What Evolution is

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Mayr was a legendary biologist, who made his name in the 20's as a collector of birds in the rain forests of New Guinea, when visiting that region was fraught with risks, as the area was infested with cannibals. He escaped the fate of being killed and consumed, but was stricken with malaria and dengue fever. This did not prevent him many years later from turning a hundred and he wrote the present book at the age of 97.

It gives a sober and factual account of evolution intended for the intelligent layman, thus evading the usual vulgarizations connected with talking down to the reader, which usually mar presentations on the subject. He differs from Dawkins by deemphasizing the role of individual genes, noting correctly that natural selection works on phenotypes, and that its effects are to be seen statistically in evolving populations, because individual organisms do not evolve, only the populations of which they are members. One stumble block for appreciation of the process of evolution is its seemingly tautological nature. What survives, survives period. Or you survive and reproduce because of your fitness, and fitness is defined by survival, thus making the logic circular[1]. Mayr notes that fitness is not something a priori given, that in fact evolution depending on so many random factors, cannot be predicted, thus indeed fitness is an a posteriori conclusion. It is also misleading, because what is rejected by evolution is not only the unfit but also the very fit by any reasonable standards. This is because there is a large element of the merely accidental in rejection, no one could have predicted the event of the comet collision which ended in one go the Cretaceous era wiping out the dinosaurs. The dinosaurs were no less fit than the mammals which survived, nor their reptilian cousins such as crocodiles, turtles and snakes, on the contrary by reasonable standards they were eminently successful. It is sheer nonsense to claim that those survivors are more fit to survive future cosmological catastrophes than the dinosaurs were. A new cosmic catastrophe may present a completely different set of challenges. Thus it is not very fruitful to think of evolution as necessarily involving cut-throat competition, although such elements are of course not absent, there will always be competition when there are limited resources, which of course there always are, but that will only become apparent when the same niche is involved, and even then the competition is subtle and far from clear cut[2] . It is not the case that only the best survive,

[1] More specifically. In fact fitness must relate to reproductive success, and thus to the reproductive success of progeny, and so on! One way out of it would be to claim that the reproductive success of your issue equals that of your own, which if taken literally on the level of individuals clearly is absurd. The only reasonable approach is the statistical which means in terms of populations. Then we have the phenomena of surges, such as that of locust swarms, which eventually fade out, giving the lie to the proposition of the putative conservation of reproductive fitness. Initial success changing the rules of the game.

[2] Also 'fitness' involves reproductive fitness, which is different from viability as an organism. A typical example is sexual competition leading to sexual selection, which Darwin pointed out to be somewhat

more that the culling of nature removes what does not fulfill minimal criteria for viability. Thus by veering away from discussions of competitive fitness, which if not becoming circular invariably leads to contradictions, and instead posing more fruitful questions, amenable to popperian falsifications, the subject becomes truly interesting. And it is here that Mayr proves his mettle.

Darwinism means many things, although interlocked, which it is nevertheless necessary to keep distinct to evade confusion. Basically there are two things, the facts of Evolution and a theory of the mechanism that drives it. In fact Mayr speaks about five different things, two relating to Evolution and three to the finer points of how evolution actually proceeds in view of the theory of Natural selection. Let us look at them one by one.

Evolution is a fact, in fact almost in a Baconian sense. It stares at you, without the need of any clever interpretations. The geologist encounters stratifications, and those stratifications are correlated with a changing set of fossils. The basic assumption that stratification is a documentation of time, in the sense of lower layers being more ancient than those the lie superimposed on them goes back at least to the Dane Steno and Descartes who provided the first documented formulations of the principle. Of course in real life the situation is a bit more complicated due to the folding and erosion of geological strata presenting a rather muddled picture, which nevertheless can be straightened out by seasoned geologists. In fact the problem became much more tractable by using the shortcut of taking fingerprints so to speak provided by the fossils[3]. Now once you accept the very reasonable assumption that those fossils actually stem from organisms (an assumption irrelevant to their serving of the purpose of the ordering of stratification) you have the fact of evolution, namely that the flora and the fauna of the past differed from that of today. Cuvier, a French master anatomist of the late 18th century was the foremost expert on the anatomy of extinct animals, held the opinion that new species originated spontaneously (or what is logically equivalent were created by God at his discretion) to counteract the extinction of others. He claimed that each species was so perfect that any change would be for the worse (in modern parlance they were local maxima in the 'fitness landscape'). Lamarck on the other hand held that species changed gradually by parents transmitting characteristics they had acquired during their life time to their descendants, the theory of the inheritance of acquired characteristics referred to as Lamarckism and which is often compared to Darwinism to the detriment of the former. His most memorable example being the evolution of the long neck of the giraffe due to the parents stretching after elusive leaves thus marginally extending their necks, an extension to be passed on. Acquisition turned into inheritance. Lamarck's ideas were scoffed at by the establishment led by Cuvier as unscientific speculations. The ideas that a species underwent changes were falsified by the fact that mummified cats found in Egyptian tombs did not show any differences from modern cats. True enough. To the issue of inheritance of acquired characteristics,

'irrational'. By attracting partners there may be a selection for attributes that instead of adding to viability impede it, such as the huge antlers of the Irish Elk or the elaborate displays of the peacock, all based on whims of the females. If the whims become to extreme, the species will go extinct of course, or the excesses weeded out,

[3] The English geologist Smith who was instrumental in providing the geological mapping of Great Britain in the early 19th century availed himself of the method.

we will return, suffices it to say at this point that Darwin did not reject it.

The fact of Evolution as manifested by the fossil record is one thing, but Darwin went further and talked about common descent. This is not immediately clear from the record but is a leap of thought comparable to the Galilean and especially Newtonian one of bodies traveling in straight lines with uniform velocity when having no forces act upon them[4]. It means that basically every two organism have a common ancestor, and that a species will emerge from another, in particular that humans may be descended from apes. This was a rather revolutionary idea, but it seems to have been readily accepted, at least by the biological community. It brings forward the picture of the tree of life, that all organisms are part of a common structure, having a common heritage. It also included placing man among the animals, an idea that philosophers, such as Descartes had instinctively rejected (making the famous assertion that animals have no souls and hence are only machines, however intricate), but which was not essentially new, after all Linnaeus had included man as *homo sapiens* in his all encompassing classification of the living world. There are two general aspects of the living world, known to man since antiquity, aspects which are intimately related to common descent, namely species and homologies. There is a tendency to divide up the living world into separated units, namely species, as well as noting various degrees of similarities between them expressed in homologous characters. Such notions make no sense at all on the level of individuals, only when we think in terms of populations. The divisions into species is of course very old, and Aristotle held that species were fixed and expressed an essence, pre-modern ideas that the author dismisses as Platonic. This may bespeak a rather limited and naive, in the sense of literal, version of Plato, but I will let it pass, his point is made. In fact one cannot divide organisms in equivalence classes built on species, because transitivity will fail, although this is not clear when one considers species at a given time interval where there seems to be clear demarcations between them. For one thing one cannot confuse man with any other animal, But even back then Aristotle ought to have been a bit puzzled as to the differences between horses and donkeys due to the hybridization resulting in mules.

As to homologies, this is simply the fact that one may correspond features, especially anatomical ones, across species. It is quite clear what is a leg in most familiar species of animals such as mammals, birds and reptiles (perhaps a little bit more subtle in fishes and whales), and that the wings of a bird or a bat are modifications of forearms. In fact the presence of homologies allows the student of zoology to infer degrees of relatedness, without necessarily taking it literally, through comparative anatomy, of which the 18th and especially the 19th century, provided many specialists, some of them such as Owen in Britain, unsurpassed to this day. In fact this fact which has fed human fascination for the diversity yet connectedness of the natural world, is but a projection of the underlying tree of life which gives it coherence. As has been noted only in the light of Evolution does biology make sense. One may mischievously think of the tree of life as the underlying Platonic form of for the actual manifestation of life as we encounter it in the world of the senses, which presents but a thin slice of time. Anyway the historical fact of Evolution presents the problem of actually not only determining the branchings of the tree as a combinatorial tree but to date them, This is far from a tautological problem. The standard tools are

[4] Never mind that eventually this insight became a tautology through the very definition of force.

comparative anatomy, which through the phenomena of fossils, can also be applied to extinct animals, as practiced by Cuvier and his successors. To this has recently been added a very powerful method supplied by molecular biology a discipline of a very recent origin, and to whose fruits the author devotes a large part of his book.

To return to the problem of the definition of species to which the author has devoted a substantial part of his life work is a subtle one, showing a mixture between *bona fide* biological constraints and mere human conventions. To get a better understanding one must look at the mechanism that drives evolution according to Darwin.

Darwin often refers to Malthus as starting his train of thought. Malthus has often been dismissed as a cynical and smug, not to say callous, Victorian minister rationalizing human misery as inevitable, but that is to a large extent a case of shooting the messenger. The fact remains that in a stable environment, with necessarily stable populations, the latter cannot be subjected to exponential growth. The fact is an arithmetic tautology, but which nevertheless has profound implications as Darwin realized. What is happening to all that progeny that is produced in such embarrassing profusion, when, as the author points out, each parental couple can only produce two producing off spring on the average during their life times? There must be a lot of culling, not by design but automatically. Furthermore Darwin was familiar with human breeding and the kind of intentional [5] selection this involves, taking advantage of the fact that the progeny very much resembles their parents, allowing a transmission of characters over generations, known as hereditary. Putting two and two together he concluded that the natural and inevitable culling must act in analogy with human artificial selection, and through the mechanism of inheritance effect a moulding of characteristics similar to the one done in husbandry, but promoting as desirous traits those compatible with survival. In short he had hit upon a mechanism that would automatically with no conscious design create order out of chaos.

Now in retrospect this may appear obvious, but as anyone knows who has struggled with problems, the obvious solutions are often only obvious in retrospect. We are all fumbling in the dark and often cannot tell even if we are very close to an actual solution. In addition our search is always constrained by some prejudices, set ideas, not to say fixed ideas, setting the agenda, something that Bacon warned against. Anyone committed to the idea of divine intervention will be prevented from drawing ultimate conclusions, something which anyway often is fraught with fear[6]. And Darwin did not really come to his ideas by a flash of insight, however sudden the inspirations may have been, he proceeded carefully well aware of how easily the mind may lead you astray. He did in the end attribute to his success the pedestrian turn of his mind, instinctively distrustful of the jumping to conclusions and of a plodding temperament, lacking the brilliance of a mathematical genius[7]. The process of forming his ideas took its time, and as is usually assumed, the incubation and eventual birth took place during his traveling as an in-house naturalist on the Beagle. That he took so many years to procrastinate going public maybe in part be ascribed to his position so different from contemporary academics of being of independent

[5] And also unintentional and fortuitous

[6] One possible ultimate conclusion to draw from life is to commit suicide because of the apparent meaninglessness of it all. To think things through may end in disaster.

[7] Darwin often regretted his lack of mathematical talent, in retrospect that may have been a blessing.

means, a gentleman scientist, with no pressure to publish to evade perish. And, something for modern academic administrators to ponder, is that lack of productivity does not imply inactivity. But most importantly though was his reluctance to be dismissed as a mere speculator as had Lamarck been seen as, and hence his obsessive desire to amass enough empirical evidence to buttress his arguments. An unending quest in fact, and had it not been for the urgings of his mentor Lyell pointing out the threat of Wallace usurping his rightful priority, he may never have gone public.

Now there are concrete problems connected with natural selection, which are not visible when it is merely seen as an elegant philosophical principle. And here we come to the three theories connected with natural selection pointed out by the author, namely speciation and gradualism in addition to the principle of natural selection, which encountered a lot of resistance. How did the branching come about? And here his observations at the Galapagos Islands are often invoked. Speciation is a matter of populations splitting up and becoming isolated from each other, and the isolated islands of that archipelago provided to Darwin a mini-laboratory for the actual speeded up process of evolution. Darwin also realized that speciation must occur gradually, no saltations, and that any evolved organ must have come about in stages each of which must have been viable. Here we are presented with concrete questions whose actual elucidation depended not on general philosophical considerations but on a detailed study of the situation at hand. The devil residing in the details, as the saying goes, and as any naturalist worth his salt, Darwin was obsessed with details. Still the grand picture is clear. There is some mechanism that produce variability, a process that is basically one of chance, and a selection which is constrained by circumstances, but yet of course not wholly devoid of chance elements, as noted above in connection with astronomical disaster. It is often tempting to contrast Darwinism with Lamarckism. In the latter evolution is actually instructed by the environment (as in the Baconian sense of doing science), while in the former, nature is put to test by being asked questions. Will this solution be viable? (This corresponds to a Popperian approach). However, this is a somewhat anachronistic view, as Darwin not really having any understanding of the mechanism of inheritance, he did not rule out, as has already been noted, a Lamarckian process of acquired characteristics. It was only with the later grand synthesis of Darwinian theories and modern understanding of inheritance that pure Darwinism, as we know it, was born. Now it is a theorem, or dogma if you prefer, of modern biology that there cannot be any inheritance of acquired characteristics. The genome, i.e. the genetic information, guides the embryological formation of the phenotype, in ways which are badly understood, meaning that the DNA codes for the production of proteins, and there is a long pathway of how this translates into actual higher order properties of the phenotype; but there is no guiding in the opposite direction. That means that changes in the phenotype cannot be translated into changes of the genome, there is no such pathways. This does of course not exclude the possibility that the environment may effect the genome, but then basically by destruction, be it through radiation and other stresses, and thus randomly and undirected. In short there is no way a subtle change in the phenotype can be decoded back to the genome. To assume so would necessitate some very subtle mechanisms which no one has any idea of how they would be effected[8].

[8] One should be careful in biology to dogmatically speak of iron-clad rules which drive mathematics

There is nothing inevitable about evolution there are no such teleological principles as the drive towards perfection, with which Aristotle would be very comfortable, but which nevertheless has influenced the vulgar view of evolution, often expressed as in the ascent of man as the crowning achievement. The basic thing is that there are two kinds of bacteria, or rather two kinds of cells. Prokaryotes. and the more advanced Eukaryotes. The primitive cells still make up the larger biomass of living organisms and may not really have evolved much since their inceptions. They propagate by division and hence each cell produces clones. The process is complicated by the phenomenon of mutation, basically accidents in copying DNA or outright damage to it, as well as by collision of cells which may involve interchange of genetic material and in such a way effect new recombinations. The classification of prokaryotes is a total mess, the notion of interbreeding populations does not make sense as there is no breeding. The division into species is merely an exercise driven by nothing more profound than conventions based on apparent similarities which may mean very little if anything at all. Still the same principle holds, namely the survival of the fit, and inheritance is even more pure, as we are talking about cloning [9]. But nevertheless there has been no advance. The principle as such has limited explanatory power. What happened? The accidental creation of eukaryotes, cells with membranes, nuclei and so called organelles, such as mitochondria, completely changed the course of Evolution and biologists such as Maynard-Smith classifies it as perhaps the most important of the half a dozen revolutions that have occurred in the history of Evolution. It made possible multi-cellular organisms and sexual reproduction and has given rise to the three major kingdoms of organisms, animals, plants and fungi based on different kinds of eukaryotic cells. But the evolutionary success of the eukaryotes did not make the more primitive prokaryotes obsolete, which in terms of individuals dwarf those of the eukaryotes, thus no less fit in comparison[10].

Now to understand evolution one needs to understand sexual reproduction without which the more fascinating aspects of evolution, including its own self-reflection through the agents of man, would not appear. This belongs to the basics of biology but does not belong to the basics of peoples understanding in general. There are two types of reproduction of cells, the most common being the standard one through duplication by division producing clones, so called mitosis and is involved in the process of embryology, i.e. constructing the phenotype and keeping it in shape by repairs. In this process the genetic material is of course transmitted wholesale. The exceptional one is through meiosis, in which the genetic material is halved into a so called gamete and later on possibly fused with a complementary gamete, to produce a new cell with recombined genetic material subjected to extended mitosis when engaged in constructing a multi-cellular phenotype[11]

and the physical sciences, and lately there have been speculations as acquired characteristics can actually be imprinted on the genome, more specifically that starvation of your grandparents may have effected your genome. To me this seems rather farfetched in view of the simple principles of one-way decoding that goes on and I am sure it is a temporary fad and that a more satisfactory explanation will eventually emerge.

[9] This might have been an inspiration for Dawkins to concentrate on genes as the locus of selection

[10] Humans may easily wipe out gorillas and survive but not prokaryotes unless taking such drastic measures that their own survival will be impossible.

[11] Strictly speaking the phenotype includes not only the cellular structure which makes up the body of

The division of the genetic material cannot form randomly, because any random selection and fusing would only in truly exceptional circumstances provide something viable. Thus the genetic material needs to be suitably structured, as well as the process of division. This is done by the genetic material packaged in chromosomes, which comes in pairs, and in the process of division one member of each pair is picked. The number of chromosomes as well as their contents vary greatly, but the principle of meisosis, having a genetic basis, is the same for all eukaryotes[12].

As an illustrative toy example we may consider simple sentences adhering to a simple syntax such as SPO meaning a subject, a predicate and an object. Every sentence comes in pairs of sentences of which only one is active. The S-chromosome consists of objects (genes) such as proper names, and names of various nouns. The P-chromosome consists of various verbs or verb phrases such as 'gives, sees, watches, kills, helps, and the O-chromosomes words that designates things that can be the objects of the predicates. Thus a typical sentence could be the double with the active first ' such as Bob-likes-food'/Alice-eats-bananas' or 'The lion-jumps-the ring/The Bear-licks-honey'. Those two may together give rise to a common fuse by each going through a meiosis producing a gamet which can be done in $8 = 2^3$ *different ways , let us say 'Alice-likes-food' and 'The Lion-licks-the ring'. In the process of fusing the gamets an active chromosome is chosen at each site, say getting 'Alice-licks-food/The Lion-likes-the ring'. The sentences always make syntactic sense, and there is a great variety of them, provided that there is a wide variety of words.*

The process is complicated by the fact that there may be changes of the chromosomes due to crossing-overs, but the above principle of alleles still hold, i.e. two genes which are paired one being active the other turned off. Genes which always allow themselves to be dominated are said to be recessive, and if not, dominating. Bad dominating genes are quickly eliminated while bad recessive genes, especially if beneficial if not paired, may linger on for a long time in a population.

Sexual reproduction greatly enhances genetic recombination both as to speed and extent while cloning depends on the production of new genes, through so called mutation, to produce the desirable variation on which natural selection can act. One should also note that many other things go on in sexual reproduction. Mitochondria do not take part in the meisosis but is transmitted wholesale from mother to progeny[13] *and the part of the phenotype such as the bacterial flora of the mother. This complicates the picture as to details but does not compromise the general principle.*

Now genes code for proteins, as we have noted, but how this translates into the construction and maintaining of the phenotype is poorly understood,

the organism, but also the webs of spiders and other products of the organism, physical or mental, which form through the genes, All of that provide the feed for evolution to base its selection on.

[12] If you want, one may somewhat frivolously see it as a platonic feature

[13] At least in most animals it is supplied with the egg, among some plants such as conifers there is paternal transmission

and much of the ingenuity in clinical applications of genetic is to sidestep this basic ignorance[14]*. In particular traits depend on combinations of genes, which not always are transmitted wholesale as individual genes, which does significantly complicate the process of ostensible perfection as described in vulgarized accounts.*

The basic idea in Dawkins book on the Selfish Gene is that there is a competition between genes and only the best genes survive, because they are most successful in creating fit phenotypes. This is a radicalization of the classical conceptions of evolution but in my opinion misleading, and confirmed by Mayr as untenable. The point is that the effect of a single gene depends on in what genetic context it finds itself in. There is no such thing as a bad gene or a good gene in isolation it only makes sense in a fairly homogeneous population in which the contexts the genes will find themselves are very similar. Instead Mayr concentrates on populations an approach only through which the concepts of species and speciation can be understood.

A species is an interbreeding population. Interbreeding means that a large exchange of genetic material is going on. Not all of the members may breed, in fact as noted in many species only a tiny minority breed as there is a large culling of progeny for one thing. But even with such a general definition there are complications with transitivity, and the effect that mathematicians call monodromy occurs. There are overlappings of populations of a certain type of sea gull around the north arctic, at each overlap going east the populations can cross-breed, but when one has completed one orbit the small modifications have added up enough to have made the final population too different from the first to be able to mate.

In a big thriving population there is little evolutionary change, deviations are usually too swamped by the ambient populations not to be reabsorbed. Also there may be a large element of local perfection (as we pointed out was noted by Cuvier) making deviations less viable and competitive. Local perfection should not be confused with global one. The fruits of Evolution are never perfect, in fact by standards of intelligent design rather awkward. Darwin was very emphatic on this point emphasizing that imperfections provided a strong argument for his proposed theory of natural selection which would be very influenced by historical contingencies.

Now an interbreeding population may change over time through a statistical change in gene frequencies. Bad, meaning bad for the genetic combination prevalent in the population, may be weeded out, and good ones may acquire predominance. If the environment changes the process will be speeded up and made much more important. There are species, referred to as living fossils, which have remained intact over large geological time spans, perhaps the most famous example being the coelacanth discovered in the South Atlantic in 1938 basically unchanged since Silurian times 380 million years ago. Less of a curiosity are the insects which seem basically unchanged since Cretaceous times with their basic 'Bauplan' preserved since their original appearance. The preservations of some

[14] The much advertised mapping of the human genome has not given the insights, especially those clinically applicable, that may initially been hoped du to that fact.

species over such extended periods provide one of the evolutionary puzzles according to Mayr. Typically though parts of a population may become reproductively isolated from its parent population, usually through geographical barriers. Three things may happen. The stray population will rejoin the parent one, or it will die out, or it will spawn a new species and we may witness speciation. Typically an emerging species evolves much faster than an established, probably because it is subject to more demanding environmental stress and a lower degree of reabsorbtion. Once a rapid evolution has taken place, there will be stasis. This has been empirically observed so often in the fossil record that Gould and his co-worker Nelridge coined a term for it ' Punctuated equilibria'. Mayr states that it does not involve any significant modification of Darwinism, on the contrary the phenomenon is easily explained by standard darwinian arguments. Another example of stasis is the development of Modern humans which at one stage underwent a rapid growth of the size of the brain, only to be basically unchanged for the past 50'000 years, there never being any selection pressure on larger brains during this period[15].

There are also different kind of genes, some of them very old, and present in a very wide spread of organisms. There also seems to be a kind of hierarchy, where some genes guide the expressions of genes on the level below, and so on[16]. *There are even theories suggested by the author that much of convergent evolution can be explained by common 'master genes'*[17]. *Different kind of eyes have been developed during evolution, the most startling being the convergence between those of vertebrates and mollusks* [18]. *The great explosion of body plans (Baupläne) during the Cambrian era has been a source of fascination. Such general forms of body construction tend to be very conservative, and even Dawkins admits that they have great evolutionary potential, thereby accepting that structures above the level of genes can be the objects of natural selection. The author speculates that those structures are due to very high-level genes whose variability has decreased since then. One should not naively assume that those genes are directly*

[15] Among the most egregious mistakes stemming from a vulgar conception of actual evolution is the idea that one can breed intelligence by letting only intelligent parents interbreed. Intelligence is a fairly elusive concept and it is hard to relate it genetically. Of course parents always want their children to be intelligent if for no other reasons than to prove to the world their own, which may for some reason not have been apparent, thus tacitly assuming that it breeds like eye-color. Also evolution is slow, and in small groups it is likely to lead to extinction.

[16] Another discovery is that large parts of the genotype seems to be junk. My own personal explanation is that if we think of genotypes as programs, there is no pressure to edit them, just as when I myself develop programs in PostScript use old programs deactivating large parts without taking the trouble of excising them, thus ending up with large programs, the majority of which is junk, meaning inactive. The junk may serve historical purposes.

[17] A more reasonable suggestion is that the same problems are encountered again and again in evolution calling for similar solutions. If you want this is an explanation tinged with platonism.

[18] This is referred to in Feynman's Lectures on Physics, and I am a bit embarrassed to admit, what I remember the most from them when I plowed through them briefly in my youth,

responsible for those structures only that they seem to have played some crucial rôle in making them come about. The point being that the ways genes make themselves manifest in the phenotypes are exceedingly subtle.

What seems to fascinate the author most is the possibility of modern biology to spread light on the actual history of evolution in terms of branching and absolute dating. Those were problems that must have occupied Mayr during his active career and he has now the satisfaction at the end of his long life to be let on the secret of the 'facit'[19]*. The basic idea is that of stochastic evolution not driven by a reproductive edge. That many properties, such as the proteins used in the blood, have no particular advantages or disadvantages whatsoever, but are from the point of view of natural selection neutral. Thus changes proceed at a more or less uniform rate. This has turned out to be of invaluable help in revealing what species are close to each other, by looking at innocuous aspects of the phenotypes not their striking features and thus concomitantly judging vicinity in the tree of life by more or less subjective criteria of similarity. The latter is of course a time-honored aspect of biology, more precisely comparative anatomy, where as noted, people of the past, like the Michelangelos of renaissance painting are technically unsurpassed. One may note that Owens, already brought up as a contemporary of Darwin, was the first to point out the similarities between Dinosaurs and birds, anticipating the modern theory that birds evolved from them*[20]*. Also it allows dating of branchings. It all rests on assumptions of uniform speeds, as well as a possibility of calibration. In each particular case this is rather uncertain, but luckily there are many such neutral traits which can be checked and thus lead to confirmations.*

Darwin stressed the gradualness of evolution. That has come under much criticism, both contemporary with Darwin and later on supplying the creationists with their strongest ammunition. Darwin pointed out that the fossil record is by necessity fragmented, the phenomenon of fossilization in the first place is of a very unlikely occurrence depending on many contingent factors. Since the time of Darwin the fossil record has been greatly extended, in particular it is now possible to find many so called missing links in the recent development of hominids; yet the basic problem remains and our knowledge is hence bound to be incomplete and in many cases based on daring and unfalsifiable conjectures. In fact the situation is not that different from that of the Classic scholar who has to be content with a record where the gaps are much greater than what is actually

[19] The special meaning of this Latin word seems peculiar to Swedish, or at least Scandinavian languages. Initially it meant the answers to arithmetical problems in exercise books. Then it got a wider meaning as the solutions to problems in any text book given in the back. The underlying assumption is that those solutions are authoritative and canonical. If even the teacher get stuck, he or she can always look it up at the end of the book. The concept is of course universal, but its identification is not. The idea that there is a 'facit' to all problems in life, even if temporarily unavailable, very much characterizes pupils brought up in the system, so the expression let's look in the 'facit' is immediately understood.

[20] Of course the evidence is somewhat contradictory, as the author points out, and can be read one way or another, as is typical in biology in general and paleontology in particular

preserved. But as with the classics, the students of paleontology nevertheless have available an embarrassing riches of study. The case of complex organs where each part seems to play a crucial role and cannot be removed without disaster, a view very much promoted by Cuvier as already noted, seems thus at first hand immune to a gradual development in which furthermore at each stage presenting no serious impediment to reproductive success. One classical example is the eye, where each part seems perfectly adapted to the whole. Different scenarios for the development of the eye have been proposed, which at least make it seem plausible. One should also keep in mind that evolution has no teological aspects, there is no planning. One organ can have been developed as a response to certain selection pressures, metaphorically speaking, only to be co-opted for another[21]*. Every innovation has unintended consequences, what drives evolution is their exploitation.*

In short Mayr presents a more biological account of evolution than Dawkins and less geared to mathematical elegance and inevitability. Biology is messy and cannot be confined to dogmatic formulas. There are always 'leaks' and exceptions. Evolution in particular is a historical science, which as such can be studied by what I like to call forensic methods, i.e. studying the traces left by the past in the present and interpreting them ingeniously. Many of the strictures that R.G. Collingwood brings to the study of history are also applicable to Evolution, except that in human history the imaginative enactment of thought as a source of motivation is absent in natural history. As stressed evolution has no purpose, and can as well degenerate as advance. In particular the development of intelligence is far from inevitable. One may well imagine that eukaryotic organisms may never have developed or been postponed billions of years, in which case life on earth would have been a soup with no structures history at all, and none to try to formulate it.

Mayr may not present the most up-to-date presentation of Evolution, but at least he leads the reader out of the cul-de-sac in which Dawkins may have tricked him into.

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[21] My own favorite example is the co-option of traffic lights for giving directions in cities. Gould and Lewontine speaks about spandrels.