



Symphony in C: Carbon and the Evolution of (Almost) Everything by Robert M. Hazen, W.W. Norton & Company, 2019

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I have to admit that I am a fan of Robert Hazen. In 2005 I favorably reviewed his book *Genesis* and in 2013 I favorably reviewed his DVD course *The Origin and Evolution of Earth*. Hazen is executive director of the Deep Carbon Observatory at the Carnegie Institution and Professor of Earth Science at George Mason University. He is also a trumpet player of symphonies by Beethoven, Brahms, Schuman, and Mendelssohn. What I like about Hazen, who has produced a number of books and DVDs, is that I am always learning new things from his works which are always delivered in superlative style. In addition, Hazen's expositions of science always include fascinating descriptions of its practitioner scientists. So, when I ordered a copy of his latest book, I knew I was in for a good read.

In *Symphony in C* Hazen presents us with a carbon-centered view of Planet Earth in analogy to a symphony in four movements, which he entitles *Earth, Air, Fire, and Water*.

Earth recounts how carbon became the fourth most abundant element in the Universe, produced by stellar evolution, and subsequently became a major element of the Earth from the beginning of its evolution 4 ½ billion years ago. The Earth contains more than 400 carbon minerals. Carbon, in the form of calcium carbonate, or limestone, comprises the largest repository of carbon in the Earth's crust, roughly 100 million billion tons of such rock.

Air shows how carbon in the Earth began circulating as carbon dioxide through the Earth via its oceans and solid carbonate rocks.

Fire describes a number of thermal chemical reactions undergone by carbon within the Earth and also in chemists' laboratories. Carbon, Element No. 6, has a unique capacity to form a near infinite number of chemicals, some of which are: dry ice (frozen carbon dioxide), super glue (cyanoacrylate), wax, grease, oils, graphite, graphene, diamonds, dynamite (nitroglycerin absorbed on a stable substrate), Fullerenes, Bucky Balls, nanotubes, Bakelite, plastic, rubber, aspirin (acetylsalicylic acid), cellophane, neoprene, nylon, and pasta, to name just a few.

Finally, *Water* describes how carbon, within Earth's watery milieu, displayed its most extraordinary property of all, namely this element's ability to form life with the participation of the other

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biogenic elements and eventually creatures like us who are trying to figure out exactly how carbon accomplished this prodigious feat of chemistry.

The most glorious climatic melody of Hazen's *Symphony in C* is to be found in this fourth and final movement in which the simple note of C is woven into the naturally occurring biomonomers on the Primitive Earth and these biomonomers condensed into biopolymers which cooperate within lipid envelopes to form cells that reproduce and evolve. All life forms on Earth are mostly comprised of water, and for life as we know it, biochemistry is largely aqueous organic chemistry.

As Hazen points out, the origin-of-life problem is a daunting scientific challenge, and to make experimental progress in solving this problem, scientists have usually sought to simplify matters by focusing their experiments on one class of molecules at a time, which has resulted in a number of different primordial "worlds", such as the RNA World, the Proteinoid World, the Lipid World, the Biomineral World, etc. Each of these Worlds come in different variants as to locations where LUCA might have originated, such as ponds, hydrothermal vents, the interior of rocks, etc. At times, different schools of thought on how best to proceed in tackling this mega-problem of the origin-of-life has resulted in fierce competition for influence, funding, and negative polemics, which Hazen does not flinch from discussing. As Hazen points out in his book, the discovery of numerous Earth-like exoplanets in the early part of the twenty-first Century and the resulting advent of astrobiology, funded by NASA, rescued origin-of-life science from its parochial earth-focused beginnings in the latter half of the twentieth Century.

We have only one sample of life as we know it here on Earth, and thus, the most important question in astrobiology posited by Hazen is this: *Is the transition from geochemistry to biochemistry an intrinsic characteristic of Earth-like planets, or is life rare in the Universe?* In other words, is the beautiful, astounding, extraordinary, fantastic Symphony in C that is life on Earth a chemical melody that is found on other worlds in addition to ours? I wish I knew. I hope that I am still around when we find the answer.

Hazen's book presents a unique way of seeing the music of chemistry, in particular biochemistry. The hardback volume of 282 pages comes with an attractive color glossy section containing a number of items: informative charts, diagrams, and photographs of some of the scientists involved in deep carbon research, a photograph of a remarkable invention called the diamond anvil cell which allows scientists to observe chemicals at extremely high pressures, the carbon structure of some fullerenes, and photographs of single-cell coccolith plates and many-cell trilobite spines, both of which are comprised of carbonate minerals.

Here is Hazen's prescription for experiencing the Symphony in C: Look around you and imagine you see only carbon atoms. The chair on which you are sitting as you read this review will have wood and/or synthetic carbon fiber and will look similar to the chair as it normally appears, the wooden floor is made of carbon bearing cellulose polymers. Growing in the carbonaceous crust of the Earth are light-powered living forms of carbon known as plants, and subsisting on plants are spectacularly complex living carbon organisms called animals, including ourselves and our loved ones. This is the Symphony in C, a progression, over billions of years, of *endless forms, most beautiful and most wonderful* as Darwin said in the last sentence of *The Origin of Species*.

In summary Hazen's book is an excellent, thought-provoking work that is vastly entertaining. Therefore I highly recommend it.