In Praise of Darwin's Mistakes

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The best way of honouring a scientist is to criticize his theories. According to Karl Popper, a good scientist should in fact criticize his favourite theories as heavily and profoundly as he can, just to see whether they can withstand a deep, perceptive attack. “Kill your darlings”' was the slogan Popper coined for this approach.

But that expression doesn't seem right for criticizing the scientist we are honouring tonight, because Darwin literally saw his darling being killed without being able to do anything about it: he lost his beloved eldest daughter, Annie, at age 10 on April 23, 1851. At that time, he had been working for fourteen years bringing a theory to life, one that would take him six more years of work. The theory stated that the natural selection of random variations among hereditary traits of individual living beings was the motor that kept evolution going.

In *The Origin of Species*, providing extensive factual support for every step in the formulation and argumentation of his theory, Darwin made clear that species were not stable, God-created unities but dynamic, self-created products of natural development.

We can observe variety within species, and in the natural environment some variations survive while others die. Darwin used the term 'natural selection', as opposed to 'artificial selection', which is what breeders do. Variations within species are random, but the process of natural selection is anything but: the only individuals to survive are those that fit in best, are best 'adapted' or 'most successful', or even 'more perfect', as Darwin later wrote.

So why did Annie die?

Evolutionary theory does not answer this question. Evolution is not a linear process of cause and effect but a theory – that is, a tool that enables new observations and makes one think and perhaps experiment in the search for explanations of one's observations. Evolution is a research program, not a final truth.

In a letter published and publicized by Ernst Haeckel, then his main proponent and propagandist in Germany, Darwin wrote, “Evolution has nothing to do with Christ!” Haeckel interpreted this as Darwin saying he was anti-church and anti-Christianity – just as Haeckel himself was, for a very specific reason.

Young Haeckel had been an ambitious researcher and a passionate lover, but he could not marry his adored Anna Sethe until he had secured tenure as a professor at a university somewhere in Germany. His success as a biologist would mean his success as a lover. Haeckel finally got his professorship and married his dear Anna. And then she died, just like that.

Haeckel listened to what the Christian priests and his fellow believers told him: that her soul had gone to a better world. But he could not accept it. He had loved both her body and her soul; there was no distinction between them. Her body had given life to her soul, and her soul had died with her body.

The Christian faith was one big lie, and now that Haeckel had a professorship for life, he was in a position to attack the false hope of a spiritual afterlife offered by Christianity. According to Haeckel, there was only matter, beautiful matter, organizing itself in the most fabulous forms – the art forms of Nature, he called them – and these forms die and fall apart. Haeckel attacked the believers of his time fiercely, even brutally, for the rest of his life. And all his life, he continued to love Anna Sethe, so much that he named the most gorgeous medusae he discovered after her:

Mitrocoma Annae and *Desmonema Annasethe*.

Darwin, on the other hand, did not lose his faith because of his little girl Annie's death. He had already lost it while thinking about the geological and biological observations he had made during his trip on the Beagle.

Evolutionary theory – or the theory of natural selection, as Darwin preferred to call it – never managed to be just a science of a world outside the human condition. When he said "Evolution has nothing to do with Christ," Darwin meant that the theory was part of a different mental space from Christianity. It was a discourse in which Christ was not the Saviour but just another living body trying to survive. In the mental space of modern science, no God is needed to explain the forms and events in nature.

God is replaced by time. If you have billions of years to make things happen, everything has time to create itself. This is not a criticism of religion as such; rather, it draws a boundary line: this type of explanation is scientific, while the one that uses God to explain things is religious. Science and religion are not opposed; they are talking about totally different things. They are answering different questions.

And they use different methods to arrive at these answers, as Darwin proved in the hundreds of pages of 'summary' that was *The Origin of Species*. Darwin was very careful to remove every trace of metaphysics and transcendence from his study of nature. Believers are deeply grateful for the revelations they experience, but scientists mistrust theirs. They want to be convinced not by the emotional effect of a new idea but by the observed and repeatable facts that that idea makes visible and testable. He was a rather emotional man and preferred to trust only in his capacity for rational thought. Annie's death merely made him and his theory just a little less polemical.

Haeckel had his reasons for mixing evolutionary theory with anticlerical polemics, but it made him immune to Darwin's superior insight that evolutionary and Biblical research differed at every conceptual and epistemological level.

Darwin believed that evolutionary theory's ethical, aesthetic and metaphysical aspect lay in the fact that it explained why animals and plants and people always had to die, and only a few survived for long. Darwin wants us to believe that in the long run it's no coincidence that one little turtle reaches the waterline and swims away while all the others get eaten by gulls, or that one acorn grows into a magnificent oak tree while all the rest are consumed and end up as poo. Your survival, Darwin would argue, helps to make the human species better adapted to its environment.

What makes this such a fascinating idea is that it goes entirely against our everyday experience. It's usually sheer coincidence that certain people survive heart attacks, car crashes, tsunamis, civil wars. But this is exactly what makes evolutionary theory so powerful when it comes to provoking the religious. Evolution gives meaning to meaningless historical existence.

And the ethics of evolution says: We all come from the same beginnings, so let's leave enough room for everybody else to survive along with us. Without evolutionary theory there would be no need to respect biodiversity. Evolution inspires us to say to an ape, a fish, a flower, a bacterium: brother, you and me, we're the same. We're part of the same process; we share the same history, in the past and in the future.

An oft-overlooked fact is that neither Darwin nor his modern successors, the neo-Darwinists, explain anything about the actual origin of species. Where do species come from – not particular species but species in general? For some three billion years, bacteria ruled the earth as the only living organisms. Taking their time, slowly but surely, they produced the atmosphere and the environment in which the evolution of plants and animals could later take place. But bacteria themselves have no species, and the reason for this is that they have no sex. They exchange genes with every other bacterium they happen to meet.

Lynn Margulis, the leading voice in this argument, tells a story to explain what would happen if people swapped genes the way bacteria do. Imagine that you dive into a swimming pool where there's only one other person in the water. You don't touch this other guy; you're just in the same water as he is. When you climb out of the pool ten minutes later, you notice that your skin is turning green and large spikes are starting to shoot from your back. At the same moment, the other guy might be growing a tail that he got from your genes.

Bacteria do not produce offspring; they divide their entire bodies and duplicate into identical cells. They copy themselves, and therefore they do not die. Strictly speaking, every living bacterium on Earth is four billion years old. It's exactly the same cell that existed in the beginning – yet with an entirely different genetic make-up. All so-called higher organisms use sexual reproduction to mix their genes; bacteria don't need sex because they do this all the time anyway.

Through their long history, bacteria have incorporated all sorts of hereditary traits, and eliminated as many. But it wasn't until some bacteria moved together and created a new symbiotic life form that sex and propagation became possible. Through a process Margulis calls symbiogenesis, a cell with a nucleus was created out of two bacteria, one of which produced the outer cell membrane while the other made the inner membrane of the nucleus. In this nucleus, all the original cell's free-floating chromosomes and DNA plus the genetic material from the immigrant bacterium mixed and became what is now called a eukaryotic cell or organism.

The good thing about a eukaryote is that the nucleus protects the chromosomes from random exchanges of single genes or gene sets with other living cells. This is what makes species possible – that is, life forms that are sustained for longer periods of time. It's a different method of survival.

Then another development took place. Some bacteria moved into the new formed eukaryotic cells and became mitochondria, the cell's power plants, while retaining their own DNA. And some green bacteria moved into eukaryotic cells and became chloroplasts, the parts of the cell where photosynthesis occurs. In other words, these cells became plants, using sunlight to make food for themselves as well as every animal that eats them.

Some swimming bacteria affixed themselves to eukaryotic cells and became flagellae, turning those cells into actively moving plankton. Other bacteria moved together, coalesced, and became multicellular organisms. Some of these multicellular organisms joined together to become complex bodies – plants, animals, and finally, us. Those bacteria allowed us to come into being: they created our environment, and then they created us; and they are still keeping us alive as we speak.

Yet Darwin overlooked all smaller life forms and claimed that mammals were the highest, most complete living beings on Earth. He was a mammalian chauvinist. In fact, bacteria created all the essential mechanisms needed for life on this planet; evolution is little more than an endless recombination of the clever things bacteria discovered or made billions of years ago.

And they still are far cleverer than us. Bacteria don't die. And neither do their genes. There are 500 immortal genes that have stayed exactly the same in all living organisms for the four billion years of life on Earth, while everything around them has changed with amazing speed. These 500 genes make us breath, metabolize, propagate. Where do they come from? Nobody knows. Where will they take us? They'll stay with us, so don't worry.

So, who are we? Our cells are combinations of bacteria keeping their life processes going together. We are assemblages of bacteria, which interact so sublimely as to bring about organs, limbs, flesh, senses, consciousness. Who governs our synapses? Who digests our food? Who gives the alert to our immune systems? Who allows us to perceive the world around us? As white blood cells, as the flora in our guts, as the tails of spermatozoa, bacteria run our body, and basically our planet as well. And yes – they can also be germs that make us sick and even kill us: Annie Darwin died of tuberculosis caused by a bacterium that wasn't discovered until 40 years after her death.

For five long years, Darwin did nothing but study barnacles, or the subclass Cirripedia, a group of curious hermaphroditic animals one centimetre high with penises up to 38 centimetres long. These crustaceans start as fertilized eggs and then develop into free-swimming larvae, or nauplii, and then transform into different swimming larvae called cyprids. The cyprid finally bangs its head against a stone or other solid object, builds a hard armour around its soft body, and then, yet again, becomes something entirely different: a tentacled living crust residing on a rock or ship's hull.

The genome of this animal seems to consist of three subgenomes: those of the nauplius, the cyprid, and the adult barnacle. The reason, Lynn Margulis argues, is that the animal in fact does have three different genomes. Three individuals, three bacterial assemblages, have come together, shared their genomes, and created one species with three life stages. We find the same phenomenon in red algae, in fungi, ferns and mosses, and in all flowering plants and trees as well. And think of the bizarre life cycle of the butterfly!

When you combine different genomes, you get different species. The neo-Darwinists say mutation is what keeps evolution going. But mutation is nearly always destructive: it makes you less fit, not more so. Nobody ever saw a new species arise solely out of genetic mutation, not even in the lab with fruit flies, the most manipulated, experimented-on species on the planet. But the merging of two genomes would be positive, constructive, and observable within one generation.

Darwinian theory treats variation too lightly. It simply happens, the Darwinians say, and then natural selection sets in. But for variation to take place, something has to vary in an organism's genetic underpinnings. From the 1940s onward, these underpinnings were thought to reside in the chromosomes, in the genes contained in the double helix of DNA, a cell's stable, enduring, but sometimes slightly mutating information carrier. DNA was considered an omnipotent ruler that issued all the orders, taking none from anyone. This has turned out to be fundamentally wrong.

Information means nothing unless there is a device that can read it as such. DNA would be meaningless as a genetic code without mechanisms in the living cell capable of reading it as a code. Variations happen mainly in these reading devices – the so-called switches – rather than in the genes. The switches are where evolution actually takes place.

Ninety-nine percent of our DNA consists of junk: genes or fragments of genes that can no longer be expressed. Natural selection selects only for genes that can be expressed. If a gene mutates in such a way that it can no longer be expressed, it merely stays where it is and

becomes junk DNA, never changing again.

The important transformations take place in the 'genetic network' that reads the information in the genes and expresses them within a set timeframe. The interaction is what changes, not the commands. Genes as such mean very little. Every eye in the animal kingdom is produced according to instructions from the same gene. If this gene is switched on for a long time in certain cells in a developing embryo, the creature will have large camera eyes, like ours and those of octopi and certain snails. But if it is switched on many times for short intervals, a creature will have a greater number of smaller eyes, as in the compound eye of an insect. The different stripes of the three zebra species come from a single gene, which is switched on for a short time in one species and for longer in the others, producing different striping patterns.

And there is even a type of heredity that does not involve DNA – so-called epigenetic heredity, which is what makes kidney cells produce more kidney cells even though they contain the information for all cells of the entire body they are part of. The development of a fertilized egg into a full-blown, properly formed plant or animal is a matter of interactive processes. We have no gene containing a blueprint for our cardiovascular system. Our hands are more or less symmetrical, but the blood vessels under their skin are not. The reason is that blood vessels develop from one point in all directions, in what is known as 'exploratory behaviour', and only those vessels that happen to hit a muscle cell or another cell that needs blood survive; the others eventually wither away. Bodies are the result of interactivity – an internal interactivity. Genes and parts of genes are continuously being replaced, repaired, even rewritten. Genes jump from one chromosome to another. They are constantly breaking down and being rebuilt. Everything is unstable; everything is continuously reorganizing. This is what evolution is about.

So let us honour Charles Darwin, who was willing to stick his neck out and make all the mistakes that you make when you start down a new track, for he was a man who was 'remarkable for being so unremarkable'. And then let us continue, let us make mistakes of our own, and maybe come up with some better proposals for how evolution works – and how it can be influenced. We live in an entirely different world with an entirely different mindset from the one Darwin inhabited, with its ‘dark, satanic mills’. Those are gone, and may the nihilism that went with them be gone too. Today there is much repairing to be done, and much reorientation with respect to nature and life on Earth. In the 21st century, evolutionary theory offers us the hope that all the species that died too early, as Darwin's Annie did, will one day reemerge – not as their old selves with body and soul intact, but as new life forms that will start new lives of their own. Perhaps without us; perhaps not.

After all, life is perfect only for bacteria.

Commissioned by Shift Time - a Festival of Ideas, Shrewsbury 2009, on the occasion of the Bi-centenary of Charles Darwin's birth. World Premiere, Saturday 11th July, Theatre Severn, Shrewsbury. Performed by Geoffrey Streatfeild, Directed by Maggie Love. Toured by Opera North, Leeds as part of the innovative triple bill The Weather Man.