On the conformity between armchair reasoning and experience: reconciling naturalism and rationalism

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1 Introduction

Kant noted that we come to opinions by a priori reasoning (in advance of experience), which experience then appears to conform to. Reasoning in the armchair leads us to conclusions like 'everything is self identical', which our limited experience seems to bear out (or at least not conflict with), rather than conclusions which it *would* conflict with, like 'everything is lime green'. This fit between, on the one hand, reasoning whose justification does not depend on experience, and, on the other, the subsequent results of experience, can seem quite spooky.

Does this fit show that we're the beneficiaries of some kind of divinely established harmony, which matched our psychology to the relevant facts about the world, even in advance of our having any experiences of the world? Or does it force us to accept some surprising conclusions about the subject matter of armchair reasoning (e.g. mathematics)? One might argue that the desire to solve this problem without positing a pre-established harmony was what prompted Kant's whole radical theory of mathematics a mere artifact of the way the human mind organizes experience.

In this essay, I'll show that no such radical solution is necessary. I'll propose an explanation for why we accept the kind of a priori reasoning which leads us to results that experience then appears to conform to, which is compatible with straightforward realism about mathematics (unlike Kant's account) and naturalism about us.

2 The explanandum: how do we get the kind of mathematical beliefs which don't lead us to build bridges that fall down?

First, let's think a bit about the sense in which our a priori reasoning (in particular, our mathematical beliefs) seems to be 'in conformity with' experience. Call this lack of conflict the practical benign-ness of our mathematical beliefs. Our methods of a priori reasoning are practically benign in the sense that we don't (usually) reason ourselves to the kind of conclusions that lead us to build bridges that fall down, or conclude that all the things we will ever see in the future will be lime green (one can think of false predictions about experience as a kind of practical failure).

Now, this fact that our mathematical beliefs are practically benign isn't just determined by the content of these beliefs. Rather, it's a matter of how these mathematical beliefs fit together with other empirical beliefs, observational practices and dispositions to act on beliefs. For example, suppose I look at a computer and a particular computer program its running, prove that that program leads to an infinite loop if run, and then -in light of these facts- perform some action whose success depends on the computer being tied up for the next 5 minutes (e.g. I might take a bet that the program won't halt in the next 5 minutes).

In this case, my successful behavior can be explained by the combination of a number of different things about me: my eyes allow me to inspect the computer and come to some conclusions about how what program is about to be run, how likely it is to run out of power in the next few minutes etc., my physical theory of computers, electricity etc lets me predict some things about how a computer given that string of key strokes is likely to respond, my mathematical and logical faculties lead me from this belief (the computer will realize such and such an algorithm) to another belief (it won't output an answer) and then my desires and various other beliefs lead me to decide to take the action, and finally this leads to my vocal chords producing the right noises to commit me to the bet.

To sum that up, the practical benign-ness of my mathematical beliefs consists in their combining with the rest of my web of beliefs, and my dispositions to go from sense input to beliefs, and beliefs to actions in a suitable way. How can we have gotten the kind of mathematical beliefs which so combine?

3 A Quinean answer, and three objections to it

Quine has (at least part of) an answer: we revise our beliefs when they lead us to make predictions that fail. If my expectation that the computer would not halt in the next 5 minutes had lead me to expect to not see it spitting out a certain line of text, but then I *did* see it spitting out a certain line of text I would come to revise some of my beliefs, my observational practices or my behaviors in response to observing certain things. If we suppose ourselves and our scientific community to constantly be undergoing such practical testing and revising our beliefs, observational practices, and ways of acting on our beliefs in response to practical failure, this would easily explain how we might wind up with a total system that fits together in such a way as to *not* lead to practical failure.

But wait! Traditionally philosophers have objected that this picture of rational belief revision can't be right since a) mathematical beliefs are not rationally revisable in response to experience in the way scientific beliefs are b) some mathematical principles are specially obvious in ways that no scientific principles c) we find the falsehood of our mathematical beliefs inconceivable. Now I claim that, even if each of these three points is right, **none of these facts undermines the Quinean explanation of how we could have managed to get practically successful beliefs/beliefs that appear to be supported by all future experience**. Thus, we can accept the Quinean explanation of practical success -and hence get the explanatory benefits of Quine's well-known account of mathematics - without accepting the epistemological and psychological claims (there is no a priori knowledge, math is just another branch or science) which people have found so implausible.

4 How to get the Quinean explanation of our having a practically successful mathematics without the Quinean epistemological, phenomenological baggage

Why? Let's start with a) mathematical beliefs are not rationally revisable in response to experience. Now note, all the Quinean explanation above requires is that revisions in mathematical beliefs are causally responsive to the experience of using these beliefs to generate false predictions i.e. recalcitrant experience can reliably **cause** you to change which mathematical beliefs you hold. Now this is indubitably true as regards particular mathematical beliefs. If I calculate in my head that 23+27=41 and then punch this sum into a calculator and get 50 (i.e. not the result that my total web of mathematical and electrical beliefs prompted me to expect), this will prompt me to change some of my beliefs, in particular my mathematical beliefs. And presumably in making this change I am not doing anything irrational. Hearing testimony, or seeing scientific experiments go astray can also send us back to the chalkboard to check our calculations, and thus reliably prompt theory revision.

Is this enough? You might worry that the only way experience can prompt a revision is when we have made what we would (antecedently) have considered a calculating error. But this is not right. Firstly, observations do make people reject certain methods of a priori reasoning as fallatious (e.g. seeing light bend lead people to reject the principle that space necessarily had a certain geometry, and repeated experience with computer simulations of the Monty Haul problem leads people to reject the fallatious but tempting chain of reasoning which leads the conclusion that switching doors can't help). These are cases where people changed their very rules for how to reason a priori (not just see that something was what they would already have recognized as an error had they been more careful).

Secondly, note that the kinds of recalcitrant experience which prompt revision need not look like scientific experiments. They will often happen in the math department. Finding out that a certain set of axioms is inconsistent involves a kind of recalcitrant experience. You expect never to find any string of symbols on paper which you see ends in "0=1" and you check (or your computer checks) line by line to have certain syntactic properties corresponding to being a proof in FOL from the axioms in question. But, one day, you do find yourself seeing such a string. Here the scientific elements in question are quite minimal (you think you/your computer's output co-varies in certain ways with the syntactic properties of the string). And we probably wouldn't count our evidence for these simple scientific claims as part of our justification for believing the string is inconsistent or rejecting the axioms. But this makes no difference to the Quine-style explanation above.

If mathematical principles that lead to practical failure when combined with the rest of our beliefs, observation practices etc. reliably get revised we have our explanation of how we could have gotten mathematical principles that don't lead to practical failures [1]. It doesn't matter what we say about this revision.

Usually we will say that we should have known all along, so that the recalcitrant experience (even if it were causally necessary and sufficient for producing the revision) doesn't figure in the justification for the new beliefs (we have rationally revised our beliefs as a result of recalcitrant experience but not "in response to it"). Now it's easy to see how b) (the special obviousness of some mathematical claims) and c) (the feeling that whatever mathematical claims we accept are necessary truths) don't pose a problem for the Quinean explanation either. So long as mathematical beliefs do get revised when we have certain recalcitrant experiences like seeing an inscription of a proof of contradiction from certain axioms or getting an unexpected output from a calculator (which they clearly do), it doesn't matter whether they have a special phenomenology. The feelings of special certainty and inconceivability of falsehood [2] which once attended the idea that for any property there must be a extension i.e. a set containing all and only the things that have that property in no way prevented us from revising this principle once contradiction was derived.

[We should note here, a simple fallacy which confuses not being ready to revise a belief in response to evidence with thinking it inconceivable that one could encounter evidence which would warrant revising it. If I found a proof of contradiction in ZF I would stop believing it. Thus it's quite clear that there's one kind of experience which I would count as evidence against ZF, namely, seeing a proof of "0=1" from ZF. However, I now do believe ZF and think it's consistent. Hence, I also think the one situation which would prompt me to give up ZF is impossible. Given this, it would be (true but) very misleading for

[1] assuming there were any reasonably simple such principles out there to find

[2] Frege might well have said to himself 'it's just clearly inconceivable that there could be some property that applied to certain things, but no extension containing the things which it applied to'

me to say that no observation could possibly count as evidence against ZF. The observation of seeing a string of inkblots with a certain combination of syntactic properties (namely those which correspond to being a proof of "0=1" from ZF) would be good evidence against it. But, of course, I think there can be no such string so this "observation" is impossible.]

5 Wait, but what about innate inclination towards certain kinds of good mathematical beliefs?

We now have a semi-Quinean explanation for the fact that when you come to some conclusions about math a priori, and them apply them in building bridges the bridges you build tend to stand up. Mathematical principles which lead to bridge-failures (let's say, false predictions about whether you'll see a given bridge fall) get revised just like principles of physics or beliefs about building materials or the reliability of contractors. Mathematical beliefs have lots of special features - they can feel specially obvious, we take them to be necessary truths whose falsehood is inconceivable. And, when we revise them, we don't just form a new the mathematical belief (e.g. 'There is *not* an extension corresponding to every property') but we are also likely to form a new normative belief ('e.g. I shouldn't have ever assumed that there are extensions corresponding to every property, that is a fallacy.') and our notions of what's conceivable (we now find it conceivable that the property of being a property that doesn't belong to it's own extension doesn't have an extension). [In more interesting cases, like that of Euclidean Geometry, we change our whole notion of what descriptions count as *conceiving of* a scenario in which P as opposed to merely describing it]

But there's another kind of objection. This story all takes place at the level of adult language users revising their mathematical beliefs (causally) in response to recalcitrant experience. But what if one could show that some portion of mathematical belief is innate, i.e. that we are somehow inclined to prefer the kind of mathematical beliefs that combine in a practically successful way with the rest of our beliefs *literally in advance of any relevant experience* (e.g. when we are babies)?

There's one worry about simply accepting the above mentioned story about the revisability of logical and mathematical practice in response to experience as a full answer to the our question about the harmony between the conclusions we arrive at in the armchair and experience is that experience **couldn't** correct math. I have tried to argue against this view in this chapter. But another possible worry is that experience **doesn't need to** do much correcting because we seem to have an innate cognitive set up which already steers us towards the kinds of mathematical hypotheses which would conform to experience - and it's inexplicable how we could have got *that*.

So, in the next chapter I'll turn to the question of how one can naturalistically explain our having an innate inclination towards certain kinds of good (experience-matching) logical and mathematical hypotheses rather than others.

6 A nudge from natural selection

We left off in the previous section with a need to account for how little Quinean Revision seems to have to do in getting us to accept good (i.e. experience-matching) logical and mathematical beliefs. We seem to have a kind of nudge in the right direction, even in advance of modifying our views to fit any potentially recalcitrant experience. What do I mean by a nudge? Well, there are two phenomena which it looks like Quinean revision alone might be insufficient to account for.

Firstly, animals and pre-linguistic babies (who can't even pose scientific theories, much less engage in Quinean revision) have something suggestively like mathematical knowledge.

For example, Elizabeth Spelke's preferential looking-time experiments show that, if you put three dolls behind a cover, and then take one away, babies and apes will look much longer if they see 1 or 3 or 4 remaining dolls rather than 2 when you lift the cover. Some people would describe this by saying that the creatures in question know that 3-1=2. (The same results persist when you change the numbers, but fall apart when distinction between numbers greater than 3 is required.) Others, who take there to be a much more intimate relationship between language and thought, would deny that these creatures have any such belief. I won't take a stand on this interpretive issue, because the only thing that matters now is whether we can account for animals and babies doing what they do (call it using mathematical knowledge or not) naturalistically.

Secondly, there are certain kinds of bad (experience-resisting) mathematical theories which (we somehow expect) no one would ever pose. For example, consider the hypothesis 'Addition is symmetric, but only for numbers up to 500, then a+b=b+a+1 whenever either a or b is ¿ 500'. If someone did pose this theory - while engaging in the kinds of ordinary computational practices for computing individual sums which might make us want to attribute the meaning plus to their word '+' - they would run into recalcitrant experiences when doing particular sums like 245+688, and likely either give up this piece of doctrine, or change their algorithm for computing '+' in such a way as to reestablish fit. However, it seems plausible that no one who learned the ordinary addition algorithm would ever even *propose* something like this as a hypothesis. Thus Quinean Revision, can't explain why we don't have the kind of experience-conflicting mathematical theory described above.

To put this second point positively: we seem to have a kind of attraction towards good (experience- matching) logico-mathematical theories in advance of experience and Quinean Revision. I use the word 'nudge' here to stress how weak the phenomenon in question is. It's not as if we are irrevocably hardwired to accept certain mathematical theories (as I argued above history shows that we are quite willing to change mathematical doctrines, and reject arguments that intuitively seemed appealing as fallacious), nor are the kinds of theories that we are drawn to invariably correct (cf. the Waitson card-flipping experiments, and the gambler's fallacy).

Also, it's very important to note, that this inclination to avoid forming bad theories doesn't entail that we are innately inclined to form any *particular* good theory. Compare the claim that *we are innately inclined to prefer they hypothesis that addition is symmetric over the hypothesis that it is not symmetric in the way outlined above* with the claim that *we are innately inclined to believe that addition is symmetric* simpliciter. The former seems very plausible, while the latter is possibly also true but much more controversial. The issue at stake here is just the same as in the following empirical case. Contrast: 'We are innately inclined to prefer the hypothesis that the surface of the international space station is grey all over to the hypothesis that the space station is grey in places where we can see it an pink everywhere else' with 'We are innately inclined to believe that the international space station is grey all over'. It would be crazy to think that we are hardwired to form this (or any) particular belief about the ISS, but not to think that we are innately disposed to prefer the former hypothesis to the latter, *should we wind up forming any beliefs about the ISS at all*.

So, in this chapter I'm going to show how we can naturalistically account for these two phenomena: suggestively mathematical good behavior in babies and animals, and a nudge towards experience-matching mathematical doctrines, even in advance of experience.

7 Accounting for suggestively good mathematical behavior

I'll start with the task of accounting for what I'm calling 'suggestively mathematical good behavior' observed in pre-linguistic (and hence pre-Quinean theory revising) infants and animals (e.g. Spelke's preferential looking times). Personally, it seems obvious to me that there's no philosophical problem in accounting for this kind of well-observed natural phenomenon - why wouldn't evolution be able to build animals with these kinds of practically useful dispositions to behavior?

But for thoroughness, I'll now go through an example story of how this kind of suggestively good mathematical behavior *could* have arisen. I'm only doing this to show that we don't need to posit any kind of spooky faculty of Gödelian concept inspection or platonic recollection of the forms to explain it. There are still interesting questions to be asked about how various animals *actually* got the particular pieces of suggestively mathematical good behavior which they have. But I think we philosophers should be inspired by Hegel's success with deducing the number of planets, and Kant's in deducing the necessary truth of Newtonian Mechanics to leave those questions to the evolutionary biologists and psychologists who will go actually make relevant observations.

7.1 Mathematically-shaped problems + adaptations to solve them

The story starts with mathematical challenges and natural selection's ability to meet them. Nature poses certain kinds of mathematically structured problems.

For example: If you go north for n minutes, then east for m minutes then north again for o minutes west for p minutes, all traveling at a constant speed, what angle do you wind up from home? The Tunesian Desert Ant faces this problem when it needs to go home after foraging in the desert while the wind blows around visually recognizable landmarks. and it's nerve system has evolved to correctly calculate what angle to turn to go home using "deductive reckoning" i.e. the correct trigonometry algorithm.

People and monkeys don't face that problem, but they do face problems like the following. If 2 stable objects like apples or dolls are put behind a curtain and 1 is removed, and then the curtain is raised, how many objects should you expect to see, i.e. when should you spend extra time/energy looking for some aspect of the situation you missed? Also, if Jim always gathers berries according to such and such a pattern, are there places in this berry field which he would systematically miss?

And language-using animals living in communities where everyone has some a priori reasoning ability face challenges where having more (so that you can reason better about what they can vs. can't get using their reasoning) would be helpful e.g. if Jim reasons according to such-and-such logical laws, can he combine pieces of information which he has to discover that both: I have an basket of tasty fruit in my hut, and no one is now guarding the house? (though it may make sense to think about this example more later when we have the story about a nudge towards good logico-mathematical theories on the table)

Now, it's perfectly clear that nature can build nervous systems that realize the right kinds of algorithms to deal with these problems. Since it so happens that, the right kind of algorithm to decide what angle to turn around if you are Tunesian Desert Ant, is also the right algorithm to calculate the angle between the start and end points of a certain path in a nearly Euclidean space, it's clear that nature can build something that realizes that algorithm (at least for a range of suitably small inputs - perhaps the ant would eventually loose track if you made it make thousands of turns). In the case of preferential looking/differential looking times, the needed algorithm ('if you seem to see n Spelke objects added and m taken away, look longer if you see anything other than n-m objects remaining') is much simpler, and it's obviously physically realizable. (Interestingly though, we don't realize that algorithm for slightly larger numbers, but a more permissive one which makes you look longer if you see any number of objects outside of a certain expected *range*. Perhaps this is an adaptation to the fact that we have visual-processing inputs which very reliably co-vary with whether there are 3 things, but which only less reliably co-vary with whether there are, say, 24 things - so it pays not to be too surprised if your optical processing is off by 1 for larger numbers)

And, at least in simple cases like the differential-looking-time behavior, (I take it) there's nothing mysterious about how natural selection could have lead us to the right kind of behavior. The right kinds of algorithm is simple and easy to physically realize, and fact that when you see 1 apple removed from 3 apples leaving you with 1 apple you HAVE missed something generates selective pressure to be disposed to *look for what you've missed in such circumstances* So, we have natural selection for certain kinds of behavior which are suggestively similar to the behaviors which would flow from mathematical knowledge in an adult language speaker.

Now let's add two things.

7.2 Getting more good behavior than you need

First, let's note that something very general about the world (I don't know whether the same thing would apply to any other possible world as well). Often the physically easiest way of building something, which succeeds in a certain desired range of cases, is to build something which can also succeed in a wider range of cases. For example: suppose I give you a home electronics kit and ask you to build a machine that displays the right answer when any one of 1000 different addition problems I give you are punched in. You could build a machine that works like a look-up table and just does that. But it would be cheaper and quicker to build a different kind of machine - a calculator which correctly returns the right answer to *any* sum below the same amount. And the same thing applies even if there's no designer. If you knew that random shaking up of a home electronics kit had produced something that got these 1000 sums right, you'd be surprised if it didn't get other sums right too.

The same thing seems to apply to physical organisms as well. Selection for eyes that could e.g. let us distinguish different kinds of food and predators and whatnot, also gave us eyes that could distinguish different patterns of ink on a page. Selection for reflexes that e.g. help us dodge falling rocks, also gave us reflexes which help us dodge flying tennis balls.

So, it wouldn't be very surprising if it turned out that the Tunesian Desert Ant is able to successfully compute the angle home after trips longer than it ever actually takes in the wild, or if our preferential looking behavior lead us to expect a range of numbers including the right answer even for very large sums.

7.3 From input-output to proto-belief

A very simple creature like the Tunesian Desert Ant's suggestively good mathematical behavior, might just be a matter of always responding to one particular sensory input (e.g. from the legs and the jaws when the pick up food) with one particular behavioral output (turning around). But as we get to more complicated animals, we find that their behavior patterns can interact with one another. So we might imagine a more sophisticated ancestor of the ant which still turns around in accordance with the same algorithm (it might even be realized in a very similar way) but this turning behavior also takes account of:

- multiple sensory inputs (the creature might not rely on this calculation if it's felt itself being blown by the wind, or go home earlier if it sees a predator, or not bother calculating at all if it sees its home)
- internal state inputs (it might go home earlier if it gets too hungry, and there is food stored at home)
- multiple motor outputs (having calculated that home is at angle a, it might go straight home or stop and hide if it has seen a preditor and is in a region where it can camoflauge)
- real time modification to inputs and outputs: if the creature sees an animal which it had previously assumed to be innocuous eat one of its own kind maybe it will 'learn that animal is a predator', in the sense of acquiring the disposition to walk home

Kim Sterelney has proposed how certain kinds of environmental complexity might select for these more complicated behavior patterns [3], but whether or not he's right, surely there's no puzzle about how there could have come to be systems which integrate stored information from different sources like this to determine behavior.

I am calling these internal states with complex relationships to input and output pseudo-beliefs because of their suggestive similarity to beliefs

- multiple sensory inputs: many different observations may be relevant to forming a belief

[3] and I take the helpful terminology above from him

- internal state inputs: feelings of hunger/pain/tiredness etc. may be relevant to forming a belief
- multiple motor outputs: the same belief may lead to different actions depending on what other sensory and internal input you have
- real time modification to inputs and outputs: how you act on a given belief, or when you are willing to form it may change as you come to form other beliefs in response to experience.

We could also think about pre-linguistic-animals as having pseudo-theory-preferences in virtue of being disposed to alter their pseudo-beliefs in some ways rather than others e.g. they will be hesitant to eat melons that smell like melons that made them sick in the past, but not melons that are the same size as melons that made them sick in the past (just like a person who prefers the hypothesis 'all melons that smell like this are sick-making' over 'all melons this size are sick-making').

Let me emphasize here that I'm not suggesting any of these things have psychological reality. I'm just using the most convenient vocabulary we have for describing the complex conditional behavior patterns which even simple animals. All we need for our purposes is that pre-linguistic animals' brains have *some* kind of storage can play this kind of complex role in producing behavior, and that heritable mechanisms influence how this storage is used.

So, a more sophisticated way of dealing with mathematically shaped environments is to form proto-beliefs and proto-belief forming behaviors. Actual differential-looking behavior might be an example of one of these more subtly sensitive behavior patterns: If the monkey is hungry it might look less long at everything. If it has watched the things in question split or fuse frequently in the past, this may gradually decrease difference in looking time when it sees 'the wrong number'.

8 A nudge towards experience-matching theories

So now we see how natural selection could have produced behavior that looks suggestively like that of someone putting their mathematical knowledge to work. The baby looks longer when it sees two dolls added, one removed, and then anything but two left. The adult sees two dolls added, and one removed, forms a bunch of beliefs 'There were two dolls added and then one was removed. If there were 2 dolls behind the curtain at time t0, and only one was removed and no dolls were added or split or fused, there is now one doll behind the curtain. I didn't see any other dolls added or removed, and I don't think dolls spontaneously split and fuse, so I should be very surprised if there were anything other than 2 dolls left!' and then looks longer if he sees anything but 2 dolls.

But there's still an important gap to bridge if we want to explain away our second phenomenon: the nudge towards certain kinds of good (experience-matching) theories. The problem is to see how we can connect up (in a naturalistically acceptable manner) pre-linguistic creatures pseudo-beliefs, with language users' full-on beliefs.

How do heritable tendencies to behave a certain way before learning language wind up correlating with/producing tendencies tendencies to form combinations of beliefs and desires which yield the same patterns of behavior in the language using adult? How, for example, does a baby's liking for grapes (it tends to eat objects that look a certain way x) relate to the the toddler-it-becomes's liking for grapes (it believes that things which look like x are grapes, and it desires to eat grapes)?

Mostly, this is a question for cognitive scientists. For my purposes, it suffices to point out two things. First, it's a constraint on any plausible theory of what genuine beliefs are, that that it should be able to answer this question.

Second, to the extent that there's any intuitive *philosophical* problem about accounting for the fact that grape-liking babies become grape-liking toddlers, this is quite distinct from the intuitive philosophical problem(s) about the fact that experience appears to conform to the results of our armchair reasoning. Thus, I take it that, for my purposes I can simply assume a solution to the grape-grape problem (i.e. a mechanism whereby having pseudo-beliefs can make having corresponding beliefs more likely).

9 Conclusion

Now, putting this all together, we have an overarching story about how we could have managed to get the kinds of beliefs which experience appears to bear out.

Mathematically shaped problems in nature produce creatures suitable behavior patterns. This then leads (in creatures with language) to prefer certain kinds of logico-mathematical theories over others (namely, the ones that would lead to these good behavior patterns). And then (if the creatures wind up having the leisure and inclination to posit general theories) Quinean theory revision irons out the kinks. Where evolution just gave us a fast and frugal heuristic rather than an exceptionlesly accurate law (e.g. inclination to accept the gambler's fallacy, failures at the Wason card-selection task) and this inclination has lead us to propose a theory that conflicts with experience, recalcitrant experience leads us to revise. The end result is that we wind up with the kinds of beliefs about math and logic which experience largely seems to match.

The situation is much the same as with folk-physics. Evolution may have given us, along with other animals the dispositions to (behave like we expect) objects in the world around us to behave in certain ways. Not all these expectations are correct, but there's systematic pressure for us to get physical intuitions that are correct enough, in cases that might have been important in the context of evolution. This innate folk physics then influences what actual physical theories we posit, giving them a nudge in (usually) good directions. Now in the progress of science we test and elaborate these theories, extending them to contexts which would not have been relevant to survival on the savannah and correcting them when they fail.