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A tribute to professor Robert West, on the occasion of his 90th birthday

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ABSTRACT

This is for Bob, and for his vast number of friends and colleagues who wish to celebrate his 90th birthday. On this occasion we express our admiration, friendship, and appreciation for the wonderful adventures that he has shared with so many of us. While we are limited to providing a personal account of our experience of Bob, we believe that what we describe will in some way resonant with those who know him. Not surprisingly, the life of a great person is dedicated to all possible kinds of movement (mentally and physically) always curious and ready to find out what future brings rather than looking back upon the past. Needless to say – Bob moves quickly. Very quickly. So we will not pretend that we, or anyone else, could capture the essence of the man. As much as he immerses himself in the moment, it seems a losing proposition to try to identify something singular and unchanging about him. As Heraclitus says "we can never step into the same river twice," so has been our experience, and delight, with Bob. It is our hope that many other accounts of Bob will be told and retold during the events celebrating his 90th birthday.

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What follows is an unavoidably idiosyncratic view from two of Bob's Silicon Kid Juniors – a Ph.D. student and post-doc, who found themselves sharing a laboratory in the West Group at the same time. It doesn't rise to the level of a case study and is only one of the infinite number of possible sketches of what it could be like to be in Bob's world – to follow his trajectory of thought, action, and imagination. Of course, there *is* his science - over 600 publications having a collective impact that led him to be one of the most cited scientists for almost two decades. But we wanted to offer something different than a hurried literature review, an approach that can devolve into a historical list of "one damn thing after another." We didn't want to risk sanitizing the richness of the great team efforts, the insights, thrills, and inspiration behind the work and play. Of course, Bob's body of work could and should be reviewed and treated with the scholarly depth that it deserves – for surely there is something broader to be learned from the direction his science took and from his accomplishments than what can be found in any of his individual works.

In setting out to write this, we could not overlook the opportunity to satisfy our own curiosity about those paths that Bob had taken long before we knew him - so we indulged ourselves a bit by asking him a few questions. When we first approached Bob about this and explained our purpose, he seemed to be wholly unaware of his impending birthday - so we offer our apologies for startling him over that. One of the things that we discovered in talking with him, was that every apocryphal story comprising the West Group oral tradition turned out to be true – at least those we queried him about. And though we weren't able ask him about *every* tale, we've decided to take the liberty of assuming that the rest of them are true as well. In any case, as bona fide features of West Group lore, they cannot be omitted …

Among the things we learned about Bob's earlier life, was that while he didn't always pilot a small plane, he has, in a sense, always flown. His first passion with the natural world was in astronomy – with the tiny points of lights that lay beyond the sky – the planets, suns, galaxies and those things real and imagined that he took in through his homemade telescope in the New Jersey. Before long, his attention was absorbed by the rocks and minerals beneath his feet and the kaleidoscope of materials and the stories that can be found there. But quickly – very quickly, Bob's fascination with the natural world became fixed on what connected it all together – the chemistry. So earnestly did he pursue the subject, that he proved himself to be a chemist and scientist at only sixteen years old. The United States, short-handed during the war and sorely in need of scientific minds and hands to help with the effort, enlisted Bob to help. Solemnly sworn to secrecy, the teenage Bob began his professional career working in a metallurgy laboratory for the Manhattan Project in New Jersey. Remarkably, his inquisitive mind drove him to quickly discern what the goal of the entire Project was.

Bob's first flight took him from his New Jersey hometown to Cornell, where he excelled as a student and, according to the authoritative Wikipedia, apparently continued to dabble in secrecy with the Quill and Dagger Society (though it could have been something he only did for his resume). From there, he went on to Harvard where he studied

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under the grandfather of silicon and silicone chemistry, Eugene Rochow.

After the Manhattan Project and Cornell, Bob put no more stock in secrets or secret societies at Harvard – and we have been assured that there are no tattoos. At Harvard, his research included the synthesis and characterization of new silicon and germanium compounds. His earliest flights across the United States were constrained to the ground level – hitchhiking expeditions across the country to claim previously unclimbed peaks in the Western United States. Always upward no matter what! By Bob's descriptions, the logistics and planning that went into these adventures was slim and the "peak bagging" appears to have been accomplished rather recklessly. His treks and climbs continued in a very different way when he returned to the Harvard Laboratories – opposite in scale and dimension to those he encountered in the West – a vista available only to the Mind's eye of the imaginative chemist. Bob was well-known for both kinds of mountaineering over the years – there were many peaks climbed and cairns fashioned. We could ask Bob or some of his fellow travelers which ones were the most spectacular – our sense is that it was whichever one was being traversed at the moment.

Bob collected his Ph.D. at Harvard and struck out alone at Lehigh University where he quickly proved himself to be an original and productive scientist. After only a short time, he left Lehigh for the scale, reputation, and forward-thinking environment of the University of Wisconsin in Madison. To orient ourselves in time: these were the early 50's and it would be almost 20 years before Leigh University took the plunge and became coeducational – a gender barrier that the University of Wisconsin crossed in 1874. The University of Wisconsin was enticing – it had the reputation and gravitas that people like Bob brought to it. It was far from the Ivy League culture of the East and found its path to becoming a scientific powerhouse through providing the practical and pressing needs of the state's agricultural economy. By the time Bob arrived, pure science had been thriving for decades alongside the applied and the University of Wisconsin, like Bob, moved quickly. Even so, neither Bob nor Madison likely anticipated the tumultuous decades of the 60's and 70's that followed. When Bob first arrived in Madison, there were entire research floors in the Chemistry and Physics buildings that didn't have women's restrooms – given the demographics of the graduate student body, there simply wasn't much of a demand for them. Bob helped change that – he quietly went through the stack of graduate school applications that had been set aside before the admissions committee members had a chance to review them. He found some gems in those files and some of them were women who found a path to becoming successful scientists and educators with long and productive careers of their own. Some of their names are familiar to us.

Madison in the 1950s – if the time and place are difficult for some of us to imagine, the chemistry is as well. Gleaning through some of Bob's earliest work at Harvard, Lehigh, and Madison, we were surprised and awed by the lengths to which infrared spectroscopy was successfully employed to establish the structure of main-group compounds. Of course, this shouldn't have been surprising – the first reliable commercial NMR instruments were introduced only in 1961 and the earlier, cutting edge instruments were extremely finicky – the first NMR instrument room at Madison was shrouded in copper in attempts to reduce noise.

An examination of Bob's publication record is an invitation to a very deep and elaborate rabbit hole of chemistry (a wonderful "Best of Bob" list can be found at the UW-Madison Chemistry Department's website: https://www.chem.wisc.edu/pubs/612) . There has been much more than silicon in Bob's chemical quest. Early on, he studied organolithium compounds carefully – both their structure and their reactivity (including the kinetic isotope effects of lithium). Then were the oxocarbons, with deltic acid and its wonderfully symmetric dianion, $C_3O_3^{2-}$at the center of the story. The quinone-radialenes were spectacular - beautiful both in the symmetry of their structures and in their colors, which exhibited spectacular electronic hues far into the near infrared. Perhaps because it is eclipsed by his more recent work with silicon, one can easily overlook how much attention Bob has paid to the chemistry of carbon. It isn't quite right to describe this work as "organic chemistry", because in Bob's hands, carbon was a main-group element – he didn't care if it was "organic" or not. There were perlithiated carbon compounds, perchlorinated small carbon rings, and even the large organic radialenes still seemed more like main group compounds than they did something an organic chemist would claim. His abiding agnostism kept him (and we think, us) from prematurely classifying things. Keep your mind always open, man!

A consideration of Bob's full body of work revealed to us an element that was perhaps as central to his science as any other – oxygen. It is an element frequently taken for granted – taking second place in naming conventions and often treated, or at least spoken of, as a mere passenger. It is a heteroatom among heteroatoms. But in Bob's oeuvre, oxygen is a remarkably central and consistent feature – he has come back to it again and again. First, and perhaps most prominently it is found in the oxocarbons and radialenes and then closely and carefully in the siloxanes ('silicones'). Bob studied the acidity of silanols, investigated H-bonding to siloxanes, and was fascinated with the Si-O-Si linkage. Perhaps it was subconsciously a vestige of his early interest in minerals, or perhaps it is because of it remarkable structure, as Bob has repeatedly brought to our attention. The curiously wide range of Si-O-Si bond angles that exist in nature found its most acute limit in the West laboratories – one crystalline form of a 1,3-cyclodisiloxane features an Si-O-Si angle that is less than 90 degrees. In other siloxane linkages, the Si-O-Si bond angle approaches and occasionally reaches linearity. Bob also probed and studied the weak basicity of the siloxane oxygen atom – what indeed is going on there? That patterns like these were important to Bob is evidenced in the theoretical papers on siloxane bonding that he recently coauthored.

Considering all this in retrospect – Bob's experience probing the chemistry of lithium, carbon, oxygen, and

silicon – it seems perfectly natural that he was in a position to bring all of them together and create an improved lithium ion battery. Bob's company, Silatronix Inc., is now ten years old and offers "High-performance Organosilicon Electrolytes for Energy Storage." The world has indeed won a great windfall from Bob's expertise in main group chemistry. These new commercial materials offer greater charge capacity, higher voltage, improved safety, extend operating temperature ranges, and longer life times for lithium batteries. This is a major contribution to sustainability and toward efforts to realize a post-carbon economy. Indeed, most of his scientific work is currently focused on the applied research that he conducts daily at Silatronix.

To avoid being taken to task, we must of course mention the organosilicon work which Bob is most well-known for: the famous stable and beautifully orange crystalline tetramesityldisilene, which broke the "double-bond rule" and paved the avenue to isolable divalent silylenes. These new functional groups provided many pathways to novel chemical structures that hitherto hadn't been accessible or even imagined. Then there were the polysilanes, some of remarkably high molecular weights and which possess unprecedented thermal and opto-electronic properties. It does seem undeniable that Bob, the bold Silicon Kid, had a favorite element – even if he treated most of the other elements with equal respect.

There was one possible exception among the elements. Bob did take an issue with lead – at least in the form of tetraethyllead. Its ubiquitous use as an anti-knocking agent in gasoline and the devastating effects it had on children disturbed him. Because he was quite vocal about it, he caught the attention of the Ethyl Corporation, which in great contrast, had a special fondness for the compound. The president of the Ethyl Corporation complained directly to the University of Wisconsin's chancellor about Bob's animosity towards tetraethyl lead – as though it wasn't appropriate for a chemist to take issue with a chemical compound… In any case, Ethyl Corporation's hopes that more responsible parties would intervene and end Bob's criticism of their irreplaceable compound was met with disappointment – considering the University's traditions and its location in the Free City of Madison, it couldn't have been otherwise.

Bob's concern and general love of people is a theme that has always been present. He has a special empathy for those not in a position to help or protect themselves and has an abiding sense of fairness that has been manifested in many different venues and situations. If there is anything singular and unchanging about Bob – it is this. He has been particular concerned about population growth, unwanted or unplanned pregnancies, and the plight of powerless women. Immersed in the greater community of Madison where he found like-minded people, he acted decisively to help many women in need by co-founding the Women's Medical Fund in Wisconsin in 1972. He continues to serve on its Board of Directors to this day.

Bob's political, social, and personal positions, and his great empathy for his fellow man and woman has been far more influential to the people around him than he probably feels comfortable taking credit for. This is true whether it was a political or social statement he made, or whether it was simply the way he treated his colleagues and students. My (AM's) first meeting with Bob was as a disoriented undergraduate who had finally gathered up the nerve to find out what chemical research was about. Occasional rumors of Bob circulated among undergraduates on the instructional floors of the Chemistry Building – a chance conversation, the draw of doing research, and the novelty of meeting a professor who everyone addressed by his first name finally led me to push the elevator button that would take me up to his 6th floor research labs. Finding Bob in his office, I awkwardly tried to explain what brought me there. He quickly flashed a wonderfully warm smile, shook my hand, and welcomed me into his office to chat. As I sat down, I couldn't but help notice the large portrait of Augusto Cesar Sandino looking down upon us. Sandino was the patron saint of the powerless, but a Saint who was willing to put up a fight. I knew then that I had come to the right place.

Bob took me and everyone else into his chemistry home as though he had been expecting us the whole time. The laboratories had a spectacularly international flavor, and everyone there was made to feel welcome. This was important too for the American students, since some of us were borderline misfits and for one reason or another, felt like ex pats in own country. Some students had atypical educations and backgrounds – Ancient Greek, Education, Philosophy… No matter – we all were made to feel welcome. There was a tremendous amount of opportunity – and of a kind that no one took for granted. The students, post-docs, and visiting faculty came from all over and in the short period of time we were there, there were good friends and colleagues from the US, Israel, Poland, Korea, China, Germany, Brazil, The Netherlands, Mongolia, England, Japan, Singapore, Austria, India, and Iran. At the very same time, and with great frequency, Bob was on the other side of the world serving as a scientific, cultural, and silicon ambassador to every continent save Antarctica. The range of his collaborations, geographically and scientifically, was broad – it was also essential to his way of thinking and doing things. Researchers from everywhere visited Madison – Polish, Hungarian, and Soviet scientists found their way around the Wall to meet with a welcome reception. An attempt at offering an encyclopedic account of Bob's collaborators and visiting professorships doesn't just risk offending an individual person through the mistake of omission, but it could very well offend an entire country. As just one example, a visiting professorship at King Halie Selassie I University in Ethiopia was left out of Bob's Wikipedia entry – it was a place where he was particularly appreciated for his outstanding lecturing.

In the United States and even in Madison, Bob served as something of a cultural ambassador. The oral history of the West Group includes an episode during the Vietnam War and Madison's own War at Home. There were a number of science departments on the University of Wisconsin campus that had grants and contracts to perform war-related work and they became the frequent target of

protests. On one of these days, a large group of angry protesters had assembled outside of the front door of the Chemistry Department. Thankfully, Bob was on hand to speak with them. He greeted them with a smile and a flash of the peace sign and after some words, had successfully calmed them down or at least redirected their wrath elsewhere …

Bob was always surrounded by people. And of course, his scientific accomplishments at the University of Wisconsin were group efforts being the product of many hands and minds. His students were collaborators who were treated with more respect than the "Et Al and coworkers" of other research groups. There were group meetings – many, many group meetings, which were fueled with boxes of day-old donuts. One of the unresolved curiosities of these meetings was why Bob was so compelled to remind us, at every meeting, that they were day-old donuts – he seemed determined to convince us that they were superior to the fresh ones …

The literature meetings were wide-ranging and it wasn't uncommon to have the entire group meet together and to enjoy a couple of tasty cold Wisconsin beers afterwards. The polymer chemistry was discussed alongside the small molecule chemistry of compounds that couldn't tolerate oxygen. Everyone knew what everyone else was doing and frequently had something to say about it. One of the intuitions or senses for science that made Bob such a great fit for us and made us feel welcome was the balance he struck between theorizing and doing real chemistry. He didn't shy away from asking difficult questions of theoreticians and held their feet to the fire with regard to actually explaining themselves by using words or images. The several longstanding collaborations he developed with theoreticians underscores the fruitfulness of his approach and of sharing problems with others.

Bob would frequently pull back from experimental work and to stop and get his bearings – as though he was doing some kind of molecular orienteering through the mountains of chemistry. Taking time to look at the map, the compass, and his surroundings, he would cogitate deeply – and then plunge back into the thickets. While theory was absolutely central to what he did, he also quickly detected diminishing returns – "let's do the experiment and find out…" At the end of the day, he knew when the time for speculation was over.

Things went on and on toward more challenges by a 'flying' great scientist who always strives for a 'bigger' picture view – bold in taking new directions in science. Following the old saying "a picture speaks a thousand words" we felt it is appropriate to complete our personal view on Bob's achievements with the artwork shown below.

Here we witness Bob continuing his scientific journey – overflying some of the scientific summits he has scaled. There is lithium ion battery research, the extraterrestrial muon, which he recently helped harness to probe silicon and germanium compounds, his work on sila-pharmaceuticals and, on the top of his mountain chain, the taming of silylenes and silylines, which are portrayed as shy and headstrong goats socializing to form isolable dimers (disilenes, disilynes). We find Bob in his flight with his friend the octopus – a creature that we now understand to be far too intelligent and open-minded to be consumed on an appetizer plate. The octopus, a very special one, offers Bob and us the fantastic novelties of nature and of people – a multiplicity of hands and minds that we all benefit from. There always have been and always will be friends and collaborators – whether they are scientists or maybe even a poet.