *understand* the theory. Models (often real, physical models made of wood or plastic), diagrams and analogies play an important role. But *evidence* does not. Most people (including several of the authors of this paper) who know that genes are made of DNA and that DNA molecules have a double helical structure haven't a *clue* about the evidence for these claims. If students can be gotten to understand the theory, the fact that it is endorsed by parents, teachers and textbooks is typically more than sufficient to get them to *accept* it. We teach science to children in much the same way that people in traditional cultures teach traditional wisdom. Adults explain what they think the world is like, and (by and large) children believe them. If this is right, it highlights another way in which culture plays an important role in scientific cognition. It is *cultural transmission* that lays the groundwork on which the adult scientist builds.

All of this, of course, is bad news for theories like Gopnik's. For, on her Continuity Thesis, sketched in Figure B, the process of theory revision is much the same in young children, older children and in adult scientists. But if we are right, the acquisition of new scientific theories by older children and adolescents is subserved, in most instances at least, by a quite different process of social transmission in which authority looms large and evidence plays little or no role.[6] That process is sketched in Figure D.

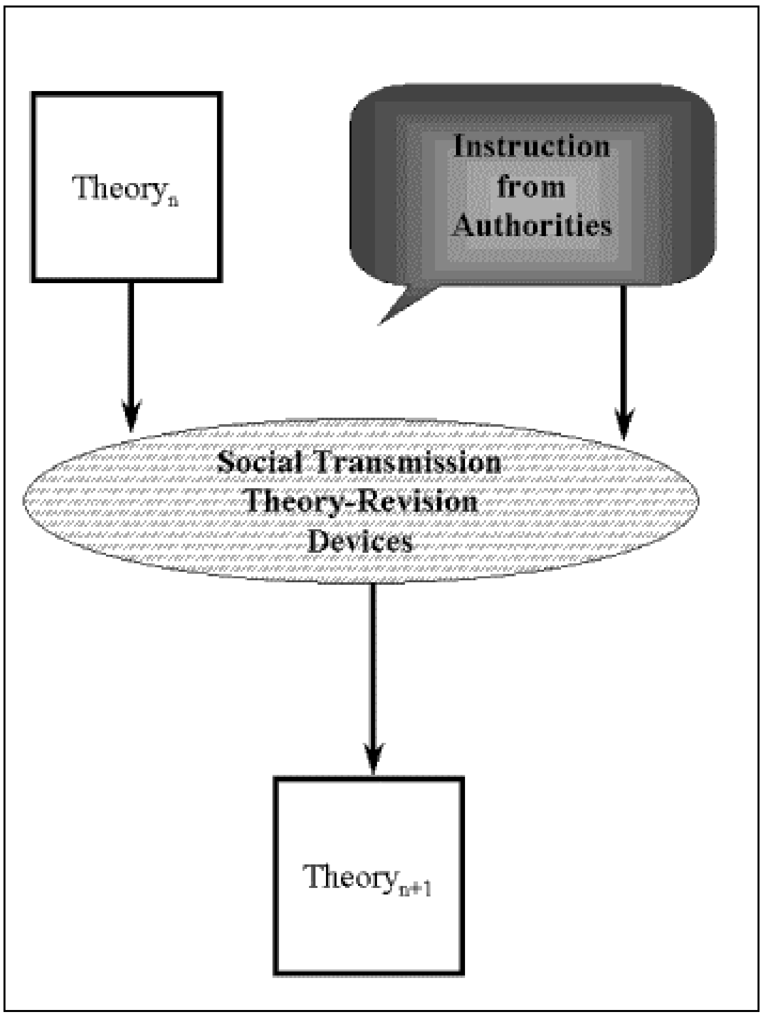

Figure D

So, if we continue to grant, for argument's sake, that Gopnik is right about young children, Figure B, which was superceded by Figure B*, must now be replaced by Figure B**.

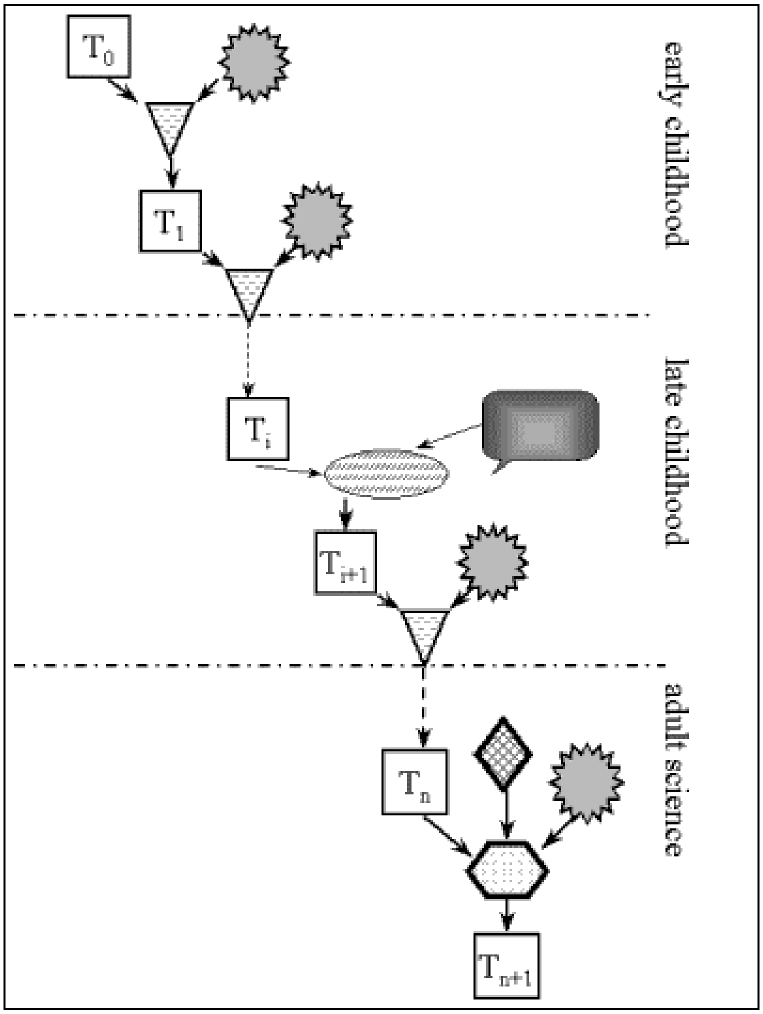

Figure B**

8 Some Surprising Examples of the Ways in Which Culture Affects Cognition

The examples of cultural transmission that we've focused on so far are hardly surprising. It comes as no news that both norms and theories are acquired from one's culture. What is surprising is that Gopnik and her collaborators have offered an account of scientific cognition that ignores the role of culturally transmitted norms and theories, and that there has been so little discussion of the cultural transmission of norms and theories in the cognitive science literature. In this section, our focus will be on some further examples of cultural transmission – examples which many people *do* find surprising. The examples we'll discuss are drawn primarily from the recent work of Richard Nisbett and his colleagues. (Nisbett et al., 2001) It is our belief that their findings have important implications for the study of the cognitive basis of science and that they provide an important part of the solution to the "1492 problem." More importantly, this work indicates that a systematic reexamination of some of the more fundamental assumptions of cognitive science may be in order.

The work of Nisbett and his colleagues was inspired, in part, by a long tradition of scholarship which maintains that there were systematic cultural differences between ancient Greek and ancient Chinese societies, and that many of these differences have endured up to the present in the cultures that have been most deeply influenced by ancient Greek and Chinese cultures. This scholarship also suggests that these cultural differences were correlated with different "mentalities" – that people in Greek influenced Western cultures perceive and think about the world around them in very different ways from people in Chinese influenced cultures, and that these differences are reflected in the way they describe and explain events and in the beliefs and theories they accept. What is novel, and startling, in the work of Nisbett and his colleagues is that they decided to explore whether these claims about differences in mentalities could be experimentally verified, and they discovered that many of them could.

One of the more important aspects of ancient Greek culture, according to the scholars that Nisbett and his colleagues cite was people's "sense of personal *agency*." (Nisbett et al. 2001, p. 292) Ordinary people took control of their lives, and their daily lives reflected a sense of choice and an absence of constraint that had no counterpart in the ancient world. One indication of this was the Greek tradition of debate, which was already well established at the time of Homer, who repeatedly emphasizes that next to being a good warrior, the most important skill for a man to have is that of the debater. Even ordinary people could participate in the debates in the market place and the political assembly, and they could and did challenge even a king.

Another aspect of Greek civilization, one that Nisbett and his colleagues suggest may have had the greatest effect on posterity, was the Greeks' sense of curiosity about the world and their conviction that it could be understood by the discovery of rules or principles.

> The Greeks speculated about the nature of the objects and events around them and created models of them. The construction of these models was done by categorizing objects and events and generating rules about them for the purpose of systematic description, prediction and explanation. This characterized their advances in, some have said invention of, the fields of physics, astronomy, axiomatic geometry, formal logic, rational philosophy, natural history, history, ethnography and representational art. Whereas many great civilizations …made systematic observations in many scientific domains, only the Greeks attempted to model such observations in terms of presumed underlying physical causes. (Nisbett et al. 2001, p. 292)

The ancient Chinese, according to scholars, present a radical contrast to this picture. Their civilization was much more technologically sophisticated than the Greeks', and they have been credited with the original or independent invention of "... irrigation systems, ink, porcelain, the magnetic compass, stirrups, the wheelbarrow, deep drilling, the Pascal triangle, pound-locks on canals, fore-and-aft sailing, watertight compartments, the sternpost rudder, the paddle-wheel boat, quantitative cartography, immunization techniques, astronomical observations of novae, seismographs, and acoustics." (Logan, 1986, p. 51; Nisbett et al. 2001, p. 293) But most experts hold that this technological sophistication was not the result of scientific investigation or theory. Rather, it reflects the Chinese emphasis on (and genius for) *practicality*; they had little interest in knowledge for it's own sake. Indeed, in the Confucian tradition, according to Munro "there was no thought of *knowing* that did not entail some consequence for action. (1969, p. 55; quoted in Nisbett et. al, 2001) The Chinese made good use of intuition and trial-and-error methods, but, many scholars insist, they never developed the notion of a law of nature, in part because they did not have the concept of *nature* as something distinct from human or spiritual entities. Neither debate nor a sense of agency played a significant role in Chinese culture. Rather there was an emphasis on harmony and obligation. Individuals felt very much a part of a large and complex social system whose behavioral prescriptions and role obligations must be adhered to scrupulously. And no one could contradict another person without fear of making an enemy. (Nisbett et al., 2001, p. 292-293.)

According to Nisbett and his colleagues, many of these "aspects of Greek and Chinese life had correspondences in the mentalities or systems of thought in the two cultures" and these differences have left an important contemporary residue. (Nisbett et al., 2001 p.293) In their account of the differences between ancient Greek and ancient Chinese mentalities, Nisbett et al. stress five themes.

Continuity vs. Discreteness. The Chinese "held the view that the world is a collection of overlapping and interpenetrating stuffs or substances" while the Greeks saw the world as "a collection of discrete objects which could be categorized by reference to some subset of universal properties that characterized the object." (Nisbett et al. 2001, p. 293)

Field vs. Object. "Since the Chinese were oriented toward continuities and relationships, the individual object was not a primary conceptual starting point…. The Greeks, in contrast, were inclined to focus primarily on the central object and its attributes." (Nisbett et al. 2001, p. 293)

Relationships and similarities vs. Categories and rules. Because of the Chinese emphasis on continuity and the Greek emphasis on discreteness, "the Chinese were concerned with relationships among objects and events. In contrast, the Greeks were more inclined to focus on the categories and rules that would help them to understand the behavior of the object independent of its context (Nakamura, 1964/1985, p. 185-186). The Chinese were convinced of the fundamental relatedness of all things and the consequent alteration of objects and events by the context in which they were located. It is only the whole that exists; and the parts are linked relationally, like the ropes in a net." (Nisbett et al. 2001, p. 293-294).

Dialectics vs. Foundational principles and logic. "The Chinese seem not to have been motivated to seek for first principles underlying their mathematical procedures or scientific assumptions…. The Chinese did not develop any formal systems of logic or anything like an Aristotelian syllogism…. In place of logic, the Chinese developed a dialectic, …. which involved reconciling, transcending or even accepting apparent contradiction." (Nisbett et al. 2001, p. 294)

Experience-based knowledge vs. Abstract analysis. "The Chinese ... sought intuitive instantaneous understanding through direct perception" (Nakumara 1964/1985, p. 171) This resulted in a focus on particular instances and concrete cases in Chinese thought …." By contrast, "many Greeks favored the epistemology of logic and abstract principles, and many Greek philosophers, especially Plato and his followers, actually viewed concrete perception and direct experiential knowledge as unreliable and incomplete at best, and downright misleading at worst.... Ironically, important as the Greek discovery of formal logic was for the development of science, it also impeded it in many ways. After the 6th-century Ionian period, the empirical tradition in Greek science was greatly weakened. It was countered by the conviction on the part of many philosophers that it ought to be possible to understand things through reason alone, without recourse to the senses (Logan, 1986, p. 114-115)". (Nisbett et al. 2001, p. 294)

Nisbett and his colleagues suggest that these differences can be loosely grouped together under the heading of *holistic* vs. *analytic* thought where holistic thought is defined as "involving an orientation to the context or field as a whole, including attention to relationships between a focal object and the field, and a preference for explaining and predicting events on the basis of such relationships" and analytic thought is defined as "involving detachment of the object from its context, a tendency to focus on attributes of the object in order to assign it to categories, and a preference for using rules about the categories to explain and predict the object's behavior." (Nisbett et al. 2001, p. 293) And, as noted earlier, they claim that these differences persist in the thought of contemporary cultures that have been influenced by China (including modern China, Japan and Korea) and by Greece (including Europe and North America). In support of this claim they assemble an impressive catalogue of experimental findings showing that there are indeed differences between Americans and East Asians in perception, attention and memory, and in the way they go about predicting, explaining, categorizing and revising beliefs in the face of new arguments and evidence. While this is not the place to offer a systematic review of these experimental results, we will very briefly sketch a few of the more remarkable findings.

Attention and perception. In one task used to test the extent to which people can perceptually isolate an object from the context in which it embedded, a square frame was rotated independently of a rod located inside it. Subjects were asked to report when the rod appeared to be vertical. East Asian subjects were significantly more influenced by the position of the frame and made many more errors than American subjects. (Nisbett et al. 2001, p. 297)

Attention and memory. In another experiment, subjects viewed realistic animated cartoons of fish and other underwater life and were then asked to report what they had seen. In each cartoon there was a focal fish or group of fish that was larger and moved more rapidly than anything else on the screen. In describing what they had seen, Japanese and American subjects were equally likely to refer to the focal fish, but the Japanese participants were much more likely to refer to background aspects of the environment. Later the subjects were tested on how well they could recognize the focal fish from the displays they had seen. Some were shown fish with the original background, others with a background the subjects had never seen. Japanese recognition was significantly harmed by showing the focal fish with the wrong background, but American recognition was unaffected. (Nisbett et al. 2001, p. 297)

Attention, curiosity and surprise. As Nisbett et al. note, the Asian tendency to attend to a broad range of factors may make it too easy to come up with explanations of unexpected events.

> If a host of factors is attended to, and if naïve metaphysics and tacit epistemology support the view that multiple, interactive factors are usually operative in any given outcome, then any outcome may seem to be understandable, even inevitable, after the fact…. An advantage of the more simplistic, rule-based stance of the Westerner may be that surprise is a frequent event. *Post hoc* explanations may be relatively difficult to generate, and epistemic curiosity may be piqued. The curiosity, in turn, may provoke a search for new, possibly superior models to explain events. In contrast, if Eastern theories about the world are less focused, and a wide range of factors are presumed to be potentially relevant to any given outcome, it may be harder to recognize that a particular outcome could not have been predicted." (Nisbett et al. 2001, p. 299)

One prediction that this suggests is that Easterners might be more susceptible to what Fischoff (1975) has called *hindsight bias* – the tendency to assume that one knew all along that a given outcome was likely. And in a series of experiments Koreans subjects did indeed show less surprise than Americans when told of the results in Darley and Batson's famous "Good Samaritan" experiment in which seminary students in a bit of a hurry refused to help a man lying in a doorway pleading for help. (Darley & Batson, 1973) Importantly, Korean and American subjects make the same predictions about the likelihood of the seminary student helping when they have not been told about the results of the experiment.

Detection of covariation. If Asians are more attentive to relationships among objects then we might expect that they do a better job at detecting covariation. And indeed they do. In one experiment requiring subjects to judge the degree of association between arbitrary objects presented together on opposite sides of a computer screen, Chinese subjects reported a higher degree of covariation than American subjects and were more confident about their judgments. Their greater confidence was quite appropriate, since their judgments calibrated better with actual covariation. (Ji, Peng & Nisbett, 1999; Nisbett et al. 2001, p. 297) In a similar experiment, American subjects showed a strong primacy effect. Their predictions of future covariation was more influenced by the first pairing they saw than by the overall degree of covariation to which they had been exposed. Chinese subjects showed no primacy effect at all. (Yates & Curley, 1996)

Spontaneous categorization. Norenzayan, Nisbett, Smith and Kim (1999) showed subjects a series of stimuli on a computer screen in which a simple target object was displayed below two groups of four similar objects. The subjects were asked to say which group the target was most similar to. The groups were constructed so that those in one group had a close family resemblance to one another and to the target object. The objects in the other group had a different family resemblance structure, one that was dissimilar to the target object. However, all the objects in the second group could be characterized by a simple "rule," like "has a curved stem" which also applied to the target object. A majority of the East Asians said that the target was more similar to the "family resemblance" group while a majority of European Americans said it was more similar to the "rule" group. (Nisbett et al. 2001, p. 300)

Plausibility vs. Logic. It has long been known that the performance of subjects who are asked to assess the logical validity of an argument is affected by a "belief bias" – an invalid argument is more likely to be judged valid if it has a plausible conclusion. However, Norenzayan, Nisbett, Smith & Kim (1999) have shown that Korean subjects show a much stronger belief bias than Americans. As Nisbett et al. note, "The results indicate that when logical structure conflicts with everyday belief, American students are more willing to set aside empirical belief in favor of logic than are Korean students." (Nisbett et al. 2001, p. 301)

Dealing with conflicting arguments. In a particularly striking experiment, Korean and American subjects were presented with a variety of arguments for and against funding a particular scientific project. The arguments were independently rated for plausibility by separate groups of Korean and American subjects, and Americans and Koreans agreed on how strong the arguments were. Korean subjects presented with a strong argument for funding and a weak argument against funding, were less in favor of funding than Korean subjects presented with just the strong pro argument. However, for

American subjects the results were just the opposite. Those presented with both a strong pro argument and a weak con argument were *more* favorable to funding than those presented with just the strong pro argument! (Davis, 1999; Davis, Nisbett & Schwartz, 1999; Nisbett et al. 2001, p. 302)

9 Conclusions

What conclusions can we draw from this large body of work that are relevant to our concerns in this paper? First, we think that the sorts of differences that Nisbett and his colleagues have found between East Asians Westerners are *bound* to affect the processes of belief change and theory change in adults of those two groups – including adults who happen to be scientists. Since all of the studies that Nisbett and his colleagues cite were done on adult subjects, we can only speculate about when the differences emerge. However, it is very likely that many of them would be found in teenagers and in younger children as well. Moreover, since the differences between East Asians and Westerners begin to disappear in Asians whose families have been in America for several generations, there is no reason to think that there is any significant genetic component to these differences. The differences are acquired, not innate, and the process by which they are acquired is another example of social transmission. So we need to make yet another addition to our evolving picture of theory revision to indicate that, to some significant extent, *the theory revision mechanisms themselves are a product of culture* – Figure A** is superceded by Figure A***, and Figure B** is superceded by Figure B***.

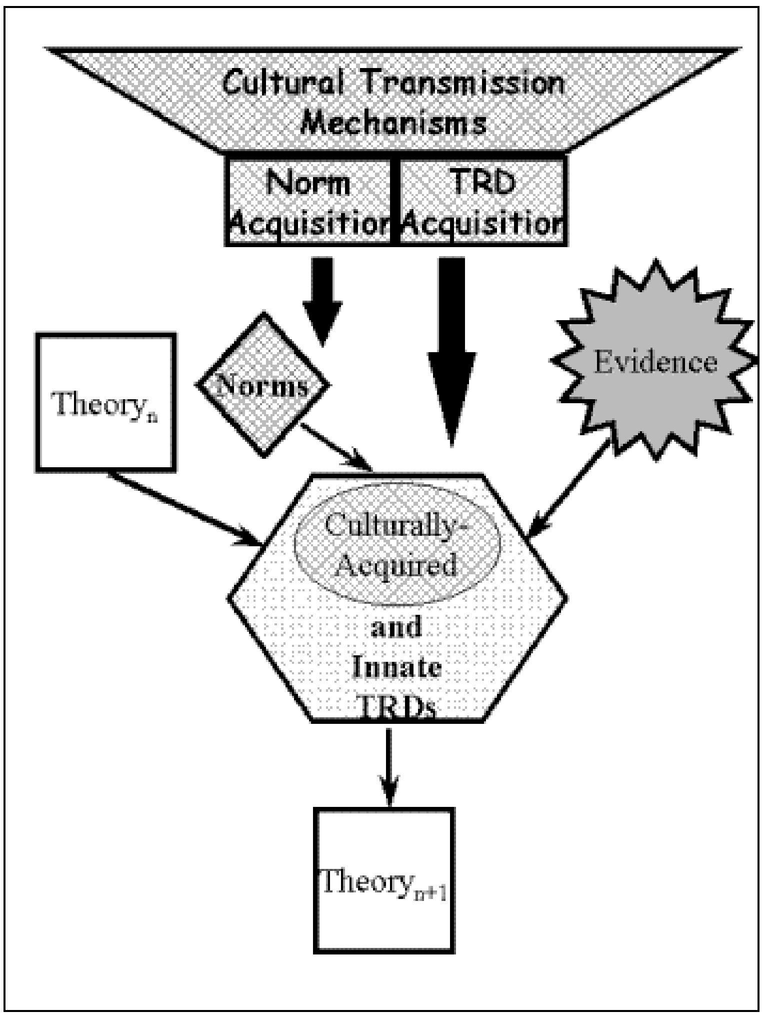

Figure A***

At this point neither Gopnik's account of adult theory revision (in Figure A) nor her Continuity Thesis (in Figure B) appear to be even remotely plausible.

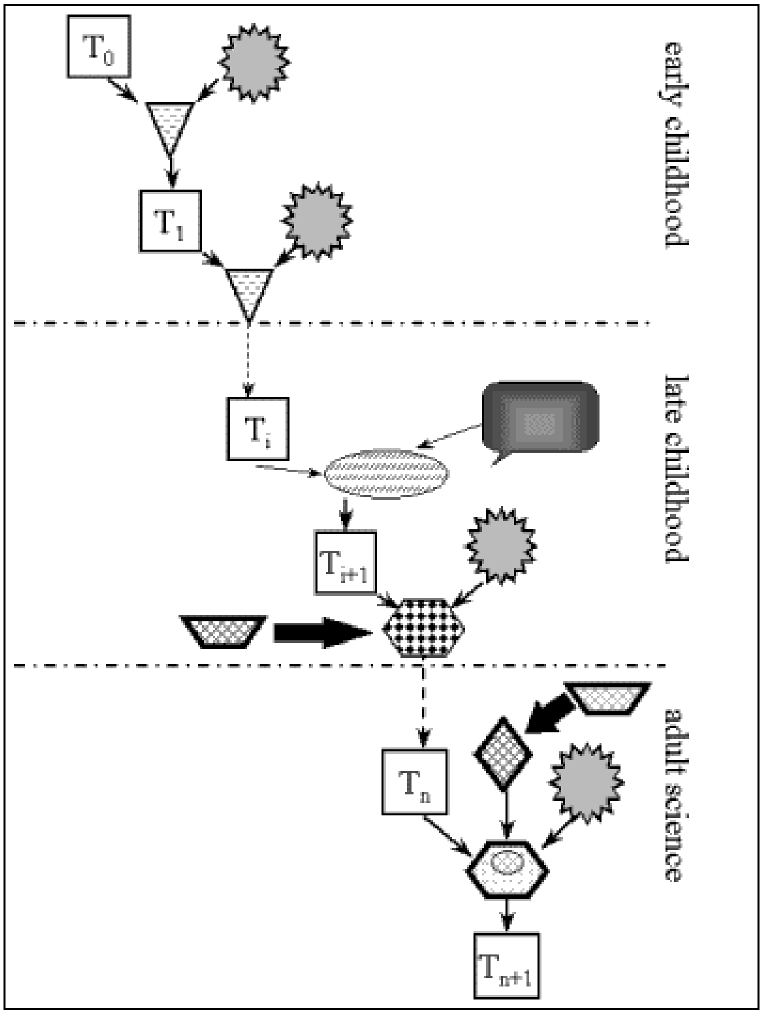

Figure B***

Nisbett's work, along with our earlier discussion of the emergence of new norms, also suggests what we take to be a much richer and more plausible solution to the "1492 Problem" than the one that Gopnik suggests. On her account, the engine that drove the emergence of science was simply the availability of new evidence produced by new technology, along with better communication and more leisure. Although we would not deny that this is part of the story, we maintain that it is only a small part. On Nisbett's account, the Western tradition, with its emphasis on reason and theory, its assumption that the important properties of things were not accessible to the senses, and its greater likelihood to be surprised by and curious about unexpected events was in a much better position to generate and embrace scientific theories about invisible processes that give rise to observable phenomena. But, as Nisbett and his colleagues note, after the 6th century BC, the conviction that the world could be understood without appeal to highly misleading sensory input stifled experimental inquiry. This reluctance to observe the world was reversed by the new norm that insisted one ought to look at nature rather than accept the pronouncements of the Ancients. And as cultural transmission spread that new norm, something resembling the Ionian experimental tradition reemerged and modern science was born. This is, we recognize, only a small fragment of the full story. But in the full story, we believe that the four factors we have emphasized:

(i) norms
(ii) the mechanisms subserving the social transmission of norms
(iii) the mechanisms subserving the cultural transmission of theory, and
(iv) culturally acquired differences in the cognitive mechanisms that subserve theory revision

will all play an important part, even if it is true, as Gopnik maintains, that none of these play a significant role in the theory revision processes in young children. Though these four factors have received little attention from either cognitive or developmental psychologists, we believe that they will play an important role in understanding not only the cognitive basis of science but cognition in other domains as well. Gopnik's baby in the lab-coat is not an adequate model for understanding scientific cognition because there are more cognitive mechanisms involved in understanding heaven and earth than are dreamt of in Gopnik's psychology.

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[1] The books are Gopnik & Meltzoff (1997) and Gopnik et al. (1999). The articles include Gopnik & Wellman (1992), Gopnik & Wellman (1994), Gopnik (1996a) and Gopnik (1996b). For brevity, we will often refer to the views we are criticizing as Gopnik's, but it should be borne in mind that her collaborators share many or all of these views and certainly deserve part of the credit (or blame!) for developing them.

[2] For some objections to Gopnik views on cognitive development in early childhood, see Stich & Nichols (1998).

[3] Locke and Boyle both discussed how people from warmer climates were skeptical of stories about ice. They wished to avoid making similar mistakes. See Shapin (1994) p. 243 and 249.

[4] Shapin makes a very strong case that these were forceful social norms in the 17th century (at least amongst those who had the time and resources for science).

[5] It is also possible that children go about discovering the norms of their society in ways that are quite different from those that an anthropologist would use. Given the importance of norms in human cultures, it is entirely possible that children have special mechanisms whose function is to facilitate the process of norm acquisition, much as they have special mechanisms whose function is to facilitate the acquisition of language. And these mechanisms may play little or no role in anthropologists' attempts to come up with an explicit statement of the norms in the cultures they are studying, just as a linguist's "language acquisition device" plays little or no role in her attempt to come up with an explicit statement of the grammar of the language she is studying. For more on this possibility, see Stich (1993) and Harman (1999).

[6] It is, we think, a remarkable fact, little noted by cognitive scientists, that theories or other knowledge structures which people acquire via cultural transmission and authority can (in some cases at least) be later modified by what are apparently quite different evidence-driven theory revision processes. And if Gopnik is right about the role of evidence in early childhood, then theories acquired via an evidence driven process can also be modified or replaced by cultural transmission.