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MARCH 28, 2007, 6:28 PM  
**Life Is Evolution**  
By BRIAN MAY

Some of you out there who know me better as a rock guitarist (of Queen, et al.) may also know that I have elected to go back to Imperial College London, after an absence of 30 years or so (I was busy!), as a post-graduate student, re-registering for the Ph.D. in astrophysics that I began around 1970. Laying my cards on the table, I am very aware of my essentially amateur status, but eager to catch up on the last 30 years of astronomical research. I get to go to some pretty high-powered seminars, plus enjoy the privilege of being around scientists who are in touch with the most distant surface of the bubble of knowledge that we are pushing out into the observable universe. And this gives me wonderful opportunities for insight.

But I have an extra secret bonus. I have taken to sneaking into my daughter's undergraduate biology lectures. The question of life was the part of our journey in writing the book "Bang!" that put the three of us most at odds – and we maintain a healthy dialogue as time goes by. So I find myself drawn to anything that can throw light on the murky question, Are we alone? I'd just like to pass on a few thoughts from a recent series of lectures (by Professor Tim Barraclough) that thrilled me, given by the biology department at Imperial College under the title, "What is Life?" The answer, brilliantly put, was in fact, "life is evolution," and "evolution is life." Let me explain.

I think most people now know that the job of mapping the human genome was recently completed – the genome being effectively a complete "recipe" for a human being – a set of instructions or decisions, if you like, about how to put the basic atoms of nature into the right order. The genomes for many other animals have now been tabulated, giving great insights into which animals are most closely related in their family histories. This is where we meet the magic of evolution.

The genomes give clear clues as to how one kind of animal, under the influence of natural selection, can evolve into a different species. By the way, it is clear here that *all* the animals alive on the planet today are the most highly evolved examples of their particular line of descent – otherwise they would not be here. Human beings have no right to consider themselves any more special than any of our fellow survivors on the planet. And as far as being the dominant species, there is no question that bacteria, not us, are way out in front – in their numbers, in the

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**About the Authors**

**Sir Patrick Moore** has been the host of "The Sky at Night," a monthly television show about astronomy on the BBC, for 50 years. He is the author of more than 60 books on astronomy, and his own studies have focused on the Moon. Moore is also an accomplished xylophone player and composer. He is a coauthor, with Chris Lintott and Brian May, of "Bang!: The Complete History of the Universe," which will be published in the United States this fall.  
[Read more about Sir Patrick Moore](#)  
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**Brian May**, best known as a guitarist, songwriter and performer for Queen, began his doctoral studies on the subject of interplanetary dust before the band hit it big in the early 1970s. Through the years, he retained a strong interest in astronomy, appearing regularly on Moore's TV show, "The Sky at Night." May has recently returned to his studies in astrophysics. He is a coauthor of "Bang!"  
[Read more about Brian May](#)  
[Queen Online](#)



**Chris Lintott**, has been a co-host (with Sir Patrick Moore) of "The Sky at Night" since 2000. He recently completed his doctorate and is now studying star formation at the University of Oxford. He is a coauthor of "Bang!"  
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number of environments they inhabit and even in total mass.

The lecturer asked us how we would define life. What distinguishes something that is alive as opposed to something inanimate? Many answers came up; movement, respiration, consciousness, the ability to replicate, the assimilation of energy, self-organization – the property of contradicting the second law of thermodynamics by making ourselves more ordered (reference [Schrödinger](#)) – metabolism, birth, death, communication and the ability *to evolve*. All of these were accepted as valid signs of life. But is there a single thing that characterises life?

The lecturer reminded us that natural selection can take place only if a) the organism can reproduce itself, and b) the reproduction is subject to mutation – i.e., “mistakes” are made in the replication so that the offspring is not quite identical to its parents. It is only these mistakes that, by rendering the animal more successful in the struggle for survival and reproduction, can drive evolution forward. Of course, we are all aware that in some quarters in the United States, shockingly for the scientific community, there is complete denial that evolution exists.

The line of thought above leads us to an interesting comment on this. We know that, for instance, a fruit fly exists. Relative to us, it’s a fairly simple organism. It exists, so how did this come about? There are perhaps three alternatives. One is that fruit flies evolved from less complex organisms over the last 3 billion years or so. This is the view of modern biologists worldwide.

Another possibility is that a fruit fly spontaneously came into existence at some point in time, and it just reproduces. Since the genome of the fruit fly is now mapped, we know that it consists of 122.7 million base pairs, arranged along the DNA helix. The chance that this sequence could happen spontaneously is something like one in 10 to the power of 200 million. This number is beyond astronomical. The number of stars in the Milky Way is reckoned to be about 100 billion, a mere 10 to the 11th. The number of stars in the whole observable universe? About 100 billion times 100 billion, or 10 to about the power of 18. Again – an insignificant number relative to that fruit fly statistic. What does this mean? If the probability of a fruit fly self-creating in *our* solar system is small, what is the probability that it might come about somewhere else in the universe? Well, doing the elementary math ... still about one in 10 to the power of 200 million.

O.K., there are simpler organisms, but the figure for *E. coli* is still 10 to the power of 8 million. So this is pretty unlikely too, to put it mildly. So the second alternative looks pretty unlikely, right? Is this an argument for some “intelligence” having pulled this off? Absolutely not! Because now that we know the mechanisms by which evolution works, it’s evident that the chance of these complex organisms evolving over the last 3 billion years is wonderfully high. We have even seen evolution in process in our lifetimes.

So what of the third option? That a superhuman being created the fly? But if this being – which we might call a higher power, or God, if we like – made the fly, would he do it in this unlikely way, rather than just letting it evolve? Probably not; as usual in scientific circles, the simplest answer is generally found to be most likely. Divine intervention theories are very unlikely to be correct, simply because we have no evidence of this kind of

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interference happening from outside, whereas we have mountains of evidence for evolution.

There is too little room here for all the details, but the conclusion that our lecturer came to was quite a thrilling revelation to me: that evolution is not something that happens once life exists – it is the *definition* of life. Life may be defined as *matter that undergoes natural selection*.

There remains a basic question that no one I know can yet answer satisfactorily: How did life get started? Once we know the answer to this, we will be able to figure out logically the probability of life beginning in other worlds. But we will still not know *why* the universe produced life at all. This, in my opinion, is where there ought to be no conflict between religion and science. One takes over where the other leaves off. I believe this is a healthy situation.

O.K. – far enough for now. But I will be watching for news from the front. As Patrick says, if we *do* find life on Mars, things will be looking a little more rosy for the theory that, given the right conditions, life always will evolve. My deepest instinct is that this is ... doubtful. But I hope to enjoy being proved wrong!

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#### 8 comments so far...

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1. March 29th, 2007 1:51 am  
Mr. May, you may be surprised to find that Britain harbors creationists. Oh, not to the embarrassing extent that such hics exist here in the states, but all countries have hics, rubes, and rustics.  
– Posted by Steve
- 
2. March 29th, 2007 1:56 am  
I like the idea of defining life as a function of process.  
There has been much ado about the size of certain genomes, and the significance of genome size. (As opposed to the probability of obtaining a specific sequence of a specific length — discussed here by Brian May.)  
At times, and absent a better understanding of how whole genomes evolve, such ado sometimes seems a tad premature.  
That said, I should point out that the *Drosophila* genome is about 180 million bases — rather than 122.7 bases. This doesn't affect May's argument, which seems to be based on the first figure.  
– Posted by Bette Phimister
- 
3. March 29th, 2007 2:18 am  
Wonderful article. I never really liked the definition of life presented to me in grade school. There we learned that life meant six essential properties: growth, acquisition of energy, use of energy, elimination of waste, response to environment, and reproduction. Even adding self-organization, these definitions are actually still broad enough to encompass entities that don't really seem like life at all, such as stars!  
(Stars change in size as they age, they start off with hydrogen fuel as their energy, they burn it, they eliminate the waste as radiant energy and as huge gas ejections or explosions when they die, they change size dynamically to maintain hydrostatic equilibrium, and they reproduce by expelling their contents when they die to be used by the next generation of stars.)  
But evolution is really something that we only see in entities that we all regard as being alive. That is indeed a nice definition. (Stars, for instance, don't appear to evolve over their generations by any kind of natural selection process!)  
Two minor notes: Life forms don't really violate the Second Law of Thermodynamics, as I'm sure May knows but didn't fully explain in his attempt at a simple presentation. The Second Law only implies

that entropy must steadily increase for closed systems, while life forms have a continuous supply of external energy (from eating each other, and ultimately from the sun, or the Earth's geothermal heat for organisms that live at the bottom of the sea). Indeed, life forms expel heat as they live, causing the overall entropy of their environment to increase. No macroscopic system that we know of violates the Second Law.

Also, I think there's a typo when May writes that the fruit fly genome has "122.7 base pairs". That seems way too few. The human genome has 3 billion base pairs! And the .7 doesn't make sense!

– Posted by Tim

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4. March 29th, 2007 2:40 am
- I have pondered the same notion of evolution as life but it it ultimately quite unsatisfying. I have pondered the same notion of evolution as life but it ultimately quite unsatisfying. There are many things in the universe that evolve but never fit the standard definition of life. Viruses are the simplest example; clearly they have evolved but biology holds that only cells (capable of reproduction without a host) are life. On a farther limb, stars, as forms of mass and energy could be seen as evolving. The idea of supernovae as births of new neutron stars and the production of new elements from their enormous energy may invoke awe and grandeur but it brings us no closer to questions we must ask as scientists. The metaphysical question of what constitutes life makes for a nice conversation or hobby, but the true scientists devotes himself or herself to arduous Kuhnian task of advancing his field, not overturning it.
- Posted by Ben Navot

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5. March 29th, 2007 2:41 am
- A yet more interesting question is what defines "natural selection." Surely we, as humans, are a part of nature since "all the animals alive on the planet today are the most highly evolved examples of their particular line of descent" there is little room for human exceptionalism. But robots, under our guidance, can reproduce. How is this guidance (or the so-called unnatural selection of dogs to be amiable pets) different from protection accorded to the clown fish by an anemone. Do these robots (and they are quite primitive, not to be mistaken for AI) constitute life as an evolvable system?
- Posted by Ben Navot

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6. March 29th, 2007 2:58 am
- Any question asked can be answered with 'but why?' Even if someone makes an all inclusive statement such as 'evolution is eternal and never ending' to that someone can counter with 'why?' In terms of the limited comprehension we have as human beings we are given the benefit of the 'why' as an impetus for moving forward. In other words 'why' and evolution are intrinsically linked. At least philosophically with the common boundaries of human understanding of life. Step out of the commonality and one is faced with what Werner Herzog calls 'the monumental indifference of nature.' It is luck that the universe we occupy has something that questions it. This makes us unique. An anomaly in this vast 'monumental indifference.'
- What we are left with is the contemplation and the actions that may lead us to a better understanding of how we can best serve it with whatever we can discover about it in the time that we have as conscious living beings. And then again... I could be wrong.
- Posted by ilan katin

- 
7. March 29th, 2007 6:35 am
- If you want to read an intriguing theory of how life originated, see Stuart Kauffman's *At Home in the Universe*, 1995.
- Posted by Marilyn Cooper

- 
8. March 29th, 2007 7:51 am
- I like the idea that life is evolution. Of course, "when" life started is a question that needs to be refined a bit. I am sure things started as some sort of self replicating chemical composition, much simpler than DNA or RNA. The process may not have even been unique, but the one that eventually evolved into us what just a bit better than any

other self replicating processes out there. The process also had the property that it suffered some sort of copy errors, which allowed it to evolve into a more efficient self replicating process. Then eventually things took off. (I wanted to end that last sentence with “and here we are”, but there were other things besides mutation that had to occur before complex organisms like mammals came about, like multicellular structures and that whole business of some “cells” incorporating themselves into other “cells”-mitochondria being the obvious example).

Anyway Brian, I envy you for the journey you have (re)begun! Graduate school can be an exciting time, probably even more so for you since you are emotionally mature (and not willing to put up with an overbearing advisor like I had to).

— Posted by Rick Phelps

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