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PRESENTATION OF THE 2012 PALEONTOLOGICAL SOCIETY MEDAL TO BILL SCHOPF

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When I first came to LA in 1979 I found that southern California hosted an academic environment rich in paleontologists. I had arrived at USC to replace Bill Easton, who had been President of the PS. Caltech had Heinz Lowenstam and UC Riverside had Mike Woodburn and Mike Murphy, while Jim Valentine and Stan Awramik were at UC Santa Barbara. UCLA was the place with the greatest concentration of paleontologists, including the Loeblichs, Helen and Al, Everett Olson, and Bill Schopf, all of whom, including tonight's medalist, have won the PS Medal. UCLA had long been the center of southern California paleontology, with former faculty (Pres Cloud, Dan Axelrod) and students (Jim Valentine) also among PS Medal winners.

I had met Bill at the 1976 GSA in Denver when I was a graduate student at Indiana. I had gone to the GSA with Gary Lane and his grad students in an IU suburban. Gary had been a professor at UCLA before coming to IU, and he and Bill were best of friends. It was through Gary that I was introduced to Bill at that GSA.

When I arrived in LA, Bill was running a big operation at UCLA. He had received the Waterman Award and from the prize money had started the first Precambrian Paleobiology Research Group or PPRG. This comprised an international team of 41 scientists from eight countries who came to UCLA for 14 month periods in 1979–1980 and 1987–1988. This team consisted mainly of younger scientists and was one of the first truly interdisciplinary team efforts to understand the evolution of life in deep time. The PPRGs were the forerunners of the kind of integrative science espoused by the new Earth-Life Transitions program at NSF that we have heard a lot about tonight. The first PPRG led to the publication of the book "Earth's Earliest Biosphere, Its Origin and Evolution", and the second PPRG resulted in publication of "The Proterozoic Biosphere, A Multidisciplinay Study". Both of these books, edited by Bill, won national book prizes and are fundamental parts of any paleobiologist's library.

Also in the 1980s Bill established at UCLA the Center for the Study of Evolution and the Origin of Life (CSEOL). The activities at CSEOL over the years included weekly Wednesday evening seminars with dinner, open to the public, on all aspects of the evolution of life, as well as yearly public symposia including international guest speakers that resulted in widely-used edited volumes on many aspects of evolution. CSEOL also has had a highly successful visiting scientist program, with guests from around the world commonly in residence.

One of the aspects of Bill Schopf's leadership in Precambrian paleobiology has been a quest to find evidence for the oldest fossils on Earth. Bill's signature contribution to this topic has been his work on the microfossils of the Apex Chert in Australia. These microfossils, with an age of ~3.5 billion years, have been championed as the oldest fossil evidence for life on Earth. Since Bill first reported on these fossils in 1993 there has been a lively debate on their meaning as well as much additional work by others to gather evidence from a variety of sources on the existence of life on Earth during this time. As a means to further investigate such ancient fossils Bill has recently pioneered the use of Raman and fluorescence imagery as well as confocal scanning laser microscopy, which has yielded much useful evidence on the characteristics and taphonomy of Precambrian and younger fossils.

Given his widespread experience in the search for Precambrian life Bill has been very influential in the development of astrobiology as a field. Many of the challenges of Precambrian paleobiology are similar to those which astrobiology faces in the search for life on other planets. Much of the interdisciplinary nature of the PPRG is also reflected in the structure of the Astrobiology Institutes currently sponsored by NASA. His scientific leadership has thus had a very significant impact on those searching for microbial life throughout the solar system as well as in deep time.

For his broad contributions to science Bill has been made a member of the National Academy of Sciences and the American Philosophical Society, as well as a fellow of the American Academy of Arts and Sciences. This recognition of his high achievement by the broad scientific community further demonstrates the significance of his efforts.

A lot has changed with paleontology in southern California in the 33 years that I have been at USC. A big program has been built at UC Riverside by Mary Droser and Nigel Hughes. The Natural History Museum is flourishing under the leadership of Luis Chiappe and Xiaoming Wang. Caltech is pursuing its paleo aspirations through Woody Fischer. At UCLA Bruce Runnegar arrived in 1987 and won the PS medal two years ago, and other additions to the faculty there include Dave Jacobs and Blaire van Valkenburgh. Charles Marshall and Mark Webster have shouldered the load there, too. But, Bill has been the constant presence at UCLA, and long has been the senior paleontologist in Los Angeles.

Next year, 2013, will mark 50 years since Bill left Oberlin College to go to Harvard to work with Elso Barghoorn. He began at UCLA in 1968 and his vision has led to many of the innovations we enjoy in modern paleobiology. His life's work has been to further understanding of the evolution of early life, and it is for these contributions that we award him the Paleontological Society Medal tonight.

November 4, 2012

RESPONSE BY BILL SCHOPF
AND
BRIEF REMARKS ABOUT FUNDAMENTAL UNSOLVED PROBLEMS IN PALEONTOLOGY

I THANK Dave Bottjer, a former President of the Paleontological Society, for his kind remarks. As he has so excellently recounted, for many years southern California has been, and is now, an active plexus of paleontology; and, as his generosity to me so nicely exemplifies, the long-thriving "cross-town rivalry" between his university, USC, and mine, UCLA—daily fodder of the Sports Section of the *L.A. Times*—vanishes when it comes to science.

There are a great number of others who also deserve my thanks. But, primarily, I want to thank the Paleontological Society—not just for this remarkable honor, but for other things that I value very much.

First, I want to thank the Society for being so generous to my university. UCLA has been the home of six previous recipients of the Paleontological Society Medal (Bottjer, 2013): I am enormously honored to follow in their footsteps!

Second, I want to thank the Society for being so generous to my family. My older brother, Tom Schopf, the founder of our journal *Paleobiology*, received the Schuchert Award in 1976—as did I in 1974. And the Society has been kind not only to my brother and me, but to my father, James M. Schopf, who received the Paleontological Society Medal in 1978. As things turned out, my dad died from leukemia a few months before he was to receive the medal. He knew about the medal and was tremendously pleased. So, it fell to me to accept the award on his behalf (Schopf, 1979).

Given the foregoing, I represent two "firsts" for the Society: (1) I am the younger member of the first father-son pair to receive this award; and (2) I am the only one who has ever *twice* given an acceptance speech for the Paleontological Society Medal—first for my dad, and now for myself!

There are, of course, many others whom I would like to acknowledge—especially, my undergraduate geology professor at Oberlin College, Larry Demott; my graduate professor at Harvard, biologist-paleobotanist Elso Barghoorn; and fossil crinoid-specialist N. Gary Lane, an SEPM medalist, a former Editor of the *Journal of Paleontology* and President of our Society, and to me a great friend, colleague, and fellow Oberlin-graduate who taught me how to teach. These were my three great mentors—but they are no longer with us to hear my words

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of appreciation. Still, I want also to acknowledge the two friends who have mattered most to me in helping me to do my work: my UCLA colleague, Anatoliy Kudryatsev, the world's expert on the optical spectroscopy of ancient fossils, and my wife, Jane, a world-class plant biologist who has managed to put up with me for a great many years.

Unlike the Academy Awards, and their typically exhaustive homage to those who have influenced the honorees, I will not here list the students, colleagues, and many other friends who have been helpful to me and taught me over the years. Instead, I want to use this opportunity—probably the only chance I will ever have to communicate with such a such large group of fellow-paleontologists—about some fundamental scientific questions that I am disappointed have not been answered. In other words, I want to use this opportunity to vent my frustration about my own inadequacies and the big problems that I have not been able to solve. I do this in the hope that among those who read these remarks there will be some paleontologists, especially the younger workers in our field, who will grab onto one or another of these questions and run with them. I will mention only three:

First, I am disappointed that the history of day-length has not been traced back over geological time.

John W. Wells received the Paleontological Society Medal in 1974 for showing us, by his studies of fossil corals, that day-length 400 million years ago was shorter, ~22 hours per day instead of 24 and yielding a 400- rather than a 365-day year (Wells, 1963). There have been a number of studies since Wells' work (e.g., Vanyo and Awramik, 1985; Zahnle and Walker, 1987; Williams, 1997) but the problem—especially in deep time—has not been nailed. Day-length is fundamental. It is of course crucial to biology, but its change over time also holds the key to unraveling the history of the Earth-Moon system. Perhaps the answer lies in understanding the molecular bases of the circadian clocks of modern organisms and extrapolating into the geological past. Such data are now available for plants (e.g., Harmer et al., 2000), animals (e.g., Shearman et al., 2000) and prokaryotes, primarily cyanobacteria (e.g., Kondo et al., 1993; Golden et al., 1997; Nkajima et al., 2005), but circadian clock-change over time, its evolutionary history, has yet to be deciphered.

Second, I am frustrated that so little seems to be known about the history of Earth's surface temperature over the geological past.

Isotopic data suggest a decline from perhaps 60°C, three billion years ago, to the present 15°C (Knauth, 2005; Robert and Chaussidon, 2006). Such a change would have profoundly affected Earth's biota. But for many workers it remains uncertain whether such a change actually occurred or what its path may have been. It seems possible that this history is recorded in the evolutionarily stable active sites of enzymes, since it must be true that when any new biosynthetic pathway arises its enzymes would have to have functioned at the then-prevailing ambient temperature. Thus, for example, I can imagine comparing the thermal stability of the stable active sites of enzymes involved in bacterial cell wall synthesis, dating from more than 3.5 billion years ago—with those required for the biosynthesis of cellulose in algae, perhaps 2 billion years ago—with those involved in the production of the cell wall chitin of fungi or the collagen connective-tissue in animals, innovations of the late Precambrian.

Finally, it has long bothered me that there is no known evidence of the "primordial soup" from which life is thought to have emerged.

The origin of life, of course, is probably the foremost unsolved problem in all of Natural Science, but I do not hold out hope of there being any direct evidence in the rock record. The organics involved are all so geochemically unstable that I do not imagine that evidence of a pre-cellular world will have been preserved. Still, if we could find the right rocks and had the right techniques, there ought to be some evidence of non-biologically produced organic matter—the hypothetical "primordial soup"—and, perhaps, traces of non-biologic organics up to around 2.4 billion years ago when the environment finally became oxygen-enriched (Holland, 2002) and shut down abiotic organic syntheses. Here I imagine that the answer may lie in isotopic analyses of the composition of molecular biomarkers extracted from ancient sediments that for biosynthesized organics, unlike those produced by abiotic syntheses, can be compound-specific (Hayes et al., 1990). Such analyses, combined with those of the intra-molecular pattern of the isotopic distribution within such biomarkers—a pattern that in enzyme-mediated biological systems can be regularly ordered (as, for example, in polyisoprenoid lipids; Susumu et al., 1997) but for non-biological organic matter should be decidedly more variable—might provide the evidence needed to differentiate abiotic from biological organic matter.

There are numerous other fundamental problems that could be mentioned and, with the tools now available, many can be solved. We are the interdisciplinary scientists who can do just that. The way I look at it, of all those in the Natural Sciences, we paleontologists are the lucky ones! More than any other group, we bridge the gap between geology and biology. And I am fully convinced that we are now seeing the onset of what will come to be known as the "Century of Evolution." The sequencing of genomes—once costly but now commonplace—provides new grist for our mill. Encoded in those genomes is the history of life and its response to changes in the physical and biological environment over geological time. But only *we* can document the timing of such change, and it is only *we* who are likely to ask the telling questions. We paleontologists stand at the crossroads, the intersection between geology and biology, and that gives us the special advantage of wondering about those two worlds and asking questions that others would never pose.

As for me, I have now spent 50 years, since 1961, learning more and more about the history of life and having enormously good fun. I am not nearly done, but it is up to the younger workers in our science to tackle the big problems that are yet unsolved. We paleontologists can do it. We are the lucky ones. But we have to ask the right questions and carry through to find their answers!

I thank the Society for its kindness to my university, to my family, and to me. I am enormously pleased and honored to be recipient of the 2012 Paleontological Society Medal.

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