Saturday 9 October, 11:30–12:30pm CET

Closing Plenary

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Closing Keynote Lecture

The origin of life: how science is addressing one of humanity's most complex and profound questions

"I would like to share with you some thoughts about one of the very profound question in science nowadays: the origin of life.

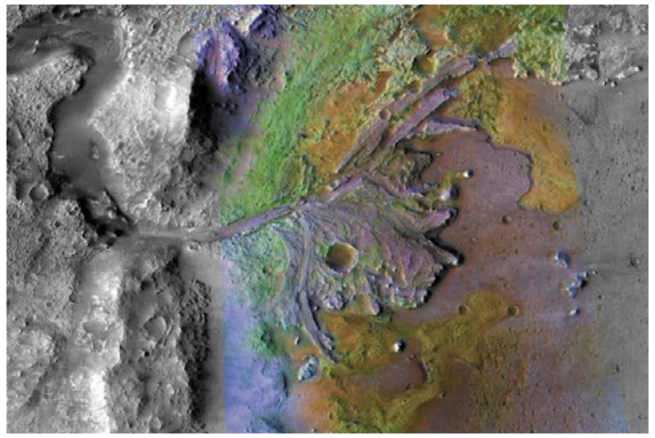
If you think about science, about knowledge, I think that, as a scientist, we can identify ourselves along with these three topics: either we are dealing with 'matter', or with 'life', or with 'consciousness'. But look closer, and you will realize that these three topics still are at the fundamental level of key questions – this even about 'the matter', of which we have an amazing understanding right now. We actually have to face the very embarrassing reality that we have no idea of what the biggest part of our Universe consists of. And for life, that is also true: we are curing diseases, we have an amazing understanding of the working mechanisms of life, but do we understand anything about the origin of life? Finally, consciousness is certainly the most profound element here. So, if we are asking ourselves about what we know about these three topics, well, the answer is very simple: not very much, actually.

I would like, today, to spend a bit of time talking about life because I think there is something happening right now, a kind of paradigm shift. Let us address these very simple and generic questions: how did life (as we know it today) start on Earth? What can we say about other forms of life in the Universe which includes our solar system? And can we know something about the nature of life? Is life always made exactly the very same? These kinds of topics seem a bit extravagant, close to science fiction. But actually, they are taken very seriously right now, and scientists are making tremendous progress. I am even taking a bet here that this century will be the one when massive changes and gains of knowledge will be made on that topic.

Similarly, if you look back at the previous times, main achievements were done in understanding the matter around the end of the 19th century. One of the most visible advances is that we are now able to reproduce on Earth – unfortunately to us – what is taking place in the sun with the thermonuclear power. Similarly, we may end up during this 21st century by being able to make life from scratch. This will drive a lot of interesting questions and fascinating societal impacts.

So, starting at the very early stage of the Earth formation, there is all this dust and rocky material being brought together. Then the Earth cools down, through a very complex geophysical evolution. But this evolution, at some point, turns out to form the location where life can begin. This is a general development that we describe. But when we look at a planet around another start [a so-called exoplanet], we can study the atmosphere of this planet; this can be done at three different stages, which we can trace down, remotely. And many big questions appear during such observations. For example: why do we have so much oxygen at some point? We know it is because of life, but why exactly? What is the consequence of that? Because it has cooled down the Earth, etc. There are a lot of very interesting effect that we can study there. On top of that, what is going to happen in the first billion years, in the case of the Earth, is the building up of life. If we want to simplify the concept, we essentially have to start from scratch. Then we have to build up the complexity, until we have something that would qualify of being alive. We know very little of that, but tremendous progress are being done these days in laboratories in combination with what we start learning on other planets.

The obvious 'origin of life' mechanism that we have some idea about, is when we have on Earth enough water, enough volcanic activity, enough of infalling comets bringing these necessary acids (which are not the most obvious gas one would think about for the origin of life) and enough UV radiation from the sun. We are then doing a very fascinating chemistry. Not so long ago, there were a couple of projects which developed a first set of chemical reactions establishing the foundations of the origin of life – and one of the most famous, done in 2015, might eventually be awarded a Nobel Prize in ten to 15 years. And what is fascinating about that is that we can test all this, in very different ways. This is a big change because science is not about ideas, it is about facts, about data.



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Let us move a bit. We are on Mars right now: we have a robot right sitting in a very precise location [inside giant Jezero crater, see image above]. You do not need to be a geophysicist to recognize that what the rover stands on is a delta of the river. And this is what Mars looked like three billion years ago. But what is fascinating is that, if you take the first billion years on Mars, this is exactly also the time at which life started on Earth. So there is a serious hint that we are going to see [on Mars] some fascinating chemistry, which is related to the origin of life. The gift of having Mars, which was almost the same as the Earth [when both planet were been created with the solar system about 4,5 billion years ago], is that it stopped its evolution as a planet, while the evolution of the Earth went on –. We have no clue exactly what Earth was like at that time, three billion years ago, but we have Mars: this is why we are so eager to bring back [Martian] rocks. You may expect tremendous changes of concept. Think about the fact that maybe there has been some life on Mars and the life would be different or the same – about the chemistry you are thinking for life on Earth. This breakthrough is going to happen. This is what will come in the next 15 years, really tomorrow in terms of science.

Now, the other big revolution, which is related to my work, is that we know there are planets everywhere. It has been a massive revolution for astrophysics. And then, of course, the obvious question is what it means for life? And do we have life on these many planets? And this reflexion comes back again and again. Therefore, this is very central to our topic to find out what we understand through 'life'.

But the clue here relates back to the atmosphere of these exoplanets I mentioned before. Any event related to the formation of life leaves traces in them, which we can read in the infrared light that we observe [of those exoplanets]: big volcanic events, big impacts [of a celestial body] make an imprint on the planet. So looking for life on the planet is not just looking for extraterrestrial radio [signals], it is looking for the signatures of life that could be at different stages of life evolution. So, now that we are also moving from one planetary system [our own] to many, we may end up having a complete understanding of the diversity of life – or not. And that, too, will be happening, in this century.

The challenge here – and I think this is the relevant element for our discussion – is that to make it work, we have to bring a couple of disciplines together: chemistry, biochemistry, geophysics, physics and a lot of technology (with these big telescopes that we are dreaming to fly, or set on the Moon). There are a whole lot of disciplines involved. But when you start embarking on this topic, you realize that the main problem is the lack of bridges between these disciplines. It is impossible for an astrophysicist to understand life if he does not talk a biologist. Well, try to explain astrophysics to biologists. Try to do experiments involving biology, chemistry and physics. In my own experience as a physicist, for example, we have something we call 'error bars' [to go with every measurement]. We love error bars in statistics. But, when you talk to a chemist, they can look at you like stubbornly and ask: 'What are you talking about?' There is a lot, lot of jargon, of language, of definitions that we have to go through. And it turns out it is not the topic which is limiting the progress, but it is the structure of the way the topic is being organized.

And it goes even further than that. The communication channels between disciplines are difficult because the way science is being organized is the same as it was in the Victorian age. We have not made very much progress. Look at the universities: they still organize themselves the same way. It is very difficult to implement a joint lectureship, or a joint programme, or a joint PhD. Try to make a proposal that brings physicists and chemists together: either one part of the panel – the physicists – will tell you the physics is not good enough or the panel of chemists will tell you the chemistry is not good enough. You will never get it to work, because both sides expect a very targeted kind of science. I think our programme [on the origin of life, that we develop at ETHZ] can certainly be applied to other kinds of topics.

That said, the most interesting aspect that I start discovering with this effort is what I call the 'philosophical preconceptions'. When you do science, you embed into your science programme your social background, your language, your education and the global perceptions about how you are reflecting about the society. It is even more profound for some topics which are directly controversial, like genetics. But already when you are dealing with the origin of life, you are entering into a fascinating debate and you cannot do science without bringing this reflection in the game. What I am telling you right now is absolutely heretical. It means bringing art and humanities together with hard-core sciences. We barely start to bring the latter into what is described as 'soft sciences', that is the social sciences. It is now getting together slowly, but to move fully to the art and humanities, there still is a bigger bridge to cross. But we may have to do that as well. And of course, it is not interest on the side of the researchers that is lacking, it is the will to make a change into the structure of the science. I am addressing this to people who are part of the national agencies, which are sponsoring science, or foundations. We all can do something here. While we know this will be fixed one day, we should all try to understand that the future is not anymore in this many silos of disciplines.

Actually, we have to bring back something that dates back to the 17th century. Let us look at Leonardo da Vinci, for example. He was a painter, an engineer and a physicist – no big deal at that time. Well, why not try to implement this in terms of structural design into science? We do not have to build a science entirely on that idea, but bringing a lot of more flexibility is needed. So I think some kind of polymath skill and training will be necessary.

All in all, if I want to give a very short message to this assembly, it is the following: this topic of 'life in the universe', which we are going to organize ourselves around at ETHZ, will also be at the heart of the other centres, at the University of Cambridge in the UK, but also at Harvard in the United States, at Princeton, at the Carnegie Institution, because they all understand the same needs now. This very same structural idea should be used on other topics to really think more globally, and embark on more global programmes.

I thank you for your attention."

Discussion

Niniane Paeffgen: You mentioned it in your talk, it is, for scientists, already very difficult to work together in a transversal way, understand the other scientists are doing in their fields. There is a need for bridges to be built, to explain the science, this also to a broader public. How can we explain what is happening within the science and reach to a more broader public?

Didier Queloz: That is a vast question. First, I believe science is an organic body: I do not think one can conduct science. Any programme that tends to be conducting science is going to fail – and there are a couple of massive failure when programme being too much oriented led to absolute catastrophes. Science is closer to arts, in terms of pure energy. So let the science do the science. Let the scientists do what they need to do. Stop telling them what to do. Stop bring in limitations, red tape and all this administrative burden. Just ask them what they want to do. And that is something that is related to the second part of the question: what about society? Well, we are all part of society! And we all feel that we are fortunate to be very educated people – especially in this audience, which is amazingly educated. I think the more educated you are, the more you feel responsible and should give back time to society. And this is something we can do much better. Sometimes, when talking to private industries, they say: "We are paying enough tax, so I do not see why we should do better". Well – I reply – you should do better because if you stop, if you keep disconnecting from the society, sooner or later, society will come back to you. And that will be really bad. We already see a little bit that problem of the disconnection between the science of knowledge and society. And I think this is something we should respect, while we tend to send all those people as not knowing what they are talking about. But I think these people, they are talking about something that they feel is important for them. As a scientist, as an educated person, as someone responsible for an institution, I feel like we do not do enough. We never do enough. We should really acknowledge that. Maybe all the entities which are spreading and funding knowledge, should consider making way more effort. And that cannot go without the help of the social sciences, through understanding the psychology of society of these topics.

More information

Video recording of the Session on YouTube