Book Review

Jorge A. Santiago-Blay[1]

Green Universe: A Microscopic Voyage into the Plant Cell
by Stephen Blackmore. Foreword by Sir Peter Crane. 2012. Royal Botanic Garden. Edinburg. Papadakis Publisher. Winterbourne, Berkshire, UK. 256 pp. ISBN: 978-1-906506-21-6 (hardbound, in English)

Beyond the blueness of most of our planet and the brownish hues of land, there is green, a celebration of plant life in *Green Universe: A Microscopic Voyage into the Plant Cell* by Stephen Blackmore. This book touched me because, back in 1987, when I was pursuing my doctorate, I became interested in herbivory and that meant learning about plants. Although I met professors in my "home" department who were unhappy about my decision to pursue two degrees simultaneously, the kind and knowledgeable botany professors and classmates I met in my other department gave me a broader perspective of life that changed me forever. I do not regret that major choice in life!

Green Universe deliberately uses botanical lingo with a phrase about what each term means, further defined in the *Glossary*, accompanied by a useful *Index*. Blackmore's book appeals both to botanists and to those interested in plants. Like any human creation, there are occasional mistakes, in my opinion, they are not distracting. Although it is impossible to do justice to this book in a few paragraphs, I want to emphasize all the good in this precious botanical work.

In *The Journey Begins*, the author communicates his love for plants at the scale of the tiny things, like cells. While our senses give us the opportunity to detect the universe, they are limited. Many tools, such as the microscope, give us greater abilities to detect what we cannot typically see with our unaided eyes.

The *History of Microscopy* is both lucid and beautifully illustrated. Although magnifying lenses have been known for millennia, the English naturalist, Robert Hooke (1635-1703), and the Dutch businessman and scientist, Antonj van Leeuwenhoek (1632-1723), began giving us legacies of the tiny objects they observed using their newly crafted microscopes. Anyone who has properly illuminated, cut, polished, and/or stained objects knows how important each of those skillful and artistic steps are to patiently create beautiful images. Many years ago, a memorable US professor of ecology at the University of Puerto Rico said to me about my being accepted in an intensive marine biology course, "Jorge, the sea is another world". His words (and the numerous incredible - and at times hilarious - experiences related to his course) resonate whenever I use any of the

[1] 217 Wynwood Road, York, Pennsylvania, USA 17402. E-mail: blayjorge@gmail.com

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many flavors of electron and light microscopes I have had the privilege of using. Seeing objects magnified approximately 1 million times has been both humbling and satisfying. In other times, we have shed further illumination on objects observed with relatively rudimentary microscopes approximately 100 years ago.

In *The Dawn of Life – First Cells*, Blackmore explores the greatest of all questions: how did life begin? The answer that Miller and Urey gave in 1952 is that, given the appropriate inorganic molecules and sources of energy, it is possible to form amino acids, simple organic molecules essential for life (Figure 1).

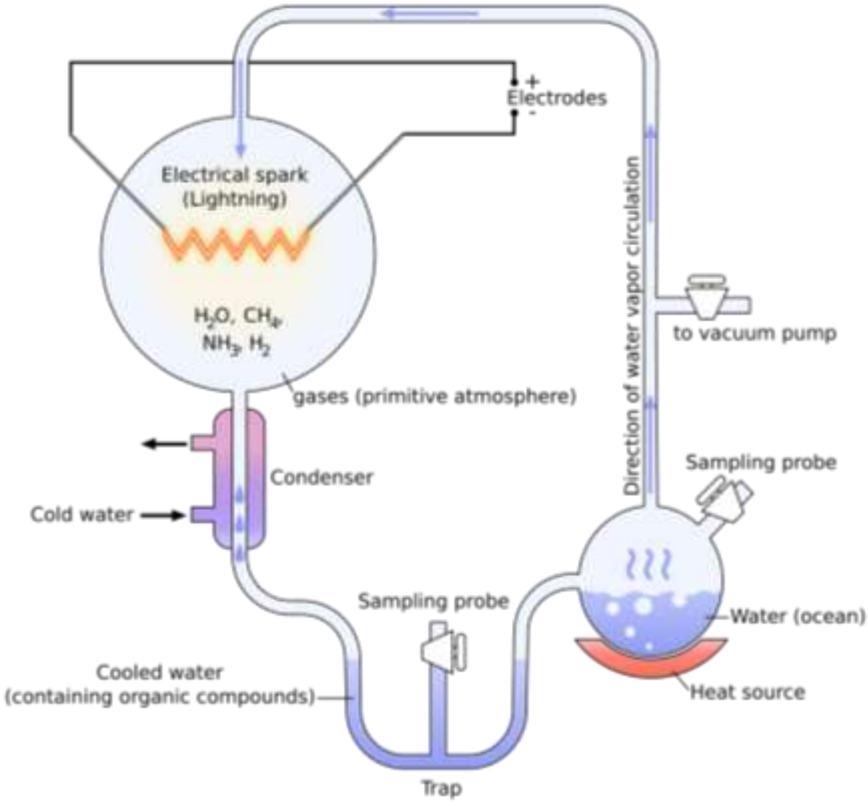

Figure 1. Simplified setup of Miller and Urey's experiment. Image from: https://www.nasa.gov/centers/goddard/images/content/283181main_volcanic_exp.jpg

Although no experiments have been able to form a cell from raw materials, scientists have been able to insert a minimum set of human-created genes into gene-free pre-existing bacteria and have those modified bacteria survive and reproduce. Based on fossil evidence, it is estimated that the first cells evolved approximately 3.9 billion years ago. These unicellular organisms formed the first two branches in the tree of life: Bacteria and Archaea. Those single-cells or colonial organisms are called "prokaryotic" as they have no nucleus and no membrane-bound organelles. Although different in their molecular machinery, both branches are collectively called "bacteria". Then, around 2 billion years ago, a new major branch in the tree of life began evolving. This branch contains organisms consisting of cells with both a nucleus and membrane-bound organelles. They are eukaryotic cells and eukaryotic organisms. From there, a plethora of relatively simpler eukaryotes, many photosynthetic, evolved.

The Invasion of Land challenges us to put ourselves in the place of plants. Recently evolved from a watery environment, how could plants cope with the dryness of air and a wind-swept desiccating environment? How could plants cope with the absence of a precious molecule, water? The Rhynie Chert, an Early Devonian (circa 400 million years old) sedimentary deposit in Scotland provides evidence for an answer. Organisms that became plants over evolutionary time developed diverse types of eukaryotic cells, such as those able to photosynthesize. Other cells anchored the organism to land and yet other cells could reproduce sexually, allowing the formation of different genetic combinations. Also, some of those cells had the ability to withstand desiccation. Thereafter, three distinct lineages of relatively small land plants, colloquially known as "bryophytes", namely liverworts, mosses, and hornworts, appeared next in the fossil record. One of their major innovations over evolutionary time was the development of alternation of generations, the ability to separate their life into a phase that is haploid, like our sperm cells or ovules, and a phase that is diploid, as in most of our body. When I teach botany, I show my students a clip from the 1972 Woody Allen's movie *Everything You Always Wanted to Know About Sex* (*But Were Afraid to Ask)* as a rough analogy of the gametophyte. In the clip, numerous sperm cells are depicted as having a separate life of sorts about to be expelled (ejaculated) on the direction of another sporophyte (woman) containing a gametophyte (ovule). Amazingly, in the first plants, the gametophytes dominate the life history of the plants physically and physiologically. This pattern has flipped with ever greater dominance of the sporophyte during evolutionary time.

In *Reaching for the Sun*, Blackmore discusses the first plants with plumbing tissues: xylem, which transport water as well as dissolved minerals, and phloem, which transport photosynthetic material to the rest of the plant. Some cells of the xylem are particularly hardened, or lignified, allowing some ferns and their allies to reach massive proportions. When the extensive forests of "pterydophytes" died and decomposed, they formed the fossilized energy deposits, or fossil fuels, that 300 million years later, now run modern civilization. Instead of reproducing with the direct agency of gametes as humans do, pterydophytes reproduce using spores that, upon germination, produce the structures that form the gametes. As in other inferred ancestral plants, the male gametes of pterydophytes are motile and, not surprisingly, many ferns thrive in humid environments.

Naked Seeds discusses the first of two plants groups with seeds, the other being the flowering plants. What is a seed? A plant embryo with some food and a (partial or complete) cover of sterile tissue. There are four groups of gymnosperms living with us: conifers, such as pines, cycads, many of which look like palms, ginkgos, and the "Gnetales" as group of plants survived by widely unlikely "siblings". The fossil record of gymnosperms is rich and it attests to a much greater diversity of these plants in past eons, particularly in the Mesozoic, when dinosaurs roamed on Earth. Like flowering plants, gymnosperms have pollen, which, upon germination into a "pollen tube", grows on the direction of the ovule. One of the most amazing features of some gymnosperms, such as cycads and *Ginkgo*, is that if there is a sperm, it is motile, just like in animals!

In *The Earth Flowers*, Blackmore "goes bananas" and with good reason: most of the botanical world we know today are flowering plants, or angiosperms. In its simplest concept, a complete flower is made from four different whorls, from the outside in: sepals, petals (the generally showy parts), male parts, and female parts. How do those parts develop? An explanation, called the ABC model, based on three interacting genes account for the development of flower parts (Figure 2).

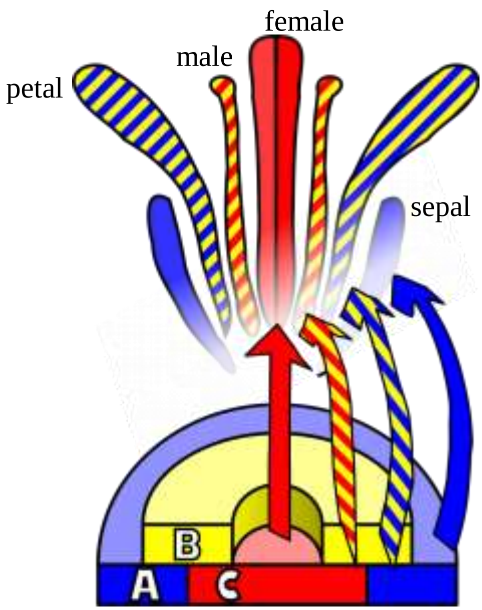

Figure 2. The four whorls of a complete flower, sepals, petals, male and female parts and the genes that directly control their development. Image taken from https://upload.wikimedia.org/wikipedia/commons/thumb/e/ee/ABC_flower_development.svg/730px-ABC_flower_development.svg.png . Approximately 400,000 described species of angiosperms have been described.

Yet, Darwin considered the relatively rapid evolutionary origin of flowers "an abominable mystery". Nowadays, we know of undisputed flowers at least 130 million years old (see Figures 3-5 for additional examples). But how to organize the botanical diversity? Linnaeus devised a practical numerological method to pigeonhole the plants known to him based on the presence/absence and/or combinations of (parts of the) whorls. For instance, one of his 24 classes were flowers with nine stamens and one pistil in a flower or, in Linnaeus words, "nine men in the same bride's chamber, with one woman", a description some found offensive to the Creator. The glorious diversity of seeds and fruits as well the magnificent pollination "syndromes", or complex sets of modifications of flowers that entice animals to enter in convenient mutually beneficial "arrangements", or mutualisms, complete this largest chapter.

Green Universe concludes with a chapter on ethnobotany, *Plants and People – Interconnected Fortunes*. Did you know that by the 1750's about half of Earth's forests were gone or that we humans are currently using about 40% of plants productivity? Blackmore energetically calls for protecting biodiversity and gardening the Earth. Tomes such as *Green Universe* can help generate understanding and develop motivation towards those goals.

Although *Green Universe* is a physically heavy and pricey tome, it is filled with countless gems of botanical, evolutionary, and historical information. Additionally, it is richly illustrated. I invite anyone curious about the world around us to read and enjoy *Green Universe: A Microscopic Voyage into the Plant Cell*. I wholeheartedly recommend it!

Figure 3. Flower preserved in amber from Chiapas, Mexico. Photo by Patrick R. Craig, Monte Rio, California, USA.

Figure 4. Flower preserved in Baltic amber. Photo by Patrick R. Craig, Monte Rio, California, USA.

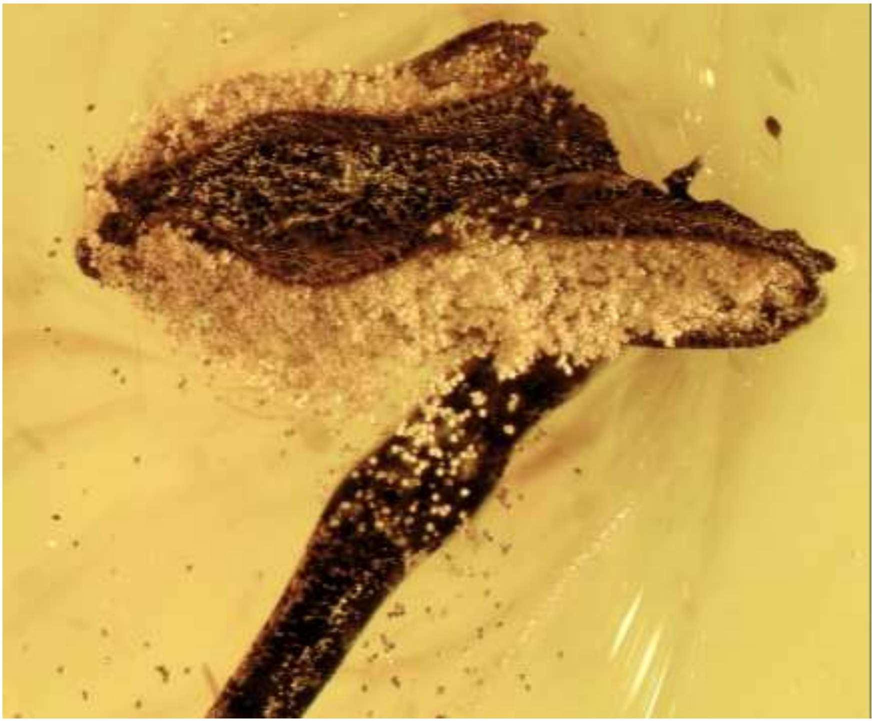

Figure 5. Pollen grains from the anthers of *Hymenaea* (Leguminosae) preserved in amber. Photo by Patrick R. Craig, Monte Rio, California, USA.