Three evolution researchers talk about Charles Darwin, evolution on other planets and mass extinction on Earth

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Celebrations are held on the 12th of February each year to commemorate the birthday of Charles Darwin, the 19th-century British naturalist, who achieved major insights into the process of evolution thereby completely revolutionising traditional concepts of life on earth

and human's position in it. For Diethard Tautz and Paul Rainey of the Max Planck Institute for Evolutionary Biology in Plön and Ralf Sommer of the Max Planck Institute for Developmental Biology in Tübingen, Darwin laid the foundations for evolutionary science, a field of research, which no longer solely considers the past but, instead, increasingly looks to the future.

Diethard Tautz:"Darwin was a revolutionary!"

What, in your opinion, was Darwin's central insight?

Darwin's greatest achievement was recognising the fact that natural selection is the driving force behind evolution. His explanation for the incredible diversity of life on earth was that those individuals that manage to reproduce and pass on their genes to future generations are locked in a struggle for scarce resources. As a result, these individuals are continuously adapting to new environmental conditions thereby spawning a wide range of different phenotypes and survival strategies. An astonishingly simple principle for such an incredibly diverse phenomenon as life!

Was he a revolutionary?

In a way he was: after all, his realisation of the fact that life does not require a supernatural creator came at a time when religion still played a central role in the lives of many people. So, the fact that he freed his mind of religious concepts of the genesis of life could certainly be thought of as revolutionary. The level of blasphemy that this represented is still evident in the degree to which he continues to be castigated by believers in the Biblical genesis myth to this day.

What can Charles Darwin still teach us today?

He was an incredibly close observer, who analysed the insights he had gained on his trips around the world with extreme care and verified them experimentally before going on to draw a wide range of conclusions. His books are virtually bursting with ideas. Whilst that does make for difficult reading in some passages, they continue to provide a rich source of ideas.

Was he never wrong?

Not really. For a while it had seemed as if his concept of genetic inheritance was completely wrong. He had postulated tiny particles, the so-called gemmules, which, he imaged, transported genetic information from every part of the body to the gonads. Yet, because somatic cells develop largely independently from the germline cells, Darwin's concept appeared to be incorrect. We now know that there actually is a connection between the somatic and germline cells, notwithstanding the fact that their actual mechanisms of genetic inheritance differ. Despite the fact that the basic principles of genetics were still unknown during his lifetime, he was not completely wrong even in this respect.

Paul Rainey: "Where there's life, there's evolution!"

Will we one day understand evolution so well that we can predict its course?

I think this is a worthy aspiration. The question is when and how exactly we will be able to do this. The least difficult to predict are the responses of asexual organisms with large population sizes (e.g. bacteria and viruses) under strong selection. This is why for microbes and viruses we already have models that can describe their future evolution quite reliably. This is of course enormously important for the development of vaccines and antibiotics.

For example, in my lab we have found some of the rules according to which a certain bacterium adapts to new living conditions. Some of these rules can be transferred to other organisms.

If we could turn time back to the origin of life, would evolution be similar again?

I think so - at least in broad outlines. This is because life will find similar ways of adapting to the same kinds of environmental challenge. We refer to this as convergence. It is something we observe today in for example, marsupial and placental mammals. These groups diverged 100 million years ago and yet within each group there are lineages that adapted independently to the same kinds of environments and have the same overall body plans.

Whether among organisms that transition to multicellular life, there will be species that are recognisably human, this is hard to know. But my money would be on the eventual evolution of some kind of bipeadal, introspective type.

There is though one reason to be less sure, and that arises from the lack of certainty surrounding evolution of the eukaryotic cell. The eukaryotic cell was a major revolution and it occured just once. In the absence of the equivalent of a eukaryotic cell life might remain purely microbial.

Is it conceivable that evolution exists elsewhere in the universe, and what kind of life would it produce?

It is entirely conceivable! Life is something that participates in the process of evolution by natural selection. For evolution to occur, entities must vary, reproduce and upon reproduction give rise to offspring that resemble parental types. The moment that such a configuration of matter

exists, the feedback between what selection "sees" and the amplification of form is guaranteed and this is life!

Life on other planets will always be discrete, it will replicate and replication will involve some mechanism for information transformation. Accordingly, life will always be hierarchically structured with self-replicating entities nested within higher order self-replicating entities. This is simply a consequence of the way that natural selection works.

On earth, we see that multicellular organisms are comprised of cells, that cells harbour organelles, that chromosomes are comprosed of genes. On other planets we may see higher levels of organisation akin to, for example, eusocial insect colonies, with humanoid-like entities nested with superorganisms. Or humanoids and artifical intelligence devices fused in a single symbiotic relationship. This may not be so far away on our own planet.

Ralf Sommer: "Evolution is rapid and often conservative!"

Everyone seems to be using the term "species extinction" these days: what effect is the mass extinction of animals, plants and microorganisms having on evolution?

There are so many media reports about this at the moment that you could think it was a new phenomenon. Yet, species extinction has been ongoing for at least 50 years and actually much longer. We now know that wherever humans have settled in the past, we have exterminated many of the large mammals such as mammoths and giant sloths. We've done the same to birds, such as the dodos of Mauritius. On the other

hand, the fact that the rate of species extinction is accelerating is something new.

By contrast with earlier mass extinction events, the current one is the result of human activity – there is no doubt about that! It is not currently possible to predict the effects this will have on the course of evolution. That will depend on the changes human kind will bring about now and in the future, and these are currently barely predictable. However, one thing is certain: we're set to lose many species!

Why can't these organisms adapt to environmental changes such as climate change? After all, they have managed to do so many times in the past.

At the geological timescale, the current episode of global warming is happening at an incredible speed. Certain species are unable to cope with such rapid changes. Others will be able to adapt, as evolution can also be extremely fast. The peppered moth, for example, was long considered an exception: in the course of just a few decades during the 19th century, it changed colour from light to dark, thus adapting to trees that had turned black as a result of high levels of air pollution in England. We now know that the kind of rapid changes undergone by the peppered moth are more the rule than the exception. In general, evolution takes place at the population level rather than the inter-species level. However, global warming is being compounded by the many other environmental changes being wrought by mankind, such as habitat destruction, the cumulative effects of which are simply beyond the adaptive potential of many species.

What has your own research taught you about evolution?

I'm particularly interested in the interplay between genetics and the environment and the emergence of novelty. So, for example, how does evolution result in something as complex as an eye or a wing and what changes are involved within the genome? Our research and that of other research groups has shown that evolution is often extremely conservative, falling back on existing genes and assigning them new tasks. This also explains why such different lifeforms as the nematodes and fruit flies possess so many of the same genes as we humans. Our research has demonstrated that this gene reassignment is a central principle of evolution and that the environment plays a decisive role in this context.

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