AMEGHINIANA
A GONDWANAN PALEONTOLOGICAL JOURNAL

THESE ARE FOSSILS TOO: A LOOK AT THE STUDY OF ANCIENT BIOMOLECULES

Review of "Remnants of Ancient Life. The new science of old fossils". Dale E. Greenwalt. 2022. 288 pp. Princeton University Press. ISBN 9780691221144

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To cite this article: Damián E. Pérez (2023). These are fossils too: a look at the study of ancient biomolecules. Review of "Remnants of Ancient Life. The new science of old fossils" *Ameghiniana 60*(3), 277–280.

ISSN 0002-7014

THESE ARE FOSSILS TOO: A LOOK AT THE STUDY OF ANCIENT BIOMOLECULES. Review of "Remnants of Ancient Life. The new science of old fossils". Dale E. Greenwalt. 2022. 288 pp. Princeton University Press. ISBN 9780691221144

Generally, the common people think of fossils as preserved bones and teeth of ancient vertebrates. If we go a little bit further, we consider fossils as preserved hard parts of organisms, internal or external molds, traces, and tracks. Nevertheless, any part or trace of an organism of the past constitutes a fossil. Remnants of Ancient Life focuses on a frequently forgotten part of the fossil record: the biomolecules. Are biomolecules part of the fossil record? The book does not ask it. It affirms it and moves on, leaving no room for doubt.

The book starts with a time chart showing diverse records of different periods, illustrating since the beginning that biomolecules are not only very modern fossils. With this presentation, the book sets out its generalist tone, presented for a broad audience. However, as we will see below, it also addresses concerns and questions that are more specific and appropriate for a specialized audience.

The Introduction uses a novelization of a personal anecdote to illustrate the book's conception and initial premise and the author's arrival to the study of biomolecules. Rapidly, this field is defined pleasantly and easy to assimilate for the reader. In addition, the important advance in Paleontology, given by this field, is presented. Perhaps, the author considers ancient DNA, accessible by preserved biomolecules, as "the very source of evolution", giving a very reductionist and gene-centered perspective. The book is arranged by the different ancient biomolecules included. Chapters 1 and 2 are introductory to the subject matter; Chapters 3 to 5 discuss ancient pigments; Chapter 6 focuses on ancient biometals; Chapters 7 and 8 on proteins; Chapter 9 and 10 on ancient DNA; Chapter 11 on plant biomolecules, and Chapter 12 deliberate about future perspectives and the limits of the discipline scope.

The first chapter is a case study: the fossil of a blood-engorged mosquito, the first fossil with biomolecule preservation studied by the author. From a personal point of view, the author introduces the main object of the book. With the explanation of this example, a case of study developed by himself, the author provides definitions for the most important elements of the book: biomolecules, fossils, and the fossil record. The image of a blood-engorged mosquito caught in amber is one of the most powerful frames of the Jurassic Park movie. Then, Dale Greenwalt transforms this frame into an actual paleontological example, discovering the real science of fossil blood remains. Greenwalt discusses the definition of a fossil and finds that there is no complete and comprehensive definition for all people. One important topic important, in this case, is the replacement for inorganic molecules (known as permineralization). A hundred percent mineralization implies a total absence of original biomolecules. However, this is different from the situation of many fossils, and the biomolecules are present and allow the development of this book. Greenwalt chose a very simple definition from a children's dictionary: "fossils are the remains or traces of plants and animals that lived long ago". Simple but very effective. With this definition open to further discussion, he presents a very broad overview of paleontology as a discipline.

Chapter 2 focuses on green-blue "algae" (cyanobacteria), stromatolites, and sponges to illustrate and show life's most ancient record. With a brief explanation of the beginning of life and its conditions, the author introduces the scarce record of very ancient life. The main object of this chapter are biomarkers, a particular kind of biomolecule very conspicuous for the Proterozoic and early Phanerozoic eons. These biomolecules frequently are the unique or the most ancient fossil record of several groups, denoting their importance. The presence of different animal or plant groups is often evidenced by the presence of biomarkers in deep time and strongly studied periods. In addition, biomolecules can be useful for solving taxonomical questions and adding paleoenvironmental info—some examples of cholesterol, chitin, or lipids preserved as biomarkers are shown in this chapter.

Color is the main topic of the third chapter. Perhaps, the fossil record is a slightly colored world in contrast to the highly colored world that we see every day. Then, how can we give colors to the animals and plants we find as fossils? We have strong evidence to consider that already the earliest animals show a great diversity of displayed colors. Based on this premise, the chapter goes into the fossil color-producing biomolecules and the new questions that arise (*e.g.*, palaeoecological, phylogenetic, or evolutionary ones). The chapter relates several examples of fossil pigments extracted from the remains of corals, crinoids, and plants. Among them, pigments obtained from fossil *Solenophora jurassica* stand out because they allow the interpretation of a symbiotic relationship with ancient bacteria.

Melanin is the pigment protagonist of Chapter 4, the most important pigment in humans and most vertebrates. It is one of the most famous biomolecules because it frequently appears in the news related to color-display in dinosaurs, constitute one of the most widely distributed among animals, and has multiple and diverse functions beyond color display. The chapter reviews the scope of its study using examples (vertebrates as ichthyosaurs and snakes, invertebrates as insects and squids) and evaluating applications beyond the description of pigments. For example, the role of pigmentation in behavior is an issue hard to explore from fossils and other paleoecological possibilities. The role of melanin in the evolution of a major feature, as is the vision is present in this chapter. In addition, the chapter propose future perspectives on these studies.

Chapter 5 goes deeper into the role of pigments in the color display of dinosaurs. This particular case of pigment preservation plays a popular role among fossil biomolecules because of the status of dinosaurs in pop culture. In the last years, the search for fossil pigments in dinosaurs allowed us to explore how these animals looked in life. Feathered dinosaurs collected in Northeast China during the past three decades are the main characters of this chapter. However, other fossils (such as the famous *Archaeopteryx lithographica*) are also present. The chapter reviews the evolutionary, physiological, ecological, and phylogenetic implications of the study of melanin and melanosomes in dinosaur feathers, showing its expanded results. Ecological concepts such as the countershading, a feature used by several animals with defensive purposes, is explained and discussed within this context. Nevertheless, feathers are not only the focus of the chapter but also include examples of color pigments in dinosaur eggs and the study of dinosaur vision.

Biometals, a particular type of biomolecule, are the subject of the chapter 6. Biometals are a minor component of the total of biomolecules in living beings. Despite this, they can be useful for detecting particular structures because they are present in specific locations of an organism's body. Metals such as zinc, copper, or nickel are found among life forms. Some organs, such as bones or liver, present a high accumulation of metals, and determined structures such as vertebrate teeth, arthropod mandibles, or leaf tips have high metal concentrations. Moreover, these biometals are likely to be found as fossil biomolecules. The study of fossil biometals and metallomes is still in its infancy but is very promising.

Proteins are another type of biomolecule that can be found as fossils. Before the discovery and study of DNA, proteins had been used for evolutionary research. Several findings of proteins and proteomes conserved as fossils can be used for evolutionary, physiological, and even taxonomical research in Paleontology. Proteins and amino acid comparisons among them are the basis of molecular clocks from the beginning of this technique. However, studies on fossil proteins and proteomes are restricted to the last million years, from Pliocene to very recent times, mostly from mammals. Chapter 7 presents and discusses the particularities of fossil protein research, which includes examples in our region (*e.g.*, Presslee *et al.*, 2019).

Dinosaurs, of course, are the main stars of Chapter 8. This one is entirely devoted to telling about the biomolecules extracted from Mesozoic dinosaurs' fossil bones. They include the discovery of dinosaur's bone cells, red blood cells, blood vessels, keratin, collagen, and even DNA molecules. The main sources are the works of Mary Schweitzer's Lab (*e.g.*, Schweitzer *et al.*, 1997). The chapter remains with the controversies arising from Schweitzer's findings and gives room to discuss and present the arguments of their detractors. Methodologies and techniques are explained simply to give the reader a proper overview of the subject matter.

The most famous molecule of contemporary times is the DNA, the basic brick of life, and the issue is included in Chapter 9. Once again, the popular frame of the mosquito trapped in amber from the Jurassic Park movie comes to mind. In that movie, this mosquito encloses ancient DNA, the source to resurrect dinosaurs. Fossil DNA (called "ancient DNA") is the most elusive of the biomolecules. It has some particularities, especially its low stability and durability. Because of this, the search for ancient DNA is a complex enterprise. Despite this, ancient DNA has been recovered from some fossil animals, mainly mammals preserved in permafrost or caves, and the author explores them. The chapter does not evade discussion about the main situation with ancient DNA. To date, only been able to be obtained from relatively modern specimens (up to 2 million years old), and, consequently, the Jurassic Park frame is yet to be possible. There are some examples of studies of ancient DNA in our country (*e.g.*, Mitchell *et al.*, 2016).

Some issues of the ancient DNA are expanded in Chapter 10, where early human's ancient DNA is the central topic. This chapter aims to describe examples of studies of ancient DNA that include data on evolution, physiology, and even behavior from early humans, including Denisovans, Neanderthals, and ancient Egyptians, among others. The boundaries between palaeoanthropology and archaeology are very diffuse in this chapter because the differences between both sciences are indeed diffuse. Interaction between disciplines is needed to study some important topics, such as this chapter's presentation. The chapter also includes examples of preserving of other fossil biomolecules from early human origin, such as Neanderthal's melanin.

Animals are the main resource of ancient biomolecules in the previous section; Chapter 11 is therefore entirely devoted to biomolecules obtained from plants. Moreover, the chapter begins by discussing sporopollenins, one of the best-known biomolecules (but rarely considered as a biomolecule) of plant origin. Sporopollenin constitutes the basis of the existence of palynology as a sub-discipline of Paleontology. Because Paleobotany includes the study of fossil plant tissues, this discipline frequently considers other biomolecules: cutin, cellulose, and lignin. Palaeobotany has a long tradition of studying biomolecules, so the role of biomolecules as fossils is well understood among palaeobotanists. Even chemotaxonomy (use of plant biomolecules for taxonomical purposes) can be considered a developing sub-discipline by palaeobotanists. Other palaeontological disciplines can learn from the palaeobotanical tradition. These approaches have already been developed in Argentina (*e.g.*, Lafuente Díaz *et al.*, 2020; 2021).

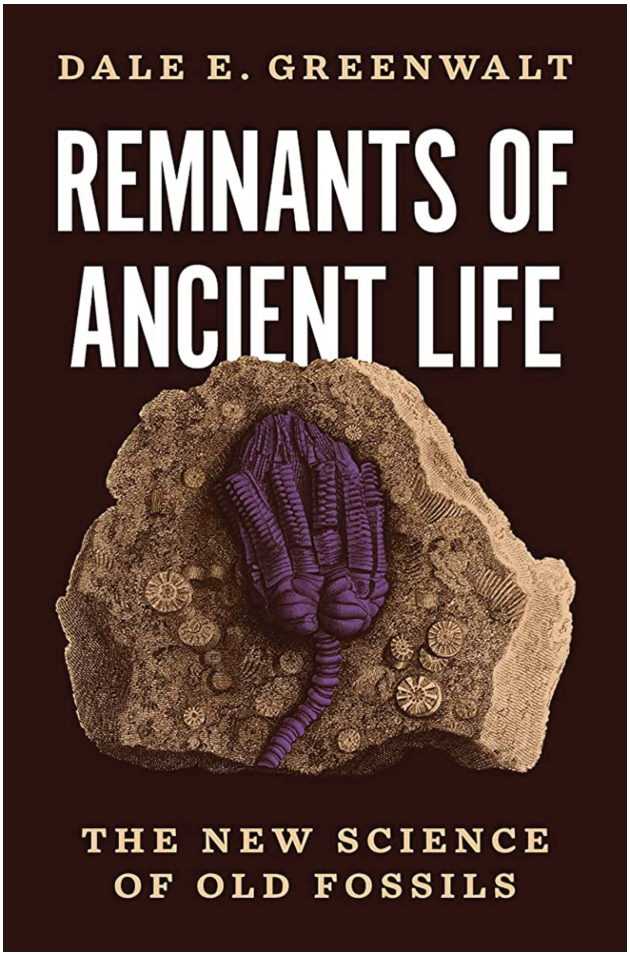

Figure 1. Cover of the reviewed book entitled Remnants of Ancient Life by Dale Greenwalt. Princeton University Press.

The last chapter is a good statement, deepening the prospects for studying fossil biomolecules. Some of them almost seem like science fiction (at least if we look at it from a few years ago), such as the astronomical search for ancient biomolecules on other planets (such as Mars, where Martian robot explorers are prepared for this search). Do these approaches constitute the seed of Astropalaeontology as a sub-discipline? Only time will tell. Another promising field considered in this chapter is Palaeogenetics, some of which are advanced in previous chapters. The text is encouraged to go even further, starting a discussion about commercial perspectives of fossil biomolecules.

Remnants of Ancient Life introduces the world of fossil biomolecules with a broad view based on reviewing several examples for each case. The study of fossil biomolecules is restricted because access to tools could be expensive. Despite this, the importance of biomolecules as a constituent part of the fossil record has been increasing in recent years—turning books like this one necessary to expand the picture. The primary definitions of fossils and fossil record used by D. Greenwalt help to consider Paleontology as a modern and broad discipline capable of adapting to the natural sciences' evolution. The writing of D. Greenwalt is designed to reach a general audience, but at the same time can be interesting for the specialist. Even paleontologists might be amazed and broaden their horizons by thinking about other types of fossils.

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