Darwins Dangerous Idea

Evolutions and the Meaning of Life

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'Why is there something rather than nothing?'. The question has been framed by every inquisitive child throughout human history, and one may say that a philosopher is an adult who has not stopped asking it[1]. It is of course very hard to conceive of a good answer, let alone come up with one, and most reasonable people eventually dismiss it by simply noting that if there was nothing we could not even frame the question. An answer that is both impeccable as well as unsatisfying. The point is that the question keeps popping up, but in different contexts and guises, and as such may be thought of as the source of all philosophical inquiry, and every philosophical text needs to dip its feet into its river. The philosophical content of Darwinism is simply put an explanation of how out of Order Design can arise. Admittedly this is not quite the same thing as to answer the original question, but it amounts to something similar, namely to show how new phenomena can 'emerge' out of simpler things that do in no way exhibit those very phenomena not even in a rudimentary state. This is what we mean by 'creation', namely the unexpected and mysterious phase-transition, to use a metaphor from physics, that is brought about. The idea that everything manifest on one level somehow has to be present on a lower level, or that every new level is a watered-down version of the old, lies behind the idea of God. God being the prime cause and everything being his creation thus partaking of some spark of his divinity. The axiom being that no being can design anything more complex than itself[2]. Thus the idea that we owe our existence not to God but to Chance is repugnant to most of us, even those of us who would claim it on its rational merits. Yet is it nothing but a play of word? If Chance created us, is not Chance the God for which we have always been seeking? (This incidentally shows that sentences are not mere formal syntactic strings of words, but that we invest words with meanings deeper than our ability to formulate them. Definitions, as Frege taught us, are not mere formalities. To this we will return later.) The purpose of Dennetts book is to persuade the reader that Darwins vision (whose implications incidentally were not fully appreciated by him) is self-sufficient and is in no need of ad-hoc explanations and the invocations of mysterious causes. In fact any such stratagem is an admission of defeat, an intellectual truncation, in the sense of abstaining from running trains of thoughts to their bitter ends. Thinkers who stay short

[1] Heideggers book on Metaphysics starts out with that very question, and inevitably it goes downhill from then on

[2] On the global scale Order decreases or rather Entropy increases (the notion of Entropy being a subtle notion, easy to formulate formally but hard to really grasp meaningfully). Thus Darwinism goes against the grain of the Second Law of Thermodynamics. I believe it was Schrödinger that proposed that what characterized life is the local defiance of that law

of appreciating Darwins idea fully are hence accused of committing a deadly sin, namely sinning against the overriding aesthetic principle of Science - Occam's razor, the principle that exhorts you always to seek the simplest and most economical explanation possible, i.e. with the fewest possible assumptions and the most basic principles of reasoning. To sin against this principle means essentially to espouse the supernatural and to encourage superstition. Thus the polemical thrust of the book is not directed against 'Creationists' and 'Intelligent Designers', those are clearly beyond the pale, but to attack those who are not willing to go that final mile and hence unwittingly give courage and confirmation to Darwinisms most egregious foes. Thus Dennett takes issue with people like Gould, Chomsky and Penrose, men of impeccable scientific credentials.

Dennett is not a scientist but a philosopher. Yet he does not really write like one, even if the philosophy of Darwinism is at the center of the book. His approach is more like that of a journalist, who has not personally taken parts in the fights, but who has had to be content with sitting at the ringside taking notes. His engagement is of course sincere not to say committed, and he has done his home-work diligently and is well-informed; yet he fails in my view to compensate for his scientific inexperience as an evolutionary biologist by offering philosophical insights that you would not gain from reading the original sources, and I am here thinking of the popular books by Dawkins which provides the foundation for Dennetts views[3]. An abstract principle becomes insipid not to say meaningless if remaining in an disembodied shape without being empirically anchored and manifested[4] Thus Darwinism as a principle can never be isolated from its natural context, namely that multifarious organic world around us, which is the ultimate source of all our sensual delights. The scientist who writes on Darwinism is in the position of titillating that very sensuality of the reader by presenting a wealth of intriguing examples, all of which have intrinsic values[5]; while the non-professional is at a disadvantage. Yet although Dennett is unable to philosophically go beyond a Dawkins, he nevertheless manages to provoke enough thought to make the writing of a review like this enjoyable not to say exciting.

When I first heard of Darwins idea I was surprised (and to be honest also a bit jealous) that clever ideas could exist outside mathematics. In a sense Dennetts tenet is that Darwins idea should in fact be viewed as mathematical, or more precisely as an algorithm, the ultimate source for all algorithms, including those which supposedly govern our thinking processes. Dennetts point of departure is that Darwins idea is in the nature of a universal acid, hence incapable of being contained in whatever vessel designed to confine it. Thus Dennett makes up for his lack of biological expertise to steer the discussion into even more intimate realms, namely that of our own thought processes. As such his conception is the ultimate materialism that is manifested in the faith in the possibility of

[3] Predictably Dawkins enthusiastically endorses the book, and has in other contexts praised the work of Dennett as that of a philosopher who has actually taken the trouble to understand what it is all about. In other words to have done his homework.

[4] This statement could be seen as a powerful indictment against pure science devoid of application. This is of course true to some extent, but the issue of pure against applied is more complicated and subtle, once again confirming that an abstract principle needs to be concretly articulated before it makes sense.

[5] This is why the essays of Gould used to be a delight to read before his overblown estimate of himself as a literay essaist caused those to degenerate into mere verbiage

strong AI, in other words that the workings of the mind cannot only be simulated but actually implemented on a sufficiently powerful computer run by a sufficiently powerful and clever algorithm. This is a conception most of us take instinctive exception to, being if anything reductionism *par excellence*. Yet, as I have noted above, materialism really amounts to the idea of building up the world and our conception of it from scratch, to climb the ladder of consequetive emergence of new phenomena, eventually leading up to our minds. A materialist does not deny the existence of moral values, intelligently guided design, emotions and meaning, phenomena that occur to us as irreducible; nor does he or she claim that there is no mystery involved, on the contrary after all each rung of the ladder involves an inexplicable emergence, only that it provides a rational appreciation of why things are the way they are, allowing systematic inquiry, also known as the scientific method, to get a purchase. Idealism on the other hand takes our own mind and its irreducible features as given, and creates matter out of mind, rather than the other way[6]. So while materialism can be thought of as a 'bottom-up' approach, idealism should be seen as 'top-down'. What tack to take is to some extent a matter of temperament and few people, as William James notes[7], are able or willing to commit themselves to a consistent stand, but usually verve from the one to the other. The purpose of this review is to present the materialistic aspect of Darwinism in a fair and consistent way, inspired by the efforts of the author.

The question Darwin addresses and answers is how Design can be created out of mere Order. The answer is essentially one of bootstrapping, eschewing the classical cop-out of positing a Designer, incidentally the strongest argument ever designed for the existence of God, and thus the most common appeal to religious faith based on rational thinking. The fallacy of such an elegant solution is that it does not really explain anything, it replaces one mystery with something even greater. And while we can study and ponder the natural world, we cannot study God, who by definition is inaccessible to us. The idea of a God is not falsiable, but that does not mean that he exists, what it means is that Science, as an activity that mixes rational thought with empirical confrontation, simply cannot get off ground with a deistic explanation. This is what makes Darwins idea so seductive to the rational mind adhering as it does to the overriding aesthetic principle of scientific explanation - Occams razor alluded to above[8]. So far I have not even formulated it, partly because most readers are familiar with it, but essentially because ideas cannot really be succinctly formulated, in fact their formulations emerge slowly as they prove themselves by being made to work in different contexts. This is why Darwin needed a book to make his argument, in its succinct form it is almost a tautology to the effect that those that survive and prevail will survive and prevail, at least for the time being. Hence a book on Darwinism must spend as much time on what Darwinism is not about, explaining the deep misunderstandings inherent in classical vulgarizations as exemplified by Spencers 'Survival of the fittest' to which we will presently return. Darwins ideas did not arise in a vaccuum. First and foremost

[6] We all know Schillers dictum *Es ist der Geist der sich den Körper baut*

[7] In his philosophical work on Pragmatism elsewhere reviewed

[8] In mathematics it takes the form of trying to reduce the number of irreducible statements (axioms and postulates) to a minimum, and thus responsible among other things for the discovery of Hyperbolic Geometry.

Darwin did not discover evolution, the empirical evidence for a transmutation of species had been amply documented, mostly by French paleontologists during the 18th century, and notable efforts of explanations for the process had been proposed by Lamarck already at the beginning of the 19th century[9]. Secondly a materialistic explanation of the Universe was clearly established by the beginning of the 18th century, and may be thought of as the impetus for the Enlightment. I am of course thinking of Newtons Celestial Mechanics that did away with God, except possibly as a first Mover, reducing his handiwork to a few simple principles, and ultimately reducing the Universe to the solutions of an equation. Famous are the words of Laplace to the effect that a sufficiently powerful intelligence able to hold all the data of the positions and velocities of all the particles in the Universe would be able to know in an instant all of the future as well as the past. The philosophical implication being of course that everything was preordained and that the notion of a free will was an illusion[10]. This philosophical conclusion has not really been refuted by Modern physics and it remains along with Consciousness one of the greatest conceptual obstacles to a truly materialistic explanation of every phenomenon in the world of which we are aware. Still the predictability in principle of everything is not feasible and thus it has no real implications, unlike Darwinism, to the mundane problems of daily life. But as noted Newton had a profound influence on thinkers during the 18th century trying to apply his elegant principles not only to the Celestial world but the mundane social worlds as well[11], one example being the economic world. Adam Smiths idea of the invisible hand to the effect that if everybody only looked out for themselves and their interests they would contribute much more to the general welfare of society than if they did try to do so explicitly[12], obviously anticipates one of the salient features of Darwinism, namely the local nature of change and the total lack of foresight usually refered metaphorically as blindness. The idea of change coming about by very small step each being able to be executed in isolation lies behind the idea of refering to it as an algorithm, an algorithm being a set of rules whose implementation requires no aforethought, in fact no intelligence at all. However Darwin differs from Adam Smith in one important aspect, namely that there is no value judgement, there is no sense to the notion of a general welfare of Nature. Other basic features of economics such as the equilibrium between supply and demand that can be traced back to late medieval times clearly predates applications of game-theory and self-regulating systems so crucial to the idea of adaptation. One particular economic thinker

[9] Lamarck has been unfairly disparaged, and Dennett does not entirely avoid the pitfall either. But such disparagement is anachronistic. Lamarck was no Creationist but a proto-Darwinian, and his efforts should not be confused with the regressions perpetrated by charlatans like Lysenko. Once the shortcomings of a theory has been exposed there is no turning back; but the judgement of hindsight is an unfair one when applied in a historical context.

[10] In the Paradigm of modern Quantum theory the notion of simultaneously knowing position and velocity (more precisely momentum) is an illusion. Also it does contain large elements of chance, at least in its popular presentations, in spite of the fact that it remains one of the best predictable theories around, this being why it evolved in the first place!

[11] Hobbes in the 17th century was a pioneer, probably uninfluenced by Newton.

[12] The point being that it is much easier to assess your own interests and how they should be furthered, then to identify the interests of Society at large let alone to figure out how to implement them

specifically influenced Darwin, an influence explicitly acknowledged by Darwin himself, namely Malthus. His idea of the growth of populations quickly outstripping available resources necessitating a drastic culling set Darwin on the right track. In fact the contrast between geometric growth (or exponential as we say nowadays) and arithmetic (linear) lies at the heart of Darwinism and can be vividly illustrated by configuration spaces, where the 'exponential' describes the potential and the 'linear' the actual, the former playing the role of virtual infinity. Configuration spaces are common in physics and the first literary (and no doubt independant) use of this is due to Borges and his Library of Babel[13] The core of Darwins insight is not that the fittest survive pace Spencer[14] but the production of variety on which (Natural) selection acts. Variety is much more than there is physical space for, thus selection has to be exacting. One should think of Natural selection as a Sieve. It lets through the small grains of sand ending up with a pile of such. Those grain of sands are not small because they made themselves small in order to pass through the sieve (the notion of Lamarck) because what would the point of this be? but because they were small from the start. In the same way if you shoot through a narrow tube, the bullets which will exit will all adher to a strict direction, not because of any volition on their part, but because you would not see them otherwise[15]. Darwins theory was incomplete at the time he presented it, because it rests on a very basic principle, namely the conservatism of inheritance. Descendants resemble their parents[16]. Darwin had no idea of its mechanism, the full-fledged theory had to wait until the rediscovery of Mendels idea of genes[17] As noted above, Darwins principles disembodied from an empirical context, means very little, and as such they had been prefigured[18]. What distinguished Darwin from the philosophers was his intimate familiarity with all the intricacies of the natural world. His principles furnished a purpose, namely to order and make intelligble the embarrasment of riches

[13] Or so I believe. I became very fond of this story when I first encountered it and it has quite a lot of potential, so although Dennett uses it a lot, and variations of it, he does not milk it for all its worth.

[14] First it is not always true, and secondly what do we really mean by 'fit'? Those that survive? if so, the notion is circular. And if the fittest always survive why worry about it?

[15] assuming that the walls of the tube are absorbing

[16] not absolutely of course, that became no longer true by the advent of sexual reproduction

[17] Mendel had of course no idea of the actual biology of genes but the concept, like so many concepts in Science did exist before it was found and identified as such. Another example being the atom, admittedly only a pure speculation by pioneering Greek materialists. Atoms were prophesized as indivisble objects of matter, thus making the claim that the Greeks thought the Atom indivisible but we know better so unconsciously absurd. As with all abstract principles in modern science and philosophy they have pure forms which can be traced to the Ancients. The point, repeatedly made in the essay, being that they suffer from the lack of empirical manifestation.

[18] Dennett refers especially to a Dialogue by Hume in which one of the protagonists gets very close to presenting an argument of Design out of mere Order, but Hume backed off at the last moment, presumably because he thought of his speculations as being too fanciful and insubstantial. Once again a case of a lack of empirical input. Also as Darwin presented his theory people wrote to him and explained that they had indeed thought of it before. In a sense there is no reason to doubt their claims, but the point once again is that ideas not anchored to an empirical reality are just figments of the imagination residing in the never-never land of clouds.

available to the senses. Thus Darwinism is more of a paradigm really than a well-defined theory which can be put to some crucial tests. It provides questions to be asked and suggest directions to pursue, and its ultimate confirmation lies in its success in harmonizing and explaining. But it has implications far less abstract than its general formulations, and it is those implications that were responsible for the furor it caused. Recall that Dennetts point is that Darwinism has implications not only to biology, that it is indeed like a universal acid burning through any container into which it is vainly imprisoned.

The immediate consequence of Darwinism at its time was the abolition of the notion of a species as an absolute entity going back to the classification schemes of Aristotle invoking the notion of essence[19]. In fact evolution posits the universal family-tree in which every living thing is connected. This threatens, as people were quick to realise, to do away with any notion that humans are at least biologically apart from other living things (and if not biologically separate in what sense really separate?). Given any two living things they can in principle be connected with a chain of beings (in general necessitating going back in time) each link connecting very close organisms making it impossible to draw clear demarcation lines between species. Yet, although the notion of species ultimately has no basis, in practice it tends to exist, the pragmatic notion being that populations that can interbreed and form fertile offsprings belong to the same species[20]. Any decomposition of a set into mutually disjoint subsets is mathematically equivalent to a so called equivalence relationship. Reflexivity and symmetry present no problems, but transitivity does, as the universal family tree illustrates[21] The universal family tree is an explicit example of a research project inspired by Darwinism and not obviously derivable from the abstract principle itself only in its empirical implementation. To derive the family tree is quite another matter as the fossile record is spotty[22] something Darwin stressed.[23]

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[19] Members of a class may show many individual quirks but they share an essence, whose nature could be quite abstract. What is really the difference between a chair and a table? One solution to the problem of identifying essences is the Platonistic idea of a heaven of forms, which in this context appears somewhat comical. One should not confuse the idea of Platonism in its mundane applications with the idea of Platonism as it makes sense in mathematics, but this is clearly too big an issue to be fitted into a mere footnote

[20] The biologist Ernst Mayr worked in New Guinea and observed that the classification of species of local fauna and flora by the indigenous populations did essentially coincide with the scientific. There is a general philosophical consensus that verdicts brought about independantly must be based on some intrinsic properties, but what are those intrinsic properties really?

[21] One needs not go back in time, one can very well imagine a sequence of overlapping and interbreedding populations whose extreme elements do not. One actual example is a species of tarns that circumscribe the arctic regions. Going one revolution around the North Pole there is no longer the option. A beautiful example of Monodromy in Zoology.

[22] The fossile record does not only involve that of first order, namely actual remains of dead organisms, but also second order classically derived from the phenotypes and in more recent years microbiologically so as well as from the genotype itself, i.e. the DNA

[23] One may be struck with the analogy with the Heliocentric theory which would predict parallax but none was (at the time) discernable leading to Copernicus rejoinder that the stars were simply so far away.

> The notion of a family tree has to be taken with a grain of salt. On the very finest level, that of individuals, we are not talking about a tree as there are plenty of cycles, it is only on the level of species there is branching with no occuring reconnection. But as we have noted above, the notion of species is a fuzzy one, but its significance is nevertheless important in biology, mainly because of the tree-structure it defines. Now on the basis of the tree we can ask and answer many questions purely mathematically, i.e. by pure thinking. Yet Dennetts derivation of a unique Eve the ancient mother of all of us is fallacious in its incompleteness. Dennetts argument is simply consider all the people alive today, then their mothers, and then the mothers of that set and inductively. The cardinalities of those set are monotonically decreasing but that does not mean necessarily that we arrive at a first instance of a singleton, the common ancestor of us all on the purely maternal line. One could as well conceive of say two parrallel lines of female descendants going very far back in evolution, in particular not being human. To exclude this strange possibility you need further input from evolution. It would be unlikely that those two lines of descent would diverge into different species, a sufficient condition of being cospecies being having common cospecious descendants. From a mathematical point of view humans could form two disjoint groups that never interbreed, each of them having different lines of descendants. Statistical sampling makes such a hypothesis extremly unlikely, even racially divergent people have no problem breeding. The possibility that two lines would exhibit such striking convergence is rejected, ultimately on statistical grounds. This does not exclude the fact that widely seperate lingeages can display striking similarities, known as anologous traits as opposed to homologous. Such phenomena have traditionally bedeviled the work of classification.

One particular implication is that there is a 'continous' transformation from the lowliest of organisms to man, and thus that all his higher faculties, supposedly setting him apart from the animals, should in principle be algorithmically derivable from scratch, including his intelligence and moral sense. It is fair to say that in this lies the bitterest and most desperate opposition towards Darwinism. In particular while most educated people do not question the Universal Tree of Life, most of us take instinctive exception to the notion that our intelligence, or even more outrageous, our very consciousness should be the outcome of mechanical computations. Dennett is not set to defend Darwinism in its purely biological setting (this has been done over and over again and is a fairly uncontroversial task) but to argue that it does imply AI, and to deny this would be to take refuge in sentimentalism invoking supernatural phenomena[24]. Now the question of the supernatural, briefly alluded to in the introductory passage is a thorny philosophical one. There are a few irreducible facets of the modern world-view, irreducible in the sense that they cannot be reduced to other components. Thus a facet irreducible with respect to others may very well be seen as miracolous. The strong nuclear force is not a consequence of gravitation, and in world view such as that of Laplace its existence must be seen as indeed miracolous, and any explanation using it consequently seen as a supernatural one[25]. In one sense there is a

[24] Using the metaphors of Dennett involving 'skyhooks' with no ultimate terrestial support as opposed to 'cranes', to distinguish between the 'greedy' reductionists, like Skinner, who do not even believe in 'cranes' as opposed to enlightened ones (like Dennett?) who merely oppose 'skyhooks'

[25] In a smilar vein few children are fascinated by gravitation, they take it in stride as the most natural thing, while few can resist being struck by magnetism, which indeed seems like magic.

certain arrogance in claiming that all the laws of nature have been found, but one should always be very weary of additional invocations, the frivolous introduction of which adds more confusion than illumination. So let us now focus on the notion of an algorithm from the view of a mathematician.

An algorithm can be very simple, yet its consequences very surprising and difficult to understand. Mathematics abound in algorithms. Long division producing periodic decimal (or whatever) expansions of rationals, is a very elementary one; yet its output seems chaotic and not *a priori* understandable. Erasthones sieve producing primes, is another very simple algorithm, but the distribution of primes, which is one of its consequences (in fact its whole purpose from a human point of view) is a very stubtle matter involving some of the deepest insights of mathematics involving algorithms far more subtle than the original. The point is that the simplest of deterministic procedures can create mysteries beyond the full comprehension of man. Thus the algorithmic nature of natural selection does in no way deter from the unfathomable mystery of the creation of life-forms, only suggests avenues of inquiry. But is it really an algorithm? Dennett dismisses Penrose argument against it by virtue of Gödels Theorem. I must admit that when I read Penrose diatribe against the strong claims of AI (the essence of which is the possibility of downloading a human brain in a sufficiently large computer based on the idea that its working can be perfectly simulated by an algorithm) I did not find myself very impressed, although I was very sympathetic to his mission[26], because in what way did it differ from the spontaneous response of the proverbial man in the street, exclaiming that how could a computer have his sense of humor or his emotional depth? Also the basic assumption in the proof of Gödel is the ability of the mathematician to simply imagine (countable) infinity being ticked off one by one, something that is denied the computer[27]. The point is that the algorithmic nature of Natural selection is really nothing more than a figure of speech[28]. As long as it is not being pinned down in any mathematical precise sense it will be impervious to the kind of contradictions brought about by self-reference and the diagonal principle (which somewhat fancifully can be seen as the manifestation of free will). Natural selection is a paradigm of thought, it is a process notoriously difficult to predict in advance if seductively easy to explain by hindsight[29] Yet of course its nature positively invites computer simulations extensive enough to sprout another sub-discipline - artificial life[30].

That complexity can arise out of simple rules is a well-known yet striking phenomenon

[26] This brings to mind an observaton due to Maynard Smith and relayed by Dennett, to the effect that those people who praise Penrose book the most are also those who do not understand him, only revelling in the support given to their misgivings by an authority whose scientific credentials are beyond doubt.

[27] Admittedly Penrose also adduced additional arguments to do with the unpredictability of quantum theory, the details of which I never got, to upset a deterministic process

[28] A metaphor whose purpose is to evoke rather than to explain, thus most metaphors when pushed beyond their proper domains degenerate into mere silliness

[29] the abuses of which - just so stories, are legio, and the butt of the criticism by Gould and Lewontine.

[30] Dennett (as to be expected by a buddy of Hofstader) is an enthusiastic user of the computer and reports to his mild consternation that Gould does not even use a word-processor but seems content to write his papers in the old-fashioned way. 'Algorithmically' inclined biologists like Dawkins are also computer afficionadoes stessing the ultimate nature of biology as being about engineering and information processing

amply illustrated on the computer. The first well-advertised effort is the Game of Life invented and marketed by Conway and his students. The rules, the exact nature of which needs not concern us, are very simple, yet as many other simple mathematical algorithms iy generates fascinating complexity, achieving a critical mass of which allowing for an inductive process. By that I mean that on a first level it produces phenomeno like self-regulating configurations, which in their turn can be used as building blocks for a new level of phenomena. In particular many structures like algorithms can be embedded in the system, which hence can be used for simulations of algorithms running on a computer. In other words the computer is simulating itself. Simple as the rules of the Game of Life are, the finding of them was not simple but the result of much experimenting about which rules are the most fruitful[31] efforts invisible in the rules themselves only indirectly manifested in their subsequent applications.

What is creativity? Who was most 'creative' Shakespeare or Newton? Or differently put, if we had to abandon the works of either, which ones would we most willingly send to oblivion? The manifestation of the minds of either Shakespeare or Newton can be codified into books, each one in a formal sense being nothing than a string of symbols[32]. In a sense all books exist as being combinations of letters, by restricting the lengths of the books and the alphabets employed, we can easily derive the exact numbers of such objects, and surely you can only count objects that 'exist'. This suggests a simple and fool-proof algorithm for producing all possible books, you simply write down the numbers systematically, each number being coded into a text[33] What is wrong with such an approach? Surely it will yield all combinations. As Mozart said, all music exists it is only a matter of writing it down[34]. Yes it is an algorithm, each step is done mindlessly, and thus in principle the proverbial monkey could have written Hamlet simply by pressing the right kind of keys on the computer[35] as there are no physical constraints on it stringing those very strings of letters along, just as the copyist of the text experiences no obstructions. But of course the meaning of the text does not reside in the text itself only in the reader who plays

[31] A systematic account of such can be found in the works of Wolfram and his cellular automata, in which he incidentally makes outrageous claims succumbing to the seductions inherent in the reductionistic approach.

[32] This being most drastically illustrated in the case of Shakespeare as his texts are essentially the only things through which we know of him. In fact in the absence of additional information, it is *a priori* not obvious that those different texts can be attributed to a single author, a fact that has inspired many crack-pots to come up with theories, the gist of most being that the plays by Shakespeare were not written by Shakespeare but by one who called himself 'Shakespeare'.

[33] The particulars are very simple. Instead of using base ten you use a base encoded by the alphabet, to make it very simple, write down the numbers systematically, and consider the digits two by two, each pair coding for one of hundred different letters, including upper and lower case, spaces, parenthesis, punctation marks, special letters and whatever you would like to throw in.

[34] This statement relayed by our music teacher at school was the one that made the deepest impact on me during music lessons. He would probably have forgotten it, but to me it was an exciting idea preparing me for Borges tale some ten years later.

[35] In former times those monkeys were all banging at typewriters having to change the paper all the time, now they have been relieved of such distractions.

the role of God and Selector. Now as a practical algorithm this is unfeasible, the numbers involved, although easy to compute are simply unimaginable large[36] and for all intents and purposes infinite. The set of all possible books is an example of a configuration of possible or potential objects, which do exist in a well-defined abstract sense, but not as physical objects to be held in your hand and pondered. While the books you actually read, or which eventually will be written and read, constitute a vanishing[37] subset of the potential. The feasibly algorithm is the one that selects the exciting and meaningful, and it is in this sense we can make a difference between the works of Newton and those of Shakespeare. The difference is an essential one and to which we will return and elabourate.

In Darwinism (as opposed to Lamarckism) there is an essential difference between the geneotype and the phenotype. It is the geneotype that is passed on to succeeding generations (with minor modifications due to mutations) and it is the fitness of the phenotype that decides how succesful those transmissions are. The vulgar simplified version that are taught to the general public is that the geneotype determines the phenotype, in fact acts like a program whose output is the phenotype. The image of a compactly encoded instruction to be unfolded is powerful and suggestive and like all illuminating image it contains a large core of truth, but in biology as opposed to mathematics, there is always fuzz at the edges. The embryological development through which the unfolding occurs is probably among the least understood processes of modern biology. The process does not only entail instructions from the genes, which to start out with are very indirect, but is also driven by other principles. The phenomenon of conjoined twins exhibit intricate solutions involving shared organs, solutions which in no way are encoded genetically[38]. In addition to the transmission of genetic material, there are a hoist of other features that provide continuity between parent and progeny. There is in addition to the regular DNA also the mitochondrical carried along purely maternal lines; furthermore each organism carries with it a hoist of other organisms, mostly bacterial, which stand in a symbiotic relationship to their host. In the case of 'higher' animals also cultural features enter the picture. Thus even if ancient DNA from extinct species (say dinosaurs) could be retrieved and unfolded this does not mean that viable organisms would be produced. Once a lineage has been terminated it is essentially impossible to recreate it. Thus, contrary to intriguing anecdotes, it is not clear whether humans reared in the wild (i.e. bereft of basic culture) would survive. But neglecting those details we may resort to a refinement of the metaphor of the Library of Borges and consider the Mendelian library which consists of DNA sequences. While the meaning of a book resided externally in a reader, the meaning of a DNA sequence, reside in the 'fitness' of its phenotype, which can be thought of as

[36] Not to be taken literally of course we have just imagined them, and we can easily write them down given the right notation. But there is a difference between saying to somebody that I am thinking of all your thoughts or that I am thinking all your thoughts, the first is an example of the kind of abstraction so common in mathematical reasonings, and to which thought itself so naturally invites: the second is a reference to an actual act as opposed to thought and is as such far more difficult to carry through.

[37] Or in the terminology of the author a Vanishing

[38] A majority of conceptions end in misscarraige, often before the woman becomes aware of it. Obviously some of those miscarriages may be due to genetic defects, but whether they actually constitute a majority or whether the mishaps are instead mainly due to external embryological disturbances I do not know

algorithmically derived from the genetic sequence. Some sequences are 'fitter' than others and it is tempting to posit a fitnesslandscape on the configuration space, and consider Natural selection essentially as being an efficient algorithm to navigate skillfully seeking out fitter and fitter sequences, essentially by gradient flow in the configuration space. The situation is of course very complicated as there is no separation between sequences and the environment in which their corresponding phenotypes dwell, in fact the very latter changes the environment for all other organisms. Yet it suffices to describe the basic feature of natural selection as gradual incremental change profiting from conservatism and continuity, meaning that small changes from fit sequences do not result in significant loss of fitness[39]. Without this fact natural selection simply would not work and the abstract principle of the fittest survive would have no meaning unless the tacit assumption of its essential hereditary would not be true. This algorithm is indeed slow if systematic and it ensures that the search tree is indeed connected as manifested by the Universal Tree of Life. There is no such thing as a random configuration of genes, each configuration is the result of large numbers of sieves. We have not been produced by pure change, the odds against such random occurences[40] are in fact overwhelming as even the Creationists appreciate. This has testable consequences, first evolution demands time, how much time is not *a priori* clear and clearly not computable from first principles; yet the stability of species over historical time clearly indicated that the time-spans would have to be very long, hence Darwin was alarmed by the estimates performed by the physicists in the late 19th century[41]. Furthermore any 'designed' feature of an organism has to be the result of adaptation through a connected sequence of intermediate stages each giving a selective advantage. Such explanations are not always easy to come with, the intricate working of say the veretebrate eye, in which each facet seems dependant upon the rest and worthless in isolation. However, absence of evidence is not evidence of absence, and the lack of human imagination does not always imply impossibility. Nowadays with Darwinisms so deeply entranched the burden of proof has shifted. Continuity is taken for granted, the challenge is to exhibit it[42]. The case of the eye is interesting as it provides a problem that has, like flight, been solved repeatedly during evolution, and the convergence between the vertebrate eye and that of the Octapus - a 'mere' mollusc, is striking[43]. This leads to one of the more fascinating aspects of evolution, namely the tension between the drift and the 'forced move'. Some solutions are equivalent and the one evolution will happen to choose is a matter of pure chance, other problems come up against constraints, forcing their searches for solutions into narrow grooves. Thus evolution exhibits both divergence

[39] some small changes may of course have catastrophic effects, but in general they do not, this is why most children turn out fit profiting from the fitness of their parents

[40] hopeful monsters in the terminology of Dennett

[41] No known process, including gravitational collapse, could account at the time for the sustained energy output of the sun necessary for a long-term evolution, something miracolous was clearly needed. The 'miracle' turned out to be nuclear energy, the conversion of matter into energy, that was discovered in the decades to come.

[42] There is a difference between solving a problem you know has a solution and one of whose solution you despair

[43] This is one of the facts in Feynmans Lectures on Physics I recall most vividly

as well as convergence. Many evolutionaries, Gould being one prime example, stress divergence and the fact that evolution has neither goals nor agendas, while the opposite camp, mostly consisting of outsiders, tend to overestimate the forces of inevitability and hence see Man as a logical outcome (conclusion?) of evolution and in particular sanguine in their expectations of extra-terrestial intelligence. In his book 'Wonderful Life' Gould exalts in the diversity of life present at the early Cambrian period as preserved in the Burgess shales. His point is that evolution makes arbitrary decisions and once entered upon a certain path there simply is no going back, exactly as in history at large or at an individual level[44]. Evolution is flexible, but ones a 'Bauplan' has been set it is very difficult, if at all impossible, to stray from it[45]. Thus the bisymmetry of most advanced animals seems so basic that it is hard to imagine how it could ever be evolved away. The idea of convergence means on the other hand that some regions of the Mendelian landscape are natural sinks in which evolution repeatedly will find itself. Thus while the accidental gets irretrivably lost the logical is bound to be rediscovered eventually. This provides a solution to the question posed before. What would be worse to lose the works of Shakespeare or those of Newton? Hamlet or Principia? The argument goes that if Hamlet was lost it would never be regained, but the discoveries of Newton would be bound to be made sooner or later. Had Hamlet never been written no one would have missed it, on the other hand had Principia not survived we might feel its absence, yet we think of the former as being more precious. It is the same with your own personal memories, you are attached to them in a sense you cannot be attached to general memories, as once they are lost, they will be lost for ever, while culturally shared memories belong to everyone and are hence far less perishable. Of course from a wider perspective human cultures are but accidental manifestations which in the universal perspective of evolution do not differ from the idiosyncracies of our own personal lives. It all boils down to the difference between the actual and the potential. That which is only accidentally actual is far more precarious than that which is not, the latter having a far more robust existence. The world is a mixture of the accidental and the forced, and without the former it would be a barren place indeed, and in fact the latter would not be manifestable without it. The complexities of the Natural World is indeed a wonderful thing to contemplate, but without conscious intelligences to do so, it appears meaningless and shadowy.

As noted above one cannot predict evolution in the same way as one cannot predict history. On the other hand, just as with history, it does not prevent you from explaining it retrospectively. And just as with history it is very easy, and hence tempting, to come up with impressive and convincing chains of arguments. Darwinism has an advantage over history as its basic tenets gives to natural history a purpose, not an intrinsic one, but one helpful to its study; while no one has so far come up with any equally helpful paradigms as

[44] The fact that you were born at all is a highly contingent fact that minute changes in the past would have prevented, also known as the Butterfly effect and first stated by Poincaré. The same goes of course for the particulars of your own life, thus twin studies of identical twins who have been separated are so fascinating.

[45] I was first alerted to this notion reading a book by the Finnish paleontologist Kurtén on the age of mammals. He pointed out that the horse had entered an evolutionary *cul de sac* and could evolve to nothing more than a 'more horse'. While humans still retained a lot of evolutionary flexibility.

to the study of human history[46]. The crucial question to ask about any feature is its role as an adaptation. However natural history may be finely grained, yet it is still granular. Unlike the case of statistical mechanics, the numbers involved are not so large nor are the observations to make so simple as to allow the statistical laws of large numbers even everything out to iron-clad laws. In many ways it is a Panglossian phenomenon, but not so on the finer scales. There have been just so much time for so many experiments to have been performed. First and foremost a phenotype exhibits many features, in fact too many features to make a one-to-one correspondence between the genetic information available and the the actual structure of the organism. The neurological wiring of the brain is one example that is not governed in its tiny details by the genes, nor the information in the immune system. It is now assumed that those details have been formed by micro-Darwinian processes. But there are lots of other features that are genetically determined but have no direct value of adaptation but just hike a free ride. One silly example, silly to illustrate the silliness of the assumption, is that elephants have more eyes than tails. What would be the adaptive value of that? Hence in order to make a convincing story of adaptation one has to exercise great caution[47]. Some features are very central, others are of the second, third or fourth order so to speak, and thus too subtle to be subject to direct selection pressures. There is also a strong tendency to read into natural selection a purpose, any feature is there for a reason so to speak, i.e. an adaptational one. But as Gould points out some features just happen to be there accidentally as byproducts of other adaptations. They may linger on and then suddenly be exploited by evolution. Gould refers to them as exaptions, and takes as an illustration spandrels in medieval architecture. And finally on what level does natural selection operate? On the species (and recall this is a notion fuzzy at the edges)? On the individual? Or as Dawkins radically suggested on the level of genes? Now the latter can be made into a tautology, as needless to remark, features are not caused by single genes, but combinations thereof, and the fitness of an individual is not a mere sum of the fitnesses of its individual genes, but fitness is an emergent phenomenon. True though that genes that propagate quickly tend to predominate. One would then be tempted to conclude that those aggressively 'selfish-genes' might eventually take over all evolution dismounting the complexities that have so far developed. In principle this is not impossible, there is no purpose to evolution (a lesson that cannot be emphasized too often), at least no long-range, and it does not always lead to greater complexity as the developement of parasites illustrates, their niches being an inducement to simplification and loss of unnecessary function. But the success of 'good' genes tends to be a result of the beneficial aspects they can have on the phenotypes they happen to influence, so in most cases the 'interests' of the genes and those of the phenotypes tend to agree. Now it could be appropriate to present some simple models to illustrate the subtlety of genetic adaptation.

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[46] Marx inspired by Hegel is so far the most ambitious attempts in that direction.

[47] Dennett takes as an example a theory that humans diverged from Apes and went through a acquatic phase. To the layman the arguments seem as convincing as those of other similar tales, yet this particular one is rejected by the evolutionary community. One assumes on good grounds, although Dennett seems not to have discovered any. This makes one suspicious though of many other accepted stories. Such stories do of course not cast doubts on Darwinism per se, only its practice.

It is often speculated in popular accounts that there is say a gene for smartness. A gene contains very little information, although as noted a simple algorithm can have unpredictable consequences; while being smart is clearly a far more subtle thing than say superior cardio-vascular capacity. If it would be true, some genetic engineering on the smartness gene clearly could make wonders, producing a new race of men who could even make smarter changes on the smartness gene with spectacular results, and so on. There is however a strong psychological basis for such phantasies, namely pride of breed, which lies behind the emergence of class-divisions, especially the notion of inherent aristocratic superiority. It is very reassuring for someone to be able to attribute his superiority to his inheritance. It somehow makes it more solid not being the mere whim of ones will. In particular intelligent parents would expect to raise intelligent children. This might very well be superstition but a very powerful one to which most people secretly adhere[48]. But let us assume for argument that the smartness of offspring does not depend on the smartness of genes but on the compatibility of the genes from each parents. To make the model as simple as possible. Assume that an AA combination or a BB combination (i.e. the same type from both mother and father) infers reproductive fitness, while a mixed AB results in infertility. Both genes A,B are equally 'fit' but it is the combination that is interesting to the phenotype not the individual genes, although it is the individuals genes that are directly passed on, not their combinations. Now populations that are mixed with respect to the two genes in their pools would then propagate much slower than those that would happen to be pure. Thus would not pure populations tend to dominate? Also in a given population, a slight predominance of some of the genetype would increase exponentially, as the minority gene would tend to end up more often with the majority gene than vice versa. The actual mathematics behind it is too trivial to be made explicit[49]. One could wonder whether such a phenomenon would actually lead to a split into different species. But now we can make the situation a bit more complicated, assume that the AB individuals are infertile but individually very fit and contribute to the survival of populations in which they happen to be members. How would it work out? This will of course depends on the parameters we would fit wise to introduce in the model. If the presence of AB significantly increases the prospects of high reproduction in the AA and AB one can treat it as a problem in self-regulation and come up with optimal frequencies. The AB individuals would be very fit, but their fitness would not translate directly into the fitness of their descendants as they would have none, but the presence of AB would propagate in the populations indirectly anyway. This just to illustrate the dangers in taking formulations of the Darwinian principles too literally. Of course this model is in no way new and startling, we all know of the social insects in which most members are actually sterile. Incidentally this is not an argument against selection on the level of the gene, as one can easily consider the whole colony as the phenotype not the individual members. And

[48] Bronowsky in his Ascent of Man notes that people are usually not so particular about whom they bed as opposed to whom they wed, desirous to sire excellent offsprings. This conscious, or maybe rather unconscious, belief also forms the basis for theories of adaptation itself, some extreme forms of it distinguished and refered to by Darwin as sexual selection, and meant as Natural selection going hay-wire. One should of course be careful to make a distinction between natural and perverted as selection is free of any values.

[49] But see the mathematical appendix

> in fact the distinction between a colony and an organism is more of degree than kind. In an antcolony one may think of the queen as the sexual cell, while the workers as asexual ones. The more sophisticated the colony the more specialized function for different kind of members. Evolution of ants have only proceeded for a few hundred million years give it some billion years and who knows how specialized and complicated it could become.

In addition to the Mendelian synthesis with Darwinism there are some more fundamental questions that are rarely discussed at least in popular accounts. First and foremost how did DNA arise in the first place? Clearly it is a matter of molecular evolution, but why is DNA the only molecular entrance into life? Clearly there could be other self-replicating molecules? What is life is a question that could be put concretely and abstractely. Put concretly here on earth it has a simple answer, anything based on DNA is Life, neither more nor less. Put abstractly, as by Schrdinger, or by necessity by the engineers responsible for the first Mars lander on the look out for extra-terrestial life it is much harder to answer. But why could there not be two competing life systems here on earth, when the variety of competing life forms is so large? Secondly we have the phenomenon of sexual reproduction, incidentally pondered by the evolutionist Maynard-Smith. Now obviously if two individual organisms would simply mix their genetic material, say half and half, the result would be, except in a few highly improbable circumstances something non-viable, and in particular there would be little resemblance between parents and progeny. The process has to be structured, and as we all know the solution is that the genetic material is divided up into sites, the number of which that varies from species to species[50]. To each site there are two copies of packaged genetic material - so called chromosomes, which essentially are duplications of each other[51]. In this way one is assured that the structure of the genetic material of the the offspring is essentially viable, no crucial genes are missing. In particular a descendant shares exactly half the chromosomes from each of its parents. Close relatives share chromosomes and it is easy to calculate how many you would statistically expect[52]. But even humans who share no common chromosomes can be quite initimately related for the simple reasons that the chromosomes belonging to a specific site are very closely related. When we look at the level of genes, humans do not only share a large percentage between themselves but also with their mammalian cousins. The solution to the mixing problem is thus quite elegant and to some extent canonical, and thus, in the terminology of Dennett something of a 'forced move'[53]. Deviations from the procedure

[50] 23 in the case of humans

[51] The compound effects are subtle as illustrated by dominant and recessive genes, and shades between

[52] As noted the exact numbers are given for the parents, but with a grandparent the number of shared chromosomes could be anything from zero to a half, with the most likely case around a quarter. First cousins an eighth, second cousins a fourth of that, keeping in mind the limited number of chromosomes, pretty soon you expect no common packages. Thus beyond a certain limited kinship people are in principle not more related to their relatives than to people at large within their larger populations. Then of course we enter the notion of race, which as opposed to species, has no really intrinsic meaning (and even the meaning of species is as we have noted above quite fuzzy at the edges) yet is fascinating as a fossilization of human migrations and interbreeding patterns. Yet so infected has the notion of race become that even fully legitimate inquiries are met with suspicion and discouraged.

[53] If you have only been given a fragmentary explanation you are able to fill in the missing details and

invariably lead to no issue and thus become invisible. In particular it is shared with all organisms using sexual reproduction. One may ask whether there is a gene (or combinations thereof) that is responsible, or whether it is a meta-feature of the genetic material. The result of sexual reproduction is to speed up navigation in the genetic library, variety now not only intermittently being available through mutation, but by active recombinations.

How far can we push Darwinism? According to Dennett all the way, and in fact notable efforts have been made to explain intelligence, moral sense including altruism as well as cultural adaptations through evolutionary adaptation. That grand attempt at synthesis is mainly associated with the specialist on Ants - E.O.Wilson under the name of Sociobiology. At the time - the mid seventies, it brought about a lot of hostile barrage, not least from his Harvard colleagues Gould and Lewontine. The enterprise was discredited and many of its more outrageous claims have since been quietly dropped by its proponents[54]. Now admittedly many of the evolutionary stories concocted in so called evolutionary psychology are rather fanciful and unfalsifiable. But simply because something may be unfeasible does not mean that it is in principle wrong, yet even Dawkins and hence also Dennett draw away from it. Dennett notes rightly that you cannot base morality on questions of utility, such algorithmic calculations are simply not feasible as there are no natural horizons[55]. So while Dennett is an enthusiastic proponent of Artificial Intelligence his stand on Artificial Morality is far more conventional. Dawkins whose 'Selfish-genes' theory advocated a radically unsentimental approach to evolution wanted concomitantly to exalt the human spirit who was now free to shatter the shackles of genetic determinism. His introduction of 'memes' was meant as an explanation that with the creation of the human brain evolution in the wider sense transcended its genetic components, with human ideas perpetuating themselves in brains carrying on the torch[56]. As William James noted no person really is able to adhere strictly to one philosophical point of view as we have already recalled. When it comes to morality Dennett (and Dawkins?) becomes an idealist. Top-down approach. Moral sense, intentionality and meaning, those are things which are given and in our minds irreducible. Although they in principle could be treated as emergent

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figure out how it has to be

[54] Wilson does preserve, in the late 90's he published 'Conscilience' a book I bought and half read back in '99, maybe it would be worth a second try

[55] By utility calculations any atrocity can be retroactively vindicated by the presumed good effects it will have in a distant future.

[56] Initially I thought 'memes' was a rather insipid idea thrown in by Dawkins merely to illustrate that the Darwinian principles in their abstract sense also could be manifested outside the biological context. But it took on a 'life on its own' much to the gratification of its erstwhile creator, who now seems to take it much more seriously than he initially intended. It is, as Dawkins noted, an example of Lamarckian evolution rather than Darwinian, and as such far more rapid. The weakness of the theory is that it is both too vague and too precise. Vague as the memes can be almost anything, just like thoughts, as supposedly irreducible entities in the sense of William James, could be anything from the simples passing spark to a most elabourate structure. Too precise as it has the ambition of providing sharp analogies with the genetically based involution. As repeatedly pointed out, Darwins ideas in the abstract are simply tautological if formulated, it is only in a definite context they become meaningful. Everything that has been said about memes could as well be said about cultural adaptation and perpetuation thereof.

phenomena in practice it is impossible to consider them as such. A student of evolution must stand apart from evolution itself, his ultimate object is the truth about it, and as such it stands above evolution. If you try and explain your insights about evolution as the results of evolution itself (which on one hand they invariable are) you find yourself in a self-referential logical fix[57]. There is nothing objective about our moral sense, it is really in the manner of an evolutionary idiosyncracy, but just because of that it is so precious to us. If we do not protect it, who will?

However speculative ideas about the adaptive evolution of our psychological idiosyncracies abound. In particular the supposed sexually vagrant instincts of the male are given persuasive adaptive explanations in terms of cost-efficiency when it comes to reproduction, explanations which likewise would explain the supposed possessive instinct of the female. One should be wary of such arguments, commendable as the attitude of exploring evolutionary constraints on human expression may be as an anti-dote to a fixation on the paradigm of the *tabula rasa*; because in the absence of falsifiability wishful thinking is given a free rein. Nowadays the social astuteness of humans is extolled as the true pinnacle of human intelligence, disparaging men of genius as sufferers of brain defects allowing social skills to be channeled into other inquiries[58]. The moral of the story being that the man of mediocricity is superior to the man of genius as his gifts are far more subtle and natural (whatever that is supposed to mean). It is true that the arbitrary chosen man instinctively perform impressive feats like balancing his body and recognising human faces even if given only rudimentary input (as noted in the preceeding footnote). Such things are always reassuring to learn. How much are we ultimately able to learn about our own mysteries? What would understanding of them ultimately be? People like Chomsky posit the idea of cognitive closure, simply that there are things that will be forever beyond us. After all what does the earthworm know about electrons? Clearly every organism that we know of

[57] In the same way if the world is deterministic, why should it be determined that we should get a conviction of that fact?

[58] Dennett presents a puzzle, three cards each of which consist of a number and a letter on each side are presented on a table. How many cards have to be overturned to verify or falsify a certain hypothesis. The exact test is irrelevant, except that it is very simple. The point is that many educated people fail it (including myself incidentally). Then an alternative but completly isomorphic test is presented, which no one fails. The point is why the first test presented formal rules, the second presents a meaningful social situation. Dennetts conclusion is that we have been evolved to think in socially not logically, hence we are far more susceptible to errors of abstract thinking. Maybe, but to me the situation is far simpler. In the formal situation I simply forgot one of the conditions, but in the meaningful situation I was not able to overlook its equivalent. I cared nothing for the first but was more engaged in the second. Of course one could argue that all of our sense of meaning and intentionality derives from our social persona, and that we are only able to perform intellectual feats if we are able to somehow connect abstract principles to our social skills. Thus what distiguished a mathematicians from the mathematically illiterate is not so much brain-power as the ability to become 'socially' and 'emotionally' attached to his problems and concepts, which thereby acquire a vividness and richness of association, normally reserved for the assessment of other people. It is conjectured that the incredible mental tasks performed by so called 'savants' are due to their hapless ability to exploit centers of the brain that is normally used for complicated processes, like the recognition of faces, feats we normally do every day and think nothing of.

exhibit severe restrictions as to cognition, especially when compared to those of man, so why should not man himself be similarly constrained? It is not really a rational argument but a philosophical one. Philosophy is not science and is consequently not restricted to arguments alone but is free to be evocative. This is why one may refer to it as the poetry of science, meant not as a disparagment but as a homage. Dennett has no truck with that idea, to him there are no limits to the inquiry of man and the mental powers he can submit to the task[59]. Some of the arguments he adduces seem to me a bit feeble relating to the fact that we surely would be able to understand all the meaningful texts in the Borges library. His main point is that the analogy is misleading, the earthworm could not care less about electrons, it is not baffled by it, while we are baffled by many things, which no doubt will eventually be resolved (as it is hard to imagine that they will not be).

Does evolution have a purpose and does it proceed at a steady rate? The second question is more technical than the first and hence admits a more precise answer. It is assumed that random changes with no reproductive advantages proceed at a constant rate. It is refered to as drift, and can be thought of as random walk along a flat fitness landscape. It has formed the basis for various genetic clocks[60]. But as to real drastic changes in phenotypes, Gould along with Eldridge proposed the theory of punctuated equilibriums, to describe the fact that most specie sseem to undergo long period of stasis in which nothing really changes, only to experience rapid change. However it is hard to see in what sense this means a drastic revision of drawinism, which admittedly speaks about gradual change, but there are levels of graduations, and the theory has effortlessly been absorbed in standard Darwinism. It is hard to avoid the suspicion that Gould was desperate for making a significant and original contribution to Darwinism.

As to purpose it is easy to read one into it given the facts. First one should not be surprised at the complexity of organisms. It is well-known since Malthus that sustained exponential growth in a material world is impossible[61] But not in the virtual world. Small but steady changes do accumulate especially when multiplied and not only added. But as has been noted above there is no drive towards greater complexity it has just occured. The prospect of evolution degenerating into mindless organisms cannot be discounted. Foresight and planning are supposed to be invaluable strategies for survival, but one should not exaggarate them, especially in view of the follies that invariably accompany them.

Finally the notion of convergence is another philosophical issue on which we have touched briefly. Is the emergence of life preordained in any situation friendly to complicated chemistry[62]? Or is its appearance just a lucky break? The fact that all life on earth has a

[59] This makes one think of Hilberts optimistic credo *Wir wollen wissen, wir werden wissen*

[60] Initially in the 70's one considered so called molecular clocks based on the slow change of proteins. later on one has studied changes on the genetic material itself, especially the mithocondrial, which explains the intresets in the Eve we all descend from.

[61] This does not prevent governments to maintain a steady economical growth, or to present exemplary tales of how someone who at the time of Christ made a modest investment in a savings account in a bank would have incredible riches to distribute to his descendants.

[62] Why chemistry, why not one based on nuclear as opposed to electrical forces. Freeman Dyson has speculated about fast life on neutron stars.

common origin tends to point in that direction. It is often argued that there are so many galaxies, and so many stars in each, that statistically there is bound to be extra-terrestial life. People then make a confusion between the existence of planets on which life could be sustained and planets on which life has evolved. As to the former there are probably billions in the universe, but such astronomical numbers are very small, vanishingly small when compared to those associated with the configuration spaces we have considered. And finally even on Earth intelligence has only evolved once. Why are there no intelligent fish? A few hundred million years ago veterbrate life split into one which remianed in the Sea and one which claimed the Land. One may argue that the latter were more venturesome, but then we are close to falling into the trap of teology. Or more drastically put, how come there has evolved no intelligence among plants? So even if there would be many planets on which life, in the sense of defying entropy, has evolved, there is little reason that intelligence will as well, let alone intelligence friendly to us.

`May 21-31, 2006`

Appendix So let us briefly treat mathematically some of the suggestions above. So let us consider a population of M members consisting of A members of type AA and B members of type BB and C infertile members of mixed type AB. Assume that the reproduction rate of each pure (and fertile) member is α in the sense that in a pure population the growth of the total number of members would be given by $Me^{\alpha t}$ where say $t = 1$ corresponds to a generation time. (Alternatively we could think of $t = 1$ as also being the lifeexpectancy and thus after each generation a generation with αM members has replaced the old.) We then can set up the system

$$A(t+1) = \alpha \frac{A(t)}{M(t)} A(t)$$
$$B(t+1) = \alpha \frac{B(t)}{M(t)} B(t)$$
$$C(t+1) = 2\alpha \frac{A(t)}{M(t)} B(t)$$

In particular the ratio $\frac{A}{B}$ satisfies

$$\frac{A(t+1)}{B(t+1)} = \frac{A^2(t)}{B^2(t)}$$

In particular a small advantage of A over B will pretty soon translate into a big advantage. Setting $\lambda(t) = \frac{A(t)}{B(t)}$ we get $\lambda(k) = \lambda(0)^{2^k}$. If $\lambda(0) = 1.001$ then after ten generations (an eye-blink in evolutionary time) we have $\lambda \sim e \sim 3$ while in twenty generations we would get $\lambda \sim e^{1000}$ thus considering the fact that the total population would tend to be in equilibrium the population of BB types would pretty soon get wiped out. This is of course a mathematical model whose simplifications do not take into account the granular structure. If the population would be say a million, with an initial predominance of 500 individuals as to A the initial vagaries would lead to a different outcome, it is like a needle

trying to balance in an upright position. It could fall either way, but once it starts falling, things will be reinforced. The model also presupposes that mating is blind, once there is any kind of 'recognition' of the same kind, the odds for the future of the minority genes look much brighter. One natural way for this to come about would be for small parts of the population to split off and establish colonies. Incidentally knowing the function $\lambda(t)$ we can simplify the above equations. First $A(t) = \lambda(t)B(t)$ but also $C(t) = 2\lambda(t)^{1/2}B(t)$ as can be easily seen ($C(t+1) = 2A(t+1)\frac{B(t+1)}{A(t+1)}$). Now if the total population grows exponentially with factor β we can solve for $B(t)$ and get

$$B(t) = \sqrt{\frac{\beta}{\alpha}}\frac{M}{\sqrt{\lambda(t)^2 + 2\lambda(t) + 1}} \sim \frac{M}{\lambda(t)}$$

as we note that for large t the population $A(t)$ is dominant hence asymptotically $\beta = \alpha$. So we note that even at exponential growth the population $B(t)$ will dwindle because their members will find it increasingly difficult to find mates with whom to sire succesfully[63].

Now if we assume that the population $C(t)$ has a benficial aspect by keeping α high, we note that as it dwindles, the ratio $\lambda(t)$ growing quickly will mean that the total population nevertheless will go down. Thus populations which will have a balanced number of A and B genes will prevail, but as soon there is some imbalance it will tend to vanish. Hence fit populations will give no fit descendant populations[64], but if there would be other feedbacks the situation could tend to some sort of equilibrium.

A more common scenario is say of A being dominant and B recessive. Simple Mendelian arithmetic leads us to set up the following system of equations

$$\begin{aligned}
A(t+1) &= \alpha(A^2(t) + \frac{1}{4}C^2(t) + A(t)C(t)) \\
B(t+1) &= \beta(B^2(t) + \frac{1}{4}C^2(t) + B(t)C(t)) \\
C(t+1) &= \gamma(\frac{1}{2}C^2(t) + 2A(t)B(t) + B(t)C(t) + A(t)C(t))
\end{aligned}$$

Considering a population in equilibrium we can assume that $A(t) + B(t) + C(t) = 1$

[63] More realistically though, mating opportunities are not uniform in a large population, more realistically a large population would be spread out and mating would tend to take place within vicinities, hence there would be a patchwork of pure breeds scattered throughout and the extinction process would be far slower. the exact nature of which would be hard to predict but provide an amusing subject for a computer simulation.

[64] As we showed it would be in the 'interest' of the population to maintain a steady supply of mixed configurations, and those who do so will in fact prevail, but there is no feedback, and past success is not a guarantee of future. On the other hand balanced populations would grow quickly and spawn many subpopulations some of which might be wel-balanced as well. Thus we would have the case of fit populations having many descendants, but as noted fitness of descendents would only have a low correlation with that of the parent, whose fitness would be unstable as well.

Now let us simplify the situation by setting $\beta = 0$. This means that the recessive gene B is fatal, i.e. no carrier of BB survives to fertile age[65].

Assuming an equlibrium, i.e. A, C independant of time we can solve the equations

$$A = \alpha(A^2 + \frac{1}{4}(1-A)^2 + A(1-A) = \frac{1}{4}(A+1)^2$$
$$1 - A = \gamma(\frac{1}{2}(1-A)^2 + A(1-A) = \frac{1}{2}(1-A^2)$$

The second equation yields $A = \frac{2-\gamma}{\gamma}$ (unless $A = 1$ which is a trivial uninteresting case), while the second shows how α is connected with γ specifically $\alpha = (2-\gamma)\gamma$.

We note that $1 \leq \gamma \leq 2$ the extreme case being $\gamma = 2$ when AA is lethal as well. Then half of the progeny of AB is surviving AB forcing $\gamma = 2$. In particular if $\gamma > 1$ it forces bad genes B to persist in the population and in fact provides a certain amount of BB to be born.

Those simple mathematical models show that evolution can bring about drastic changes quickly, but they also show that simplified models do not necessarily lead to realistic conclusions, small changes of parameters may have drastic results.

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[65] Realistic examples abound. In sub-Saharian Africa BB would cause say sickle-cell anemia, while AB would provide an enhanced resistance against malaria. Thus the B gene has survived in such populations, and hence in their American immigrants, leading to its discovery