Chapter 6
Evolution and Logic

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There is more wisdom in your body than in your deepest philosophy. Nietzsche

Biological evolution is perhaps the most revolutionary discovery ever made. For many of us it eliminates questions about our origin which otherwise would have been troubling. During the last decades a deeper understanding of the mechanisms of evolution, like the gene-perspective, has broadened the explanations to include, for instance, altruism and social structures. Edward O. Wilson, one of the leading evolutionary biologists, has even proposed a unification of all knowledge where the social sciences and humanities are integrated with the natural sciences by the theory of biological evolution (Wilson 1998).

But still, does evolution help us in answering the fundamental questions of philosophy like "What can we know?" and "What exists?"; more specifically, can evolution say something about the foundations of mathematics and logic? I will here give some personal thoughts on the subject and for me the starting point is David Hume's sceptical empiricism and in particular his view on causality. Hume's analysis, rather straightforwardly, opens up for an evolutionary understanding of our ability to form causal relations; my view is that very basic logic in a similar way can be given an evolutionary explanation.

Hume gives a restrictive limit for the knowledge we can obtain through direct empirical evidence and hence also a border which will involve metaphysical speculation to pass; and it is mainly on this other side of the border that the foundational questions of mathematics reside. Hume himself did not speculate beyond direct empirical evidence, but Kant's *Copernican revolution* can be seen

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as an answer to the questions asked by Hume's analysis. As has been observed by many people, some already in the nineteenth century, Kant's categories and forms of intuition are very much in coherence with biological evolution.

To connect Hume, evolution, and logic might seem a bit far-fetched from a traditional view on the foundations of mathematics and logic. However, this path is in consonance with philosophy developed in the perspective of biological evolution; I especially want to refer to Michael Ruse's book *Taking Darwin seriously* (Ruse 1986).

6.1 Hume's Analysis of Causality

According to Hume's famous analysis, we have no perceptual evidence for causality:

> Motion in one body is regarded upon impulse as the cause of motion in another. When we consider these objects with utmost attention, we find only that the one body approaches the other; and that the motion of it precedes that of the other, but without any, sensible interval. It is in vain to rack ourselves with farther thought and reflection upon this subject. We can go no farther in considering this particular instance.

Causality has played a crucial role in western philosophy since at least Aristotle. By Hume's analysis we must put that central position in doubt:

> It is a general maxim in philosophy, that whatever begins to exist, must have a cause of existence. This is commonly taken for granted in all reasoning, without any proof given or demanded. It is supposed to be founded on intuition, and to be one of those maxims, which though they may be denied with the lips, it is impossible for men in their hearts really to doubt of. But if we examine this maxim by the idea of knowledge above-explained, we shall discover in it no mark of any such intuitive certainty; but on the contrary shall find, that it is of a nature quite foreign to that species of conviction.

What remains is just that

> All our reasoning concerning causes and effects are deriv'd from nothing but custom; and that belief is more properly an act of the sensitive, than of the cogitative part of our natures.

These quotations are from Hume's *A Treatise of Human Nature* (1739–1740), his magnum opus in philosophy.

Hume's conclusions may be compared to the rationalist Descartes who, a 100 years earlier, begins with even less than what the empirist Hume accepts, *Cogito ergo sum*, but from that derives knowledge about the world. How is that possible? The answer is that Descartes had an absolute belief in the existence of God. He does give a proof of the existence of God, but, as all such proofs, it is not particularly convincing: it is clear that he is constructing an argument for something which for him is obviously true. Once the omnipotent and benevolent God is present, Descartes can proceed to deduce reality. The existence of God was not questioned by any of the rationalist of the seventeenth century, Leibniz even has it among the obvious truths on pair with $1 + 1 = 2$.

Hume had a profound impact on Kant. In the *Prolegomena* (1783) to his *Critique of Pure Reasoning* (1781), Kant writes

> It was Hume that first roused me from a dogmatic slumber of many years, and gave quite a new direction to my researches in the field of speculative philosophy.

and without reservation he accepts Hume's analysis of causality. Kant's *Copernican revolution* in the *Critique* puts the basic concepts space and time inside ourselves. They are forms of intuition and we cannot give them any existence independent of us. We cannot know anything about *Das Ding an sich* which does not exist in space and time and does not enter into causal relations. This radical solution puts causality on pair with time and space as a mean for us to organize the outside world. It is only through our innate forms of intuition that we, according to Kant, can have knowledge of the external world.

Hume's empiricism and scepticism were important to British science in the early nineteenth century. According to his unpublished notebooks, Darwin read Hume "during a month to six weeks" in 1838 during the time when his first ideas on evolution were conceived (Huntley 1972). Another striking example of Hume's influence on opening up for new ideas can be found in a letter by Einstein to Schlick (Einstein 1915):

> You have also correctly seen that this trend of thought was of great influence on my efforts, and specifically E. Mach and still much more Hume, whose treatise on understanding I studied with fervor and admiration shortly before the discovery of the theory of relativity. It is very well possible that without these philosophical studies I would not have arrived at the solution.

Behind these influences is surely Hume's general critical attitude of questioning what might seem obvious. But in the case of at least Kant, the influence is definitely deeper, resulting in a fundamentally new perspective on what can be known.

6.2 Evolutionistic Understanding of Causality

It is obvious that structuring the world by causality is extremely important for survival and that there, hence, must have been a very strong evolutionary pressure to develop this ability; as Ruse expresses it in *Taking Darwin Seriously* (Op. cit., p. 174):

> The world works in a regular way. It is in our biological interests to take note of this, and so as an adaptive response we tend to make something of the regularities. But, as philosophers, we should not try to make more of the regularities than what they are. Causes are projected into the world by us . . . The human who believes in real connections has the biological edge over the human who only sees contingency.

This is reflecting Hume's analysis in an evolutionary perspective. Of course, Hume, who was born almost 100 years before Darwin, cannot have had ideas in this direction, but still he has formulations which can be put in that context (*Treates*):

> Nature, by an absolute and uncountroulable necessity has determin'd us to judge as well as to breathe and feel.

Kant's *Copernican revolution* offers an explanation of causality which is in accordance with evolution in the sense that the explanation in terms of categories and forms of intuition puts the concept inside ourselves as biological beings. An evolutionary interpretation of Kant's ideas was given by Konrad Lorenz in *Kants Lehre vom apriorischen im Lichte gegenwärtiger Biologie* (Lorenz 1941) and it also appears later in *Behind the Mirror* (Lorenz 1973) where he writes (p. 37):

> . . . the categories and modes of perception of man's cognitive apparatus are the natural products of phylogeny and thus adapted to the parameters of external reality in the same way, and for the same reason, as the horse's hooves are adapted to the prairie, or the fish's fins to the water.

Adaption through evolution thus becomes a biological description of the world, in Kant's terminology *Das Ding an sich*. That our cognitive apparatus developed by evolution should give us such a direct, although not complete, image of reality might be looked upon as a rather naïve form of realism.

In Donald T. Campbell's influential paper *Evolutionary epistemology* (Campbell 1974) evolution is understood in a broader sense to not only include biology (p. 413):

> . . . evolution – even in its biological aspects – is a knowledge process, and . . . the natural-selection paradigm for such knowledge increments can be generalized to other epistemic activities, such as learning, thought, and science.

Campbell's view on Kant's connection to evolution focuses on psychology (Op. cit., p. 441):

> The evolutionary perspective is of course at odds with any view of an *ipso facto* necessarily synthetic a priori. But it provides a perspective under which Kant's categories of thought and intuition can be seen as descriptive contribution to psychological epistemology. Though we reject Kant's claim of a necessary a priori for these categories, we can in evolutionary perspective see the categories as highly edited, much tested presumptions, "validated" only as scientific truth is validated, synthetic a posteriori from the point of view of species-history, synthetic and in several way a priori (but not in terms of necessary validity) from the point of view of an individual organism.

Obviously, the forms of intuition have changed during evolution, they must have been very different in the early animals we descend from; in this sense they are a posteriori and not static. But taking the evolutionary perspective seriously and regarding our biology as a prerequisite and frame for our thoughts, then it is the biology of the human species as it is now that is relevant; hence, in our context, we cannot agree with Campbell's statement that evolution is at odds with any necessarily synthetic a priori.

6.3 Evolutionistic Understanding of Logic

As for causality, it is obvious that the ability to perform simple logical reasoning is important for survival. For instance, by *modus ponens* one can retrieve information from earlier experiences when getting into a similar situation, *or-elimination* is case analysis of importance when figuring what is best to do next, etc. Of course, I do not claim that a particular logical system, like Gentzen's *Natural deduction*, is there by evolution; rather that there is some innate capacity for very basic logic. Already a simple argument consisting of more than one step will involve some cognitive activity, and more complex reasoning will certainly need language. I fully agree with Ruse (Op. cit., p. 169):

> My suspicion is that, far from being useless, logic is so necessary and deeply ingrained in our nature that we cannot imagine ourselves thus structure and inform our experiences.

Hume's analysis of causality makes the explanation of causality by evolution rather straightforward, but in the case of logical reasoning it might be less obvious. I think that a reason is that logical truth, since Frege, is often seen as the prime example of analytic truth and hence not in need of any further understanding. But one must not confuse the validity of logic with that of a derivation using logic; in my opinion, the underlying basic logic is not analytic but it is there because of evolution.

If we go back to the early history of logic, there is a connection between causality and rules of logic. Aristotle writes in *Posterior Analytics*:

> We think we have scientific knowledge when we know the cause.
>
> By demonstration I mean a syllogism productive of scientific knowledge.
>
> The premisses must be the causes of the conclusion, better known than it, and prior to it; its causes, since we possess scientific knowledge of a thing only when we know its cause; prior, in order to be causes; antecedently known, this antecedent knowledge being not our mere understanding of the meaning, but knowledge of the fact as well.

I do not want to make too much out of Aristotle's use of the word "cause" in this context, just remark that the cause-effect of the rules of logic might have been more natural for Aristotle with the practical use of logic he had in mind than for us today with our more mathematical and formal perspective on logic.

From the evolutionary point of view, elementary arithmetic is similar to logic; as Ruse puts it (Op. cit., p. 162):

> The proto-human who innately preferred '$2 + 2 = 4$' to '$2 + 2 = 5$' was at a selective advantage over his/her less discriminating cousin.

However, I do not agree entirely with Ruse's formulation here. I believe that very basic properties of arithmetic are in inborn, like the insight that '$1 + 1 = 2$' and not '$= 1$' or '$= 3$', but already to see that '$2 + 2 = 4$' might involve some form reasoning.

Kant considered arithmetical truths to be synthetic a priori which is in accordance with an evolutionary explanation. This is in contrast with his view on logic, which he held to be analytic. So, I deviate here from Kant since the evolutionary explanation of logic entails that logic is synthetic a priori. Basic logic is a fundamental prerequisite for our cognitive abilities and I would claim that basic logic is a form of intuition equally fundamental as time and space.

6.4 Foundations of Mathematics

Given that biological evolution explains why there is mathematics, can it single out any of the different views on the foundations of mathematics as the correct one? I do not think that is the case: although Formalism, Platonism, and Intuitionism have very different explanations of mathematics, it seems to me be possible for a devotee of any of them to argue for an evolutionary origin.

Formalism is rather straightforward: you may accept that mathematics has an evolutionary origin but that the practise of mathematics nevertheless is a formal game. Although I am not an adherent of formalism, my point would here be that the very basic rules of the game, those of logic, are set up by evolution.

Platonism seems to me more difficult to connect to evolution, but even if you have a naïve realistic view that the mathematical objects exist on the same level as material objects and exist independently of us humans, you may perhaps believe in an evolutionary explanation: in the spirit of Lorenz you might argue that our conception of mathematical objects comes from an adaption to the real mathematical world you believe in. I find this hard to imagine, but I already find naïve Platonism in itself a stance difficult to understand.

Intuitionism, however, is more directly coherent with evolution since it puts constructions by us humans in the centre. In Brouwer's writing, there are many references to Kant and time is for Brouwer the basic intuition behind all of mathematics, beginning with the natural and real numbers. But he did not agree with Kant on space because of the discovery of non-Euclidean geometries; in *Intuitionism and Formalism* (Brouwer 1912) he writes (p. 127):

> However weak the position of intuitionism seemed to be after this period of mathematical development; it has recovered by abandoning Kant's apriority of space but adhering more resolutely to the apriority of time.

Space is by Brouwer understood through analytic geometry and, hence, reduced to real numbers and thereby to the intuition of time.

Also Poincaré was inspired by Kant and in *The Value of Science* (Poincaré 1905) he even refers to evolution; selection will favour those that find regularities and have ideals beneficial for their survival (pp. 5, 9):

> [In a world without regularities] there would be no science; perhaps thought and even life would be impossible since evolution could not there develop the preservational instincts.

> . . . is there a play of evolution and natural selection? Have the peoples whose ideal most conformed to their highest interest exterminated the other and taken their place? All pursued their ideals without reference to consequences, but while this quest led some to destruction, to others it gave empire. One is tempted to believe it.

According to Poincaré, mathematics is a cognitive result of evolution because of our search for harmony and regularities. Poincaré is aiming at explaining abstract mathematics holistically, while I am arguing that very basic mathematics, and in particular logic, is a direct consequence of evolution. However, neither Brouwer nor Poincaré paid much attention to logic.

6.5 Martin-Löf Type Theory and the Synthetic A Priori

In the paper *Analytic and synthetic judgements in type theory* (Martin-Löf 1994), Martin-Löf has connected his semantics of type theory to Kant. The judgement that a is an object of type A is, according to Martin-Löf, analytic since "the judgement is evident solely by virtue of the meanings of the terms that occur in it". However, the judgement that the proposition A is true, written $A\ true$, is synthetic a priori since a construction is needed to get an object a of A which makes $A\ true$ evident; for instance, $(A\&B \supset A)\ true$ is synthetic since it comes without a proof (although in this case it is trivial to find one).

Analytical judgements are not the focus of Kant, most of his *Critique* is concerned with the synthetic a priori, and his definition of analytic is confusing. In the *Prolegomena* he says

> Analytical judgments express nothing in the predicate but what has been already actually thought in the concept of the subject, though not so distinctly or with the same (full) consciousness.

but on the same page continues with

> All analytical judgments depend wholly on the law of Contradiction . . . the predicate of an affirmative analytical judgment is already contained in the concept of the subject, of which it cannot be denied without contradiction.

The second characterization may lead to a logical understanding of analytic which is different from the first one, a fact which Frege was well aware of. In *The Foundations of Arithmetic* (Frege 1884) he explicates Kant's second definition and defines analytic as logical truth (p. 4):

> If in carrying out this process [of finding a proof], we come only on general logical laws and on definitions, then the truth is an analytic one, . . . If, however, it is impossible to give the proof without making use of truths which are not of a general logical nature, but belong to the sphere of some special science, then the proposition is a synthetic one.

Martin-Löf's interpretation of analytic is the first one of containment of the subject in the predicate and it is different from Frege's by which all logical truths are analytic. Martin-Löf's understanding of synthetic a priori is also different from the one I am advocating and which comes from the forms of intuition; as Kant expresses it in the *Prolegomena*:

> . . . the intuitions which pure mathematics lays at the foundation of all its cognitions and judgments which appear at once apodictic and necessary are space and time. For mathematics must first have all its concepts in intuition, and pure mathematics in pure intuition, that is, it must construct them.

Hence, according to Kant, mathematics is constructed from the forms of intuition. In the evolutionary interpretation of the forms of intuition, this means that mathematics is there because of evolution. I see the word "intuition" as the important part of Kant's characterisation of mathematics, while Martin-Löf puts emphasis on "construction" which, hence, leads to his view that *A true* is synthetic since a construction is needed to see that the judgement is valid. But I agree with Martin-Löf that formal derivations are analytic, albeit with an underlying evidence which is synthetic a priori.

It is worth mentioning that, in spite of Frege's strong influence on analytic philosophy, Russell in *The Principles of Mathematics* (Russell 1903) considered logic to be synthetic (p. 457):

> Kant never doubted for a moment that the propositions of logic are analytic, whereas he rightly perceived that those of mathematics are synthetic. It has since appeared that logic is just as synthetic as all other kinds of truth; but this is a purely philosophical question, which I shall here pass by.

6.6 Ontology

Accepting Kant's forms of intuition does not mean that you also have to accept his view that *Das ding an sich* exists nor that, if you believe that it exists, we cannot know anything about it.

The idealistic view that *Das ding an sich* does not exist, held by both Fichte and Mach, must be ruled out in an evolutionary perspective since the very idea of biological evolution is adaption to some kind of reality. The opposite view, held by Lorenz, does presuppose a reality which we get to know directly by our adoption to it; ontologically Lorenz agrees with Kant but not epistemically since Kant denies any knowledge of *Das ding an sich*.

Modern physics reveals a reality which in many respects is fundamentally different from our everyday experience of it. The Copenhagen interpretation of quantum mechanics in terms of measurements and probabilities makes it difficult to transfer our macro experiences of how particles behave to elementary particles. Although Hume did not question causality per se but rather the evidence for it, it is clear that in quantum mechanics basic concepts like causality and determinism must be seen in a different perspective than our common sense view of these concepts. Also, the four-dimensional space-time of the theory of relativity is, especially on the cosmic scale, very different from our everyday experience of time and space.

From the evolutionary perspective, it is a striking fact that mathematics is able to describe physics far from the everyday reality we are adopted to. The explanation must be, I guess, that the world functions in a very regular way so

that our cognitive abilities, developed for survival, can be used in domains of no relevance to our adaption. However, one should not exclude that our ever more advanced physical experiments and observations could come to a limit where our logic and mathematics do not function anymore and, hence, also a limit beyond which knowledge is not possible.

Hume's sceptical analysis together with modern physics make me reluctant to make any strong ontological commitments. There is an evolutionary adaption but it is doubtful if it is possible for us to have any knowledge about the nature of what we are adopted to; after all, our cognitive apparatus is there for survival and not for metaphysical knowledge (taking an evolutionary perspective also on this question itself). What we can be sure of are the forms of intuition, although probably not precisely in the way Kant envisioned them, and evolution explains why they are there. This is clearly close to Kant's view of *Das ding an sich* but from a very different point of view.

6.7 Concluding Remarks

I believe that very little, if anything, can be said objectively in metaphysics, in Kant's terminology "der spekulativen Philosophie"; rather, metaphysical stances are inevitably dependent on ones general convictions. The frame of mind of the rationalists of the seventeenth century is the scientific revolution of this period together with the belief of the existence of God. Hume is part of the British empiricism which, together with his scepticism, led to his radical analysis of causality as well as to his reluctance to metaphysical speculation.

Hume's analysis and the explanatory power of evolutionary adaption have convinced me that we possess an innate ability for forming causal relations; and that insight leads me to a similar view on logic. I am not claiming precise knowledge of our innate abilities for logic, I cannot tell whether there is a rule structure or if logic is there in some other way; if we had deeper knowledge about human evolution and how the brain functions, we could say more here. But I do not think that the details, important and interesting as they are, matters for general philosophical conclusions coming from the mindset of biological evolution and Humean scepticism; and in particular not for the conclusion that basic logic is synthetic a priori.

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