Conversation with Bruce Damer and David Deamer

Bruce Frederick Damer, PhD (born 31 January 1962) is a Canadian-American multi disciplinary scientist, designer, and author. Dr. Bruce Damer collaborates with colleagues developing and testing new models for the origin of life on Earth and in the design of spacecraft architectures to provide a viable path for the expansion of human civilization beyond the Earth. He began his career in the 1980s developing some of the earliest user interfaces for personal computers, led a community in the 1990s bringing the first multi-user virtual worlds to the Internet, and since 2000 supported NASA and the space industry on numerous simulations and spacecraft designs. He currently serves as Principal Scientist at DigitalSpace; Associate Researcher in the Department of Biomolecular Engineering at UC Santa Cruz; Associate of the NASA Astrobiology Centre; Member of the International Society for the Study of the Origin of Life, and Founding Director of the Contact Consortium. He received his PhD from University College, Dublin; MSEE from the University of Southern California and BSc from the University of Victoria.

David Wilson Deamer (born April 21, 1939) is an American biologist and Research Professor of Biomolecular Engineering at the University of California, Santa Cruz. Deamer has made significant contributions to the field of membrane biophysics. His work led to a novel method of DNA sequencing and a more complete understanding of the role of membranes in the origin of life.

He is the author or editor of 198 research papers and 12 books, including The Origins of Life (2010), co-edited with Jack W. Szostak, and First Life (2011), published by the University of California Press.

He was awarded a Guggenheim Fellowship in 1985, which supported research at the Australian National University in Canberra to investigate organic compounds in the Murchison meteorite. He served as the president of the International Society for the Study of the Origin of Life, 2013 - 14.

8.3.2018

Prof. Kulczyk,
Prof. Abraham forwarded on your message and your book. I work on a new approach to the origin of life at UCSC and with colleagues around the world. This might be of interest to you and factor into your hypothesis. I can share our approach and publications if this is of interest.

bruce

9.3.2018

Dear Bruce,

Thank you for your email.

I am interested in your work and please send me reprints of your publications.
Regards Konrad

10.3.2018
Konrad,
Here is a short video, a TEDx talk of only 9 minutes, which describes my own quest around the fascinating question of life's origins, and a simple explanation of how the model developed with David Deamer works.

In the Beginning: The Origin & Purpose of Life | Dr. Bruce Damer | TEDxSantaCruz
Are we compelled to become an interplanetary species?
Scientist and designer Bruce Damer thinks so. In this philosophical talk he elaborates on a new theory of the origin of life, and makes the case that the future of all life on earth lies in complete, and radical, collaboration.
https://www.youtube.com/watch?v=6qiW4aUqtvA
(there is a second TEDx talk on the future in space if interested, it should come up)

Experimentally we are advancing along, having shown that we can nonenzymatically synthesize RNA from AMP and UMP (without activation) through wet-dry cycling. This is a discovery Dave Deamer made in the 1990s. Adding lipid to our solutions we can encapsulate these random sequence polymers within liposomes during rehydration cycles. Polymers that stabilize these fragile, fatty acid vesicles are selected for as they survive the hydration cycle and end up being "coupled" back into a moist accumulation of surviving protocells which then fuse back together into the lamellae where they can be re-synthesized or subject to templating. This is described in the Coupled Phases paper.

So this model tests out empirically (in the lab and in actual volcanic hydrothermal conditions like Yellowstone and Bumpass Hell) to a point. It makes a number of predictions. I am attaching the two fundamental papers and the Scientific American cover story (from last August attached). It may well be that hydrothermal field pools subject to regular refilling and drying could be the "engine of creation" to life the functions (like an OS) of life into being. Its actually the first end-to-end hypothesis proposed in science (surprisingly). Solution chemists dont have a systems view, so they tend to focus only on a few experiments that wind down to equilibrium,. hence no model.

Dave Deamer's book from Oxford is coming out in the summer and will put the entire synthesis out to the scientific community. I am presenting this model plus implications at a number of events outside our field, one at the "Science and Nonduality" conference last year, which is also a short connection between this origins model and a model for consciousness and the larger "field" that it resides in (Huxley's concept of an overmind I suppose)... a reductionist explanation:
https://www.youtube.com/watch?v=StiSkRMQOV4

I hope this is of interest. I am now looking through your book as it provides an apt summary of all the issues for OoL and the conundrum of how such a complex thing as a cell (any cell that can divide) can arise. I think we have a plausible proposal for this as it would be a network of simpler entities (protocells) sharing innovations and products within a Woesean "progenote" that could lift such a system out of the background (this is described in the attached "Darwins Warm Little Pond" essay.

This is new to science and a number of laboratories are now testing elements of this, including synthesis of large peptide libraries, and work with protocells.

bruce

encl. 17-08-SciAm-wCOVER_NewOriginsOfLife-V

13.03.2018
Bruce,

I found your three presentations very interesting and visionary. Your solution for harvesting asteroids is a piece of brilliant engineering.

Your hypothesis of hydrothermal fields is far more plausible than that of hydrothermal underwater vents. I doubt if sea vents could produce a high concentration of organic molecules and high temperature gradients would destroy any molecular structures formed.

I have some questions relating to the paper in Scientific American.

1) Page 35. “*the numbers of combinations in terrestrial geothermal fields suggest that life could have originated and begun to evolve in as little as 10 million years*”. What were the assumptions used to estimate this period of time? How complex was the first living cell used in this estimation?

2) Illustration Page 33. *“**Distribution 5**. The best-adapted protocells spread to other pools or streams, moving by wind and water, and some develop the ability to use carbon dioxide for photosynthesis”.*

What are the criteria of best adaptation?

How have protocells developed the process of photosynthesis which is critical for life?

Regards

Konrad,

14.03.2018 (from Damer)

Thank you very much Konrad. I am copying my colleague David Deamer (co-author of the SciAm article) to address your questions below.

My responses, the 10 million year time frame is a total guess (totally hand waving). We wanted to point out that life might be able to start rather quickly (not hundreds of millions of years) as the chemical process to synthesize, cycle and select polymers happen rapidly (hours to days) not on geological time scales.

My other response is that Dave had proposed the polycyclic hydrocarbon compounds might have provided the first pigments to capture sunlight. They are abundant in space and would have been falling into the Hadean atmosphere in much larger quantity (as they still do today on dust particles and meteorites).

I hope this helps!

bruce

15.03.2018

Thank you Bruce,

I would like to know about any assumptions or data used to estimate the 10 million years period.

I am interested in the transition from nonliving to living matter and any information will be appreciated.

Konrad

15.03.2018 (from D. Deamer, copy to Damer)

Konrad wrote: *"I would like to know about any assumptions or data used to estimate the 10 million years period*."

Bruce replied: *"My responses, the 10 million year time frame is a total guess (totally hand waving). We wanted to point out that life might be able to start rather quickly (not hundreds of millions of years) as the chemical process to synthesize, cycle and select polymers happen rapidly (hours to days) not on geological time scales*."

Dear Konrad and Bruce -- We might be able to reduce Bruce's "totally hand waving" to "informed speculation." For instance, a billion years went by between Earth's origin 4.5 billion years ago to the 3.5 billion year old microbial stromatolites in Western Australia. These microorganisms were pretty advanced, so more primitive organisms and LUCA existed before that time. We can reduce the billion year time span by the zircon results indicating that an ocean had condensed over 4 billion years ago. Life requires liquid water, so we might propose that the earliest time for life to have originated was perhaps 4.1 billion years ago with an uncertainty of plus or minus 100 million years. This number is consistent with the recent paper in PNAS by Pearce et al. who came to the same conclusion by an entirely different approach.

Now let's go to the other extreme, which is the time required for protocells to emerge, defined as random polymers encapsulated in membrane-bounded vesicles. As Bruce pointed out, given a few milligrams of membrane-forming amphiphiles such as fatty acids, and a source of monomers like amino acids and nucleotides, such mixtures assemble into trillions of protocells within a few hours when exposed to wet-dry cycles simulating hydrothermal conditions associated with terrestrial volcanism. So, on a geological time scale, the assembly of protocells is virtually instantaneous!

If that is not a rate limiting step, then the question comes down to the amount of time required for populations of random protocells to undergo selection and evolution in which the polymers become increasingly functional. Bruce and I have speculated about what the functional properties might be, which include stabilization of fragile membranes, pore formation in the lipid bilayers, and catalysis of polymerization reactions and primitive metabolic reactions. This is where the informed speculation begins, because we just don't know enough yet. Bruce's 10 million years is somewhere between one year, which would seem to be not enough time, and 100 million years which seems to be more than enough time. What I cling to optimistically is the 1993 paper by Bartel and Szostak in which they synthesized 300mers of RNA with entirely random sequences, then selected for ligase activity by cycles of selection and amplifications. In just ten cycles, the random sequences had evolved into species of ribozymes with an activity 7 million times greater than the starting material. Our task now is to perform a similar experiment with the random protocells we are producing in the laboratory.

Dave Deamer

19.03.2018

Dear David, (copy to Damer)
Thank you for your email and explanation of the timescale and the RNA World.
In your paper *On the origin of systems* in EMBO *reports* you describe the immense complexity of the living organism. You write, *Primitive versions of these four syst-tems must have comprised the first unit of life*. My understanding is that these four systems must have developed in parallel to function in the living cell. I am not sure how different they could be from present day simple bacteria systems because they must have included photosynthesis and respiration processes.
I would like to know how you envisage the transition from simple protocellsÂ to these four systems which would need at leastÂ 500 proteins/enzymes to function. How could natural selection operate on non-living matter to develop these 500 genes?
Regards
Konrad

20.03.2018 (copy to Deamer)

Konrad,

Weighing in here in case Dave is busy (and he is getting that way these days).

You nail the next problem on the head! This phase of prebiotic evolution, or "pre-life" is a major frontier which will be colonized first by thought experiments, as experimentation to "cross the gap" from non-living to living matter (coherent, dividing cells) is going to be years or more likely, decades hence.

For some clues as to what this shape might take, we are relying on Carl Woese and George Fox's concept of the "progenote", a kind of "boot up phase" of life in which the "relationship between phenotype and genotype is being established". In the attached Essay I cover our proposal of a candidate for this progenote, a "gel phase" mass of increasingly robust protocells which will accumulate in each wet-dry cycle as stable and increasingly robust protocells aggregate at the bottom of their pools. This third phase is critical to crossing the gap as it possesses the compelling property of "the whole being greater than the sum of its parts". Like the Internet, or any network (including chemical circuits and economic trading arrangements), the properties and capacities of the whole network vastly exceeds the individual building blocks.The gel phase "progenote" is a structure or "niche" which will enable polymers and solutes to interact in a concentrating medium (the drying pool) and could begin to support metabolic processes, including the emergence of catalysts, and the sharing of products of these reactions between the units of the gel, the protocells. Note that this gel aggregate continues to dry down and fuses back into layers (lamellae) which then permits the synthesis of polymers. Some sets of polymers formerly associated with a protocell might stay together within the lamellae, others are mixed, some are broken down. But overall the system is a "kinetic trap" enabling synthesis (and testing) of more complex (longer) sets of polymers.

So this is our "back of an envelope" sketch of a plausible (and ultimately testable) networked system to accelerate the emergence of the functions of biology (such as enzymes) in a cycling system which is entirely initially driven by the physics of a cycling pool and self-assembly. The whole system can be thought of as like a "boot up" of a chemical OS with services gradually coming online to make previously physically-driven functions more efficient and then replacing them with active processes driven by captured energy. Over time one service will make new services possible, and the system stacks up (like the Internet or the computer I am writing this to you on now).

Note that in the progenote world (the "progenean" if you will) there would be no efficient, optimized protein/enzyme interactions. All chemical processes would be probabilistic, or "rickety" (a term Dave and I use to describe this earliest phase of pre-life). The entire system is actually a brownian ratchet with a better than fifty percent chance of working for the protocell line, or at least the shared polymer systems to go on. This is derived from Freeman Dyson, who has been following and critiquing this work for almost a decade now. Note also that in the progenote world, there is not yet any cell division carried out under distinct controls so there is no "vertical descent" of genetic material. In addition, in this system that is gradually becoming the microbial community there is no efficient translation system with repair mechanisms, tight coupling between processes and garbage collection that we see in modern biology. This phase cannot be viewed through the lens of the modern (even minimal) biological cell. One has to take the viewpoint of a rickety scaffolding emerging, still largely supported by regularly delivered energy (through wet-dry cycling and hydrothermal waters and possibly UV), a steady influx of monomers and other compounds from available sources, and that it can take place only in ideal "Goldilocks" conditions. In the progenean there will be many, many starts and failures, but as there is distribution of units of protocell aggregates between pools, the products of molecular evolution can be shared horizontally across the landscape, lowering the risk of their loss due to changing conditions.

None of our colleague think in these terms, as they don't have an end-to-end model for their scenarios. The field is mainly dominated by solution chemists, geochemists and geologists (and theorists detached from experiment) who get excited about a few reactions that might generate a prebiotic component, or the chemistry of water/mineral interactions, or computer models. Most of our colleagues do not think systemically or understand the full scope of the origin of life problem you stated below: how does one cross the chasm between inanimate and animate matter (ie cellular life). On the one hand it is frustrating as we have to explain this approach again and again, mostly to deaf ears, but on the other it has provided us a completely open opportunity to put forward this, the first comprehensive proposal that takes the entire path, the landscape and the chemical combinatorics, into account. Still it would be good to have another, real, competing hypothesis, which there are none. But then again we have people like you, who ask such good questions and write "whole system" pieces like the book you sent. The generalists, the meta-theorists really have a part to play right now.

I hope this has cast some light on the seemingly implausible pathway from mixtures of simple chemicals up to cellular life. This model is a guess but it is a well informed one, and it is testable at different stages, perhaps even jump starting it by building a synth-bio system and not waiting for selection of functions from random sequences (grad students and postdocs wouldn't live that long!).

Best,

bruce

21.03.2018 (copy to Deamer)

Bruce,

You presented your project development path very clearly and probably it is the best hypothesis at this moment.

In the origin of life work the critical question is the final one – What is life?

David answered this in his paper *On the origin of system.* Life is a very complex control system. I believe that this paper should be on the desk of every researcher in this field.

However the control system will not arise spontaneously. If you put all the right components in the bag and shake it, you will not obtain the working control system. A control system, to operate, needs defined input, output, transfer function, feedback loop, relevant sensors, noise immunity etc. Control is not the product of components, it is a mathematical concept transformed into hardware. Prof McAdams (FEBS Letters 583 (2009) 3984–3991) believes that the cell control system is similar to engineer designed electronic control systems. Obviously in the cell we have complex interactions between various control systems, control loops, nest loops, etc. In such a situation it is difficult to envisage a molecular path leading to such a system.

Best wishes

Konrad

21.03.2018 (from Deamer)

konrad wrote:

In your paper On the origin of systems in EMBO reports you describe the immense complexity of the living organism. You write, "Primitive versions of these four systems must have comprised the first unit of life". My understanding is that these four systems must have developed in parallel to function in the living cell. I am not sure how different they could be from present day simple bacteria systems because they must have included photosynthesis and respiration processes.

I agree energy must have been available, but the source is still uncertain. Photosynthesis requires a pigment system, but it couldn't have been as complex a structure as chlorophyll. I have speculated that certain polycyclic aromatic hydrocarbons (PAH) might have served as pigments. PAH are abundant in the interstellar medium and dozens of species are present in carbonaceous meteorites. Each of the primary photochemical reactions of photosynthesis has been demonstrated with various PAH, including photoreduction of an acceptor, release of protons when illuminated and carbon fixation. However, these are not cyclic reactions, but instead just go in one direction and use up a reactant, so there is more to learn.

There was no molecular oxygen available, so aerobic respiration could not be occurring. Other redox couples have been proposed, such as hydrogen gas or hydrogen sulfide as reducing agents, and CO2 as an acceptor, but the problem is how to capture the energy in a useful way. I wish I knew the answer!

I would like to know how you envisage the transition from simple protocells to these four systems which would need at least 500 proteins/enzymes to function. How could natural selection operate on non-living matter to develop these 500 genes?

It's obvious that they could not have popped into existence all at once. That would be a miracle! So it must have happened incrementally in mixtures of molecules that had the potential to become increasingly complex. Our idea is that if such mixtures undergo indefinite numbers of cycles that both synthesize and hydrolyze polymers in the presence of membranous compartments that can encapsulate the polymers, some of the polymers by chance will have properties that tend to preserve the compartments they inhabit. The simplest property is a stabilizing effect. In other words, if a polymer interacts with a self-assembled lipid bilayer and stabilizes it against dispersive forces, those compartments with their contents will be selected, while others are disrupted. In cells today, such polymers are called cytoskeletal elements. Another property is pore formation. During wet-dry cycles the vesicles (compartments) will be subjected to substantial osmotic pressure variations. For instance, if the hydrothermal water has 10 mM ionic solutes, during evaporation 99% of the water is lost and the ionic concentration increases to 1 molar. Then when the dry film is rewetted (rainfall for instance) there will be a huge osmotic gradient. Vesicles with pores can accommodate the pressure by releasing the salt ions, but those lacking pores may swell so much that their contents are lost to the medium. By the way, some of our research is directed toward testing these concerns because the experiments are easy to do.

But what about the 500 genes you mentioned above. The only thing I can think of is to start not with 500 genes, but just one that might improve the chances for survival. The simplest energy source that can drive biologically relevant reactions is the chemical potential made available by hydration-dehydration cycles. Three physical processes happen in solutions undergoing evaporation. Solutes become increasingly concentrated by more than 100-fold, as described above, and if they are monomers (amino acids, nucleotides) they undergo polymerization by condensation reactions when the water activity is sufficiently reduced. The polymers produced in the first cycle are now available as templates, and this dramatically changes things because if the monomers line of up on the templates by base pairing and then polymerize, it means that non-enzymatic replication has been initiated. So, the first "genes" are simply those template molecules with sequences that are most efficient in replication, and they will be selected to initiate the next cycle.

Here are a couple papers that provide a foundation for my comments above.

Olasagasti F, Kim HJ, Pourmand N, Deamer DW. 2011. Non-enzymatic transfer of sequence information under plausible prebiotic conditions. *Biochimie.* 93:556-61

21.03.2018

David, (copy to Damer)

Thank you for your email and enclosed publications.

It looks as though the earliest fossils were cyanobacteria, so probably photosynthesis was the first source of energy. In the photosynthesis process the most critical is the operation of the water splitting catalyst which is still not fully understood. This complex contains three large proteins, four manganese and one calcium atom. How were these proteins coded to work with these atoms, whilst metals are not coded by the genes? What is the molecular path leading to such catalyst?

Coming back to the biological systems it is not clear how a part of the biological system could work on its own. We know from experience that a cell system consists of many interactive parts, control loops, sensors etc. and even one break in the loop can make the system inoperative. We know that even one mutation could be lethal.

You mentioned that molecule mixtures undergo indefinite numbers of cycles, but taking into account that even to make one working gene would need, say 10^200 steps, how much time would be needed to arrive at a meaningful result?

The model of the membrane you use is quite simplified. We know that the cell membrane contains thousands of different molecules enabling active and passive transport in and out of the cell. This transport is controlled by a very complex system. So should there be some control included in the model? How does this model differ from the living organism?

Regards

Konrad

21.03.2018

(from Deamer, copy Damer)

konrad wrote:

Coming back to the biological systems it is not clear how a part of the biological system could work on its own. We know from experience that a cell system consists of many interactive parts, control loops, sensors etc. and even one break in the loop can make the system inoperative. We know that even one mutation could be lethal.

If we jump ahead to living cells today, of course it seems inconceivable that such complexity could spontaneously emerge. But life did emerge, so unless you believe in miracles we need to sort out the components of a much simpler primitive version of life using organic compounds and energy sources available in a sterile planetary surface four billion years ago. That's what we are doing, and there are at least three components of biological systems that do "work on their own." This process is aptly called self-assembly because it does not require directions and controls to happen.

The first is the self-assembly of amphiphilic molecules. If you had never seen a soap bubble, and calculated the odds that soap molecules could assemble into a membrane by chance, the odds are beyond astronomical. And yet I'll bet you have blown soap bubbles as a kid and been enchanted by their intrinsic beauty. A cell membrane is simply a glorified soap bubble, so that's a good place to start.

The second self-assembly process occurs if you have DNA as a double helix and heat it in water. The two strands come apart, but when cooled they perform another near-miraculous feat, which is that each base precisely lines up with its complementary partner and the beautiful double helix reappears by self-assembly.

The third is the way that certain linear molecules can fold into structures that have properties related to life. For instance, heat up some RNAse in water and it becomes a linear molecule with no catalytic ability, but when cooled it precisely folds back into an active enzyme that can hydrolyze RNA at thousands of bases per second.

Konrad wrote:

You mentioned that molecule mixtures undergo indefinite numbers of cycles, but taking into account that even to make one working gene would need, say 10^200 steps, how much time would be needed to arrive at a meaningful result?

I recommend that you read the 1993 Science paper by Bartel and Szostak. They started with several trillion RNA 300mers having totally random sequences, then put them through ten cycles of selection and amplification. They selected for ligase activity, but it could have been virtually any catalytic ability. In just a few weeks their system of random polymers evolved into several species of ribozymes that could be seen in gels and had 7 million times the activity in the original mixture.

My bottom line is that we don't know yet how life can begin, but we can see a path forward, something we could not do 50 years ago because we didn't have enough knowledge of nucleic acids, enzymes and self-assembly processes. Now we do, and I'm optimistic that incremental progress will continue to be made.

Dave

28.03.2018 (to Deamer, copy to Damer)

David wrote:

If we jump ahead to living cells today, of course it seems inconceivable that such complexity could spontaneously emerge. But life did emerge, so unless you believe in miracles we need to sort out the components of a much simpler primitive version of life using organic compounds and energy sources available in a sterile planetary surface four billion years ago. That's what we are doing, and there are at least three components of biological that do "work on their own." This process is aptly called self-assembly because it does not require directions and controls to happen.

Franklin Harold, professor of biochemistry at Colorado State University wrote in his book “In search of cell history”: “*But it is not at all self evident that the origins of autopoietic systems (or of autonomous agents) can be understood as a* *consequence of incremental variations sifted by natural selection. …At the least, such musings imply that the origin of life may have called for some improbable event, effectively a miracle, that will have happened very seldom even in our enormous universe*".

So maybe life was a miracle.

David wrote:

I recommend that you read the 1993 Science paper by Bartel and Szostak. They started with several trillion RNA 300mers having totally random sequences, then put them through ten cycles of selection and amplification. They selected for ligase activity, but it could have been virtually any catalytic ability. In just a few weeks their system of random polymers evolved into several species of ribozymes that could be seen in gels and had 7 million times the activity in the original mixture.

The paper by Bartel and Szostak describes very important discovery of catalytic abilities of RNA polymers, but how this is relevant to the hypothesis that life began with an RNA replicase. They stated that "RNA replicase would be so rare that it could only arise spontaneously and in a single step from a truly enormous amount of RNA". It was a farsighted statement because 25 years later we are still awaiting for this to happen.

I am not qualified to evaluate the relevance of the RNA World hypothesis to the origin of life, but papers by Charles G. Kurland, (The RNA dreamtime, Bioessays (2010); 32: 866–871.) and Harold S Bernhardt, (The RNA world hypothesis: the worst theory of the early evolution of life (except for all the others, Biol Direct. (2012); 7: 23) should not be ignored.

David wrote:

My bottom line is that we don't know yet how life can begin, but we can see a path forward, something we could not do 50 years ago because we didn't have enough knowledge of nucleic acids, enzymes and self-assembly processes. Now we do, and I'm optimistic that incremental progress will continue to be made.

I would like to be very positive and share your vision, but when I look at the most optimistic scenario when the RNA replicase is working, I still do not see a path leading to the living cell. My concern is best expressed in the paper: J.T. Trevors, D.L. Abel, Chance and necessity do not explain the origin of life, Cell Biology International 28 (2004) 729e739. They stated:

"*No natural mechanism of nature reducible to law can explain the high information content of genomes. This is a mathematical truism, not a matter subject to overturning by future empirical data".*

"Random sequences are the antithesis of prescribed genetic information. There is no empirical or rational justification for theorizing that the random shuffling of nucleotides could generate instructions for a metabolic network".

A paper by *Shcherbak, V.I,, Makukov, M.A. (2013). The "Wow! signal" of the terrestrial genetic code. Icarus 224: 228–242* analyses the genetic code. The authors stated that:

"*simple arrangement of the code reveals an ensemble of arithmetical and ideographical patterns of symbolic language. Accurate and systematic, these underlying patterns appear as a product of precision logic and nontrivial computing rather than of stochastic processes*".

These arguments are so logical that it is very difficult to disagree with them. We can ignore them, otherwise the only logical answer is that life originated somewhere else (we do not know how) and the hypothesis of panspermia is the most plausible scientific explanation.

I would say that 50 years ago abiogenesis was much more acceptable and plausible hypothesis because we did not have adequate knowledge of functioning of the cell. For example, the cell control system has not been discovered yet. Now we know that the control system must be very sophisticated and the cell would not function without it. As I mentioned before, the control system cannot arise by random processes because it has to follow certain algorithms, so unless you believe that natural selection can solve mathematical equations we have to look for other possibilities.

I believe that we know enough about cell functions to be able to prepare hypothetical flow charts and calculate probabilities of arising of life. However when we learn more about the complexities of life, this knowledge makes these calculations even more improbable.

Regards

Konrad

28.03.2018 (from Deamer)

Dear Konrad,

I guess we need to end our discussion. You are pessimistic that we will ever find a simple pathway by which the complexity of life could emerge spontaneously, and I am optimistic that we will continue to make incremental progress. I must say that your argument is also used by intelligent design proponents who state that "irreducible complexity" supports a divine origin of life. Pessimism also leads to a sense that we can never understand the origin of life, so we might as well not try. My optimism might be foolish, but it has led to a satisfying career as a researcher.

You might enjoy reading an essay just sent to me by Ted Steele, who supports your argument and believes that panspermia is a better answer.

Dave

Progress in Biophysics and Molecular Biology.
https://doi.org/10.1016/j.pbiomolbio.2018.03.004

29.03.2018

Bruce,

It is interesting that in his last email David mentioned miracles. I can say that I have written my book because I do not believe in miracles.

However, when you look at life, it is full of bewildering events which evolution does not even try to address.

How did evolution know that water could be split into hydrogen and oxygen, and then hydrogen could be split into protons and electrons. This requires a knowledge of subatomic physics. It is a "miracle". When Mitchell proposed proton pumping as the source of energy for ATP production it was not believed by anyone for almost 20 years. Does one have to be an engineer to admire the ATP synthase design? It seems to me that evolutionists take it for granted. What is interesting is that such sophisticated and efficient energy generation and transformation was not even needed for simple cells but was only needed for higher forms of life.

Even biologists call the arrival of eukaryotic cells a "miracle" and explain it using the symbioses of bacteria rather than a slow evolutionary process. But even a perfunctory analysis of symbioses shows that it could not have been responsible for such a step increase of the eukaryotic cell's functions.

Another "miracle" is the Cambrian explosion, when during a 25 million year period all known phyla arrived simultaneously. Where is the slow and gradual development illustrated by the evolution tree? The development of multicellular life did not only increase in complexity by several orders of magnitude, but it was a new concept of life.

And the arising of the human brain with its analytical and abstract thinking and consciousness also has to be a "miracle" because there is no other explanation.

So my book was not written for strong believers on either side of the ideological battlefield but for people who have an open mind, have doubts, and at the same time want to follow the path to the truth regardless of where it takes them.

This is why it is so important to know your opinion about my book.

Best wishes

Konrad

30.03.2018 (from Damer, copy Deamer)

Konrad,
I am circling Dave back in here as he knew Mitchell personally... more below

At 07:23 AM 3/29/2018, konrad wrote:

Bruce,
It is interesting that in his last email David mentioned miracles. I can say that I have written my book because I do not believe in miracles.

Neither do we! I am sure he meant that tongue-in-cheek. Over the centuries, science is finding rather miraculous ways in which Nature can "get highly improbable things done with regularity".

However, when you look at life, it is full of bewildering events which evolution does not even try to address.
How did evolution know that water could be split into hydrogen and oxygen, and then hydrogen could be split into protons and electrons. This requires a knowledge of subatomic physics.

Evolution didn't have to "know" about subatomic physics, it only had to "wait" until Natural Selection provided access to various properties (at any scale) and then cycle it into its tool-set. Of course water is split by natural forces all the time and electrons are dissociated from their nuclei to travel along energetic pathways too. In a combinatorial system the size of the living microbial world, there are copious opportunities for pathways to new innovation to be discovered through selection. Even the quantum effects used by photosynthesis were only a matter of trial and error and building upon partial solutions until the entire chloroplast machinery was in place.
It is a "miracle"• . When Mitchell proposed proton pumping as the source of energy for ATP production it was not believed by anyone for almost 20 years. Does one have to be an engineer to admire the ATP synthase design? It seems to me that evolutionists take it for granted. What is interesting is that such sophisticated and efficient energy generation and transformation was not even needed for simple cells but was only needed for higher forms of life.

Dave can comment here. But my two cents are: simpler cells (including pre-living protocells) would have utilized simpler available forms of energy, starting with heat from the hot springs, dehydration energy coming from wet-dry cycling, and sources of chemical energy delivered into hydrothermal environments (which life still uses today). Evolution gradually replaced these simple, passively-captured forms of energy with active and more efficient mechanisms (like photosynthesis or mitochondrial-ATP generation). I believe evolutionists (I am not sure what you mean by this term), or rather, scientists, take ATP as a given due to the previously built weight of evidence. It is also a given that evolution has the power to generate very complex systems. A smart phone and the factory that assembles it are both clearly the result of the power of evolution, expressed as science and engineering driven by cultural and market forces. I see no reason to doubt the creative power of the engine of evolution at any stage and for any arising form or function.

Even biologists call the arrival of eukaryotic cells miracle• and explain it using the *symbioses of bacteria rather than a slow evolutionary process. But even a perfunctory analysis of symbioses shows that it could not have been responsible for such a step increase of the eukaryotic cell functions.*

I don't have a background in this area. Nick Lane has done some very interesting interviews and thinking on this transition. I dont think we can say much about what or how cell functions increase as the idea of symbiosis is only a few decades old. Just because something seems implausible to us in our limited current understanding doesn't mean it didn't happen in a completely plausible way. In fact in "Climbing Mount Improbable" Richard Dawkins makes the very grounded argument that billions of years of evolution and untold numbers of individuals and interactions can and does lift highly improbable events into reality.

Another miracle is the Cambrian explosion, when during a 25 million year period all known phyla arrived simultaneously. Where Â is the slow and gradual development illustrated by the evolution tree? The development of multicellular life did not only increase in complexity by several orders of magnitude, but it was a new concept of life.

This is the "punctuated evolution" vs "gradual" debates of Gould/Dawkins of years ago. I don't think we know what was slow and what happened fast for the whole tree especially far back in the record. In fact the Cambrian explosion was presaged by hundreds of millions of years of simpler animal forms, we just only have a trace fossil record of them. Woese and Fox make the case that in the earliest period, of the "progenote" or as we are calling it "the progenean" evolution could have been much more rapid, due to the horizontal sharing of genetic innovations. Before cell division and the "vertical descent" of genetic traits then "held" by lines of cells, they argue, innovations could have spread much more rapidly.

And the arising of the human brain with its analytical and abstract thinking andÂ consciousness also has to be a miracle• because there is no other explanation.
So my book was not written for strong believers on either side of the ideological battlefield but for people who have an open mind, have doubts, and at the same time want to follow the path to the truth regardless of where it takes them.

Generally those who express doubts about where life might have come from or how evolution might or might not produce what we see around us are either 1) not working in the field so don't have any background to base their doubts upon and/or 2) have a pre-existing point of view (also ungrounded) that fuels their doubts, such as a belief in a creator. Real investigators in the field of OoL are like detectives working a crime scene. We have a body (life) but we don't know how it came to be lying there. But the detective is ever the optimist and, like Poireau, patiently comes at the evidence from all angles, maintaining and open mind and a positive approach, and always (at least according to good crime fiction) always catches his or her man (or woman)! Doubts are not helpful unless they lead to trying a new avenue, at least for those gumshoes who maintain their line of work.

I will take another look at your book but I am about to go away for a month of travel, so It will have to come up when I have an actual moment to read something lengthy. I suggest bugging me in a couple of weeks when I am in place on my next global jaunt.

PS your questions and our dialogue is actually interesting enough to possibly (in some edited form) be including in the book I am now working on. Would that be OK with you (with credit of course). It is a book for the public curious about this new approach to our origins.

Best wishes in return Konrad,

bruce

2.04.2018 (copy to Deamer and Prof Ralph Abraham)
Bruce,

I feel that narrative arguments cannot convince either side, and the only scientific way forward available at present is to formulate the problem in terms of probabilities.

The starting point of the investigation is non living matter and the final target is life. We have to assume that only random processes would be considered in such an investigation.

Our reference point could be a simple living organism such as bacterium, because the probability of its existence is 1. I do not believe that we should consider any other “simpler” living structures because we do not know the probabilities of their existence.

The path leading to life is not that important, and it might follow several (hypothetical) ways. Since we do know enough about the cell, its structure and functions, and we know that it needs at least 500 genes (Venter experiment), it should be possible, (with some assumptions like the development time being less than 100 million years), to establish the probability of random events leading to such a structure. I estimated that the probability of arriving at this number of genes could be as low as $10^{-200000}$, but I am sure that experienced scientists would arrive at much more reliable numbers.

The other scientific hypothesis of the origins of life is panspermia. It has been proposed (Drake equation) that there must be thousands of civilizations in our galaxy, therefore the probability of existence of at least one advanced civilization could be about 1. Many prominent scientists believe that the probability could be so high because otherwise we would not spend so many resources on the SETI programme.

The probability that some extraterrestrial civilizations could be much older and be on a much higher technical level than ours is also reasonably high. The probability that one of these civilizations wanted to transfer life to Earth could be, say 10^{-3}, so I guess that the overall probability of panspermia being responsible for the origins of life could be, say 10^{-6}.

I do not claim that my numbers are correct, but this could be the way to compare probabilities of two hypothetical solutions leading to the origin of life. One could argue that I am moving the problem of the origin of life from Earth to somewhere else. Yes, that is true, but at this moment we do not want to solve problems of the Universe. It is important for us to know how life originated on Earth, because it would have a momentous effect on our life, our philosophy, our understanding of ourselves and our purpose in the Universe.

It looks like your book could be very interesting. You have my permission to use material from our exchanges. I would like to have your permission to use the email material in my future publications.

Best wishes

Konrad

2.04.2018 (from Deamer, copy Damer)

konrad wrote to Bruce:

I feel that narrative arguments cannot convince either side, and the only scientific way forward available at present is to formulate the problem in terms of probabilities.

The starting point of the investigation is non living matter and the final target is life. We have to assume that only random processes would be considered in such an investigation.Our reference point could be a simple living organism such as bacterium, because the probability of its existence is 1. I do not believe that we should consider any other "simpler" living structures because we do not know the probabilities of their existence.

Hi Konrad -- Bruce is busy at a meeting, and then will fly to Pakistan for a business trip, so I will respond with a brief note.

First, the only portion of your statement above that I can accept is that narrative arguments are unconvincing. As an experimentalist, I use probabilities only to guide experimental approaches, which are "the only scientific way forward available at present", quoting from your statement. Probabilities are not the end, just the beginning.

Your assumption that "only random processes would be considered" immediately goes astray, I'm afraid, because it leads to the same dead end that creationists arrive at. The forces of self-assembly of molecules transcend randomness and make things like a soap bubble or a cell membrane possible. These are mathematically impossible if we only use mathematics to describe the probability that the molecules of a cell membrane (or a micelle or a soap bubble) will assemble by chance. Finally, you wrote "I do not believe that we should consider any other “simpler” living structures because we do not know the probabilities of their existence."   Well, if we limited ourselves to a living organism I'm afraid that takes us back to Pasteur, who stated "omne vivum ex vivo." The only reason we know anything about life processes is that biochemists do take apart cells and study their simplified parts list in molecular detail. It doesn't help to consider "the probabilities of their existence" because that is essentially philosophical and doesn't get us very far.

2.04.2018 (from Deamer)

Hi Konrad -- In another thread, I responded with something that is related to what we have been discussing and thought you might like to see it. It's an interesting essay by Ted Steele, a scientific "maverick" who has latched on to a fringe idea and jumped in with both feet. (To get a sense of his personality and personal history, read his Wikipedia entry.)

Chandra Wickramasinghe is among the co-authors of Steele's essay, and I met Chandra once at the Tidbinbilla radio telescope near Canberra and a couple other times at meetings here in the States. In my book First Life, I describe one such meeting:

"Together with his colleague Chandra Wickramasinghe, now at Cardiff University in Wales, [Fred Hoyle] co-authored a series of books and papers that again proposed an alternative hypothesis for one of the remaining great questions of science, which is the topic of this book. One hypothesis is that life began as a chance event in which just the right mix or organic compounds was acted upon by an energy source so that growth and reproduction could occur. The earliest life would not resemble today’s highly evolved version, but more likely was a kind of scaffold that had the essential properties of life. The scaffold was then left behind when more efficient living systems evolved.

Hoyle and Wickramasinghe did not subscribe to this view. Instead, they elaborated an older idea championed in 1903 by Svante Arrhenius, the great Swedish chemist. Known as panspermia, this idea proposes that life exists everywhere in the universe and that life began on the Earth when frozen extraterrestrial bacteria or spores, drifting as interstellar dust through the galaxy, happened to land here four billion years ago and found it to be habitable. Hoyle took it a step further when he claimed that this was still happening, that epidemics such as the flu pandemic of 1918 were actually caused by extraterrestrial organisms in the tails of comets.

I once met Wickramasinghe in 1986 at the Tidbinbilla radio telescope observatory near Canberra, Australia, and asked whether he and Hoyle really thought that interstellar space was infested with bacteria. He was quite certain of it, he said, noting that the infrared spectrum of interstellar dust closely matched that of dried, frozen bacteria. I mentioned that I was working with the astronomer Lou Allamandola at NASA Ames Research Center, who had demonstrated that the infrared spectrum could be reproduced by ordinary compounds called polycyclic aromatic hydrocarbons (PAHs for short). This seemed a much more plausible explanation than a galaxy full of bacteria. Wickramasinghe had a ready retort: "It is up to you to prove that they are not bacteria."

I have found that a few of my colleagues are not swayed by plausibility arguments, or Occam's Razor and the weight of evidence. In general, scientists are like investors, but instead of money they invest time, limited to roughly 40 years of active research. Scientists are continuously making judgment calls to decide how to invest their time. They hope their investment will be profitable, not necessarily in monetary terms (that rarely happens) but rather in revealing significant new knowledge. A few scientists spend their lives seeking unusual explanations that others would immediately discard as implausible. Some of my colleagues avoid interacting with these mavericks, but I enjoy listening and reacting to their ideas. Most often the ideas turn out to be not just implausible, but wrong. But once in awhile a wild idea is beautifully, wonderfully correct. George Gamow had one such idea, and later in the book I will tell you about Peter Mitchell, another maverick whose implausible idea taught us how light and metabolic energy is captured as ATP in all life today."

In his essay, Ted Steele, the first author, cites my book *First Life* and claims that I described research on the origin of life as a "dismal failure." (I did no such thing!) He has a better answer that he considers to be much more plausible: Life did not begin on the Earth but was brought here on comets, as Hoyle and Wickramasinghe suggested. He also thinks that living microorganisms continue to be delivered on IDPs and contributed to the Cambrian radiation 500 million years ago.

I recommend reading the essay, which can be accessed for free in the link that Steele gives below. It's a good exercise in detecting scientific cherry picking to support a favorite scientific idea. Here is Steele's email note with a link to his essay:

Dear Colleagues in the Astrophysics & Astrobiology communities:

I work in Molecular Immunology & Evolution. The mysterious way new concepts connect with other established concepts never ceases to amaze me.

You might be interested in the way clonal selection and reverse transcriptase taken to their most extreme implication (Lamarckian soma-to-germline transmissions) also makes sense in the cosmic evolutionary setting. Organisms landing in a new cosmic environment must adapt quickly or die, a Darwinian necessity – which makes sense under the new paradigm of Hoyle–Wickramasinghe Cosmic Biology. If interested click on the link to our IN Press PDF just out in in *Progress in Biophysics and Molecular Biology.*

https://doi.org/10.1016/j.pbiomolbio.2018.03.004

Together with a range of other biomedical scientists, physicists , astronomers and two other involved scholars in the history & philosophy of science (all up n>30) - from many countries - we have critically reviewed and updated the evidence for the Hoyle-Wickramasinghe thesis of Cosmic Biology. Namely that life on Earth was seeded from space and such in-falls have continued to influence the evolutionary course of life on Earth.

A **Note in Proof** is also just added to our paper – Russian space scientists have just had their paper accepted reporting a variety of species of bacteria coating the surface of the International Space Station. The bacteria are related to terrestrial species. The explanation is open as to how they got there- but upwelling from Earth is not an explanation. Provisional version of the Russian ISS paper is on line at: https://www.hindawi.com/journals/tswj/aip/7360147/

Obviously we are open for critical discussions. The full list of Commentary and typescript texts, and our "Reply" to critics is in the attached docs.

Yours

Ted Steele

……………

Edward J Steele PhD

ASI, AIMS, ASCIA

CYO Foundation, Piara Waters, 6112

Perth, AUSTRALIA

ejsteele@cyo.edu.au

https://independent.academia.edu/EdwardJSteele

4.04.2018

Hi David,

I have read an essay by Ted Steel but I have a few reservations. He believes that increasing the time to a few billion years and the venue to the whole galaxy, could significantly improve the probability of abiogenesis. This is not a very convincing argument and probability calculations could easily show the insignificance of such expansion. I think that more important is the quality of the environment, and Earth with its hydrothermal fields must have been the best place for life to develop. It is not only the right temperature but the presence of the right amount of water which must be critical for the development of life on Earth. However, water must had arrived on Earth from outside at the right time. Development of life inside comets or icy bodies is not very convincing. I think that Earth is very special and provides the most benign environment and I do not believe that there are many planets like Earth in the Milky Way.

Steel mentioned transfer of embryos to Earth. Embryos have much more complex structure and represent a much higher form of life than bacteria. How they could arrive inside comets is not clear. Embryos are much more fragile organisms than bacteria and their transfer inside comets is very unlikely. In my paper "Advanced panspermia" I proposed that they would have to be placed in special containers to survive a trip to Earth. (https://www.omicsonline.org/open-access/advanced-panspermia-2332-2519-1000158.pdf).

I subscribed to the hypothesis of panspermia until I looked at the development of the human brain. This was a very convoluted and peculiar process. We know quite a lot about this development process because it happened very recently and we have so much genetic information about our cousins the Neanderthals.

I would be very interested to hear more about Peter Mitchell. In my opinion he is one of the greatest scientists of all time. His discovery is much more original and important to the understanding of life then the discovery of the double helix. It is unfortunate that only a few have heard about Mitchell while everybody knows Crick and Watson.

Regards

Konrad

5.04.2018 (to Deamer and Damer)

David and Bruce,

To simplify the origin of life problem I try to concentrate only on one aspect of life viz. information coded by DNA. We know for sure that for life to exist, a certain amount of information must be present in the cell. The question is how this information was generated in the cell. I do not think that this is a philosophical question. This is a scientific question but we do not know the answer yet and therefore probability can help us to evaluate the extent of the problem.

Looking more generally at the generation of coded information I envisage this process as starting from point **A** – zero, and moving in random steps (random walk) to point **B** – correct gene. We know that, for example, for a gene with 300 amino acids there are 20^{300} possible paths which the process could follow but only one path will reach point **B**. The cell would need a lot of material to go through such process.

However how the cell would know that has arrived at the correct gene. It cannot stop and wait. It can only know when all other genes are ready and working. It means that all the genes must be generated together, which is practically an impossible task (~zero probability). I am unable to see any shortcuts in this process.

.David: The forces of self-assembly of molecules transcend randomness and make things like a soap bubble or a cell membrane possible. These are mathematically impossible if we only use mathematics to describe the probability that the molecules of a cell membrane (or a micelle or a soap bubble) will assemble by chance

I agree that the forces of self assembly are common in nature such as crystals or many monomers. The problem is that such structures do not carry information (as per Shannon definition) therefore they cannot help us to solve the DNA information generation problem.

David: Well, if we limited ourselves to a living organism I'm afraid that takes us back to Pasteur, who stated "omne vivum ex vivo".

It is possible that Pasteur could be right after all. If you look at the present-day cell research you will find that “to make a cell you need a cell”. (Harold, F.M. 2005. Molecules into Cells: Specifying Spatial Architecture. *Microbiology and Molecular Biology Reviews*. Dec.69: 544–564).

Regards

Konrad