REFERENCE

John Martin (1935-1993)

by John Weier

A little over ten years ago at a lecture at the Woods Hole Oceanographic Institution, oceanographer John Martin stood up and said in his best Dr. Strangelove accent, “Give me a half tanker of iron, and I will give you an ice age.”

These inflammatory words centered around a theory known as the iron hypothesis. Martin professed that by sprinkling a relatively small amount of iron into certain areas of the ocean, known as high-nutrient, low-chlorophyll zones (HNLCs), one could create large blooms of those unicellular aquatic plants commonly known as algae. If enough of these HNLC zones were fertilized with iron, he believed the growth in algae could take in so much carbon from the atmosphere that they could reverse the greenhouse effect and cool the Earth.

Martin’s theory sparked a tremendous debate. Unlike most of the unusual, somewhat esoteric theories that float about the scientific community at any given time, Martin’s idea had teeth. It could be tested and it had the potential to impact the world on a short time scale. Many of Martin’s contemporaries reacted strongly by claiming his iron hypothesis was ill founded. They felt that his “Geritol” solution to climate change was careless and hazardous for the environment. Corporations and even some countries, however, embraced the idea. They saw Martin’s results as a way to reduce the effects of their own carbon dioxide and bring themselves within the emissions standards set up by the proposed Kyoto Protocol. Meanwhile, the press portrayed Martin as a renegade scientist that came out of nowhere with a

"Give me a half tanker of iron, and I will give you an ice age."

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Top: A portrait of John Martin. (Drawing by Roger Kammerer) mission to prove everyone wrong, calling him "Johnny Ironseed" and "Iron Man."

Martin, a burly, bearded oceanographer with an iconoclastic streak and wry sense of humor, reveled in the controversy and didn't back down. He stuck to his hypothesis to the end. Several months after his death in 1993, the theory was proven to be correct by his colleagues at the Moss Landing Marine Laboratories. They spread an iron solution into an HNLC zone near the Galapagos Islands and algae bloomed.

While the success of this contested experiment established Martin's legacy, it also overshadowed his earlier work. And there was more to Martin than just this one theory. The iron hypothesis came to him only at the end of a rich life and a prestigious career in oceanography, and it was just one in a long series of discoveries Martin and his colleagues made. In fact, Martin was among the first scientists to successfully test and catalog a wide range of trace metals in the Earth's oceans. He also demonstrated that copper and zinc could affect measurements of phytoplankton (algae) growth. With regards to the global climate, Martin's experiments into the amounts of carbon drawn into the seas by algae formed the basis for many of the current large-scale efforts to understand the ocean's role in the Earth's carbon budget. Throughout his career, Martin was a scientist with strong instincts, convictions, and ideas that altered forever how scientists regard the Earth's oceans.

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Born in Old Lyme, Connecticut, on February 27, 1935, John Martin had an ideal New England childhood. He did reasonably well in school, participated in sports, and enjoyed fishing and hiking in the woods of Connecticut and Maine with his family. Martin's comfortable life, however, came to an abrupt halt when he was diagnosed with polio just prior to his sophomore year at Colby College. The disease hospitalized him for nine months, several of which he spent in an iron lung.

"From the start, Martin's main interest was in marine life at the most basic level."

But the polio neither broke his spirit nor deterred him from his goals. Through a diet of swimming and rehabilitation exercises, Martin brought himself to the

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point where he was able to walk with canes. He then managed to finish college within three years after his recovery. “Through these adversities, John adopted the tenacity and drive that served him in his career,” says Marlene Martin, John Martin’s widow.

At the urging of his father, an influential conservationist in Connecticut, Martin enrolled in the graduate program for marine zoology at the University of Rhode Island. From the start, Martin’s main interest was in marine life at the most basic level. He wanted to explore those conditions and basic nutrients in the sea that regulate the growth of phytoplankton and zooplankton (tiny animals that feed off phytoplankton). At the University of Rhode Island, in his doctoral thesis he examined the role that zooplankton play in changing the levels of nutrients, such as nitrogen and phosphorus, that regulate algae in Nantucket Bay.

Shortly after receiving his Ph.D., Martin landed a job in Puerto Rico, working for the Nuclear Regulatory Commission (NRC). He was assigned the task of testing the long-term effects of nuclear radiation on phytoplankton in the region. The NRC and the U.S. Army Corps of Engineers were toying with the idea of detonating nuclear weapons throughout Panama to widen the Panama Canal and separate North and South America once and for all. Most scientists involved in the project, including Martin, were against the idea. Not only would the explosions contaminate the entire food web, but they would also shatter every window in Panama City. The project was scrapped in the end.

It was in Puerto Rico that Martin met his wife Marlene, who worked for the Peace Corps. She says she first met John Martin when she was trying to hunt down someone to help her understand why the poor fishermen in the village of Mayaguez could hardly support themselves with the number of fish they brought in. Marlene recounts,“When I met John, I sized him up and I decided I didn’t like him. I thought he was too preppy. John later told me that the minute I walked through the door, he knew he wanted to marry me.” John Martin did everything possible to help her in her assignment in Puerto Rico, and he made sure he never lost contact. Despite Marlene’s initial

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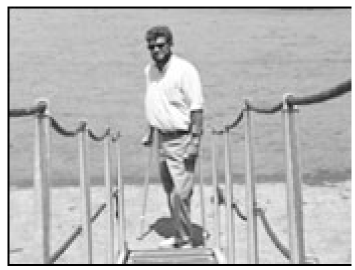

John Martin was struck by polio while in college. Despite the disability caused by the disease,forcing him to walk with braces, he was able to make important discoveries in the field of ocean chemistry and head a major scientific research center for 17 years. (Photograph courtesy California State University) misgivings, she eventually came around. In 1969 they married and settled down in Monterey Bay, California, where she teaches English at Monterey Peninsula College. “He was following his instincts. They were correct. It was a great marriage,” says Marlene Martin.

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"Martin and his colleagues found nearly an entire periodic table in the oceans."

After returning from Puerto Rico, Martin garnered the position of acting Assistant Professor in biology with the Hopkins Marine Station of Stanford University. There Martin began his work with trace metals in the ocean, which would come to dominate his career. In the early 1970s, oceanographers held fast to the idea that phosphorus and nitrogen were the only nutrients vital in determining the distribution of the world’s algae populations. They believed that the higher the levels of these non-metallic elements became, the more phytoplankton would grow and the greater the populations of zooplankton and fish would be.

Martin, however, saw this explanation as too simplistic. He wondered what role trace metals such as iron or zinc played in the growth of algae and zooplankton. After all, most land-based life forms, including humans, cannot survive without such metals in their diet. At Hopkins, Martin labored to document the amount of trace metals in zooplankton and phytoplankton specimens. He found that the most common types of plankton contained a regular number of trace metals in their chemical make-up such as zinc, iron, and copper.

Martin pursued his research at the Moss Landing Marine Laboratories where he took the position of Assistant Professor in 1972. “By the time he got to Moss Landing he was an expert in trace metals in plankton,” says Kenneth Coale, a colleague of Martin and the acting director of Moss Landing. Now that Martin knew what trace metals were in phytoplankton, the next step was to determine the general distribution of these metals in the ocean.

Martin had his work cut out for him. Very few researchers had gone to the trouble of measuring trace metals in seawater samples, and the readings they had

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taken were likely flawed. The problem with earlier studies on trace metals, Martin realized, was contamination. The iron hull of a ship will raise iron levels in a sample of water by more than 100 times, making it difficult to measure the natural iron levels. Copper tubing or leaded glass test tubes have the same effect on measurements of copper or lead in seawater samples.


John Martin's research centered on phytoplankton—the tiny marine plants that form the base of the ocean food chain. This micrograph shows a specimen of Actinocyclus ingens collected in the southern Atlantic Ocean. (Image copyright Ivo Grigorov, Southampton Oceanography Centre, from the Marine Diatom Index)

He corresponded with Claire Patterson, a geologist at the California Institute of Technology famous for uncovering the age of the Earth by analyzing lead samples in ancient meteorites. Patterson was also one of the few people to successfully isolate trace metals in water. Under Martin's direction, Moss Landing began applying Patterson's techniques in their laboratories. As it turned out, the answer lay in one word—plastics. The Moss Landing group rid the lab of all metals that could contaminate a sample of ocean water. They threw out their glass and steel funnels and test tubes and replaced them with Teflon and plastic ones. Copper and glass tubing was replaced by plastic tubing. "Everyone there became an expert at welding plastic," says Coale.

When the researchers at Moss Landing ran tests for trace metals in the newly renovated lab, they found that metal concentrations in the ocean were orders of magnitude lower than previously thought. Iron concentrations alone were thousands of times less than any measurement taken in the past. At the same time the researchers tested for trace metals that had never been documented, such as zinc, cobalt, and manganese. They found nearly an entire periodic table in the oceans.

A slew of discoveries followed their cataloging effort. Among these was the realization that trace amounts of copper and zinc actually decrease measurements of algae growth in seawater. This news did not go over well with the science community at first. Essentially the Moss Landing researchers were telling many oceanographers that the measurements on phytoplankton growth they had taken over the years may have been incorrect. "But Martin enjoyed these kinds of reactions. He liked to see himself as the underdog," says Coale. His results were eventually accepted.

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In 1975, Martin became director of the Moss Landing Marine Laboratories. Previously the research center had switched directors every four years. Martin held onto the position for nearly 18 years. It was during his term as director that the lab became a force to be reckoned with.

Many attribute his success as both a scientist and an administrator to his charisma and his ability to think creatively. "John had a knack for stumbling into difficult problems and then coming up with simple solutions to them. That is the mark of a great scientist," says Coale. Martin's disabilities from polio didn't always allow him to sit in a lab for hours on end and work out all the technical details. His innovative ideas, his attention to his colleagues' needs, and his good nature, however, attracted the interest of scientists from all over the country. In the end, he always managed to get the best from people who worked for him in the lab.

As director, Martin turned his attention to the issue of phytoplankton's role in global climate. Not only do these tiny plants give much of the ocean its green color, but they also collectively draw down millions of tons of carbon dioxide, one of the most abundant greenhouse gases, from the atmosphere each year. Phytoplankton take in carbon through the process of photosynthesis and incorporate it into their cell structure. When phytoplankton die, many will sink to the bottom of the ocean. Since the carbon is no longer allowed to roam freely in the atmosphere, it cannot contribute to the greenhouse effect and the warming of the planet. Understanding this process is vital to understanding how we affect our climate through carbon dioxide emissions.

This research was right up Martin's alley. It was complex, involved the fundamental processes of life, and was full of unanswered questions. Martin organized the Vertical Transport and Exchange of Oceanic Particulate Program (VERTEX) in 1981 to determine just how much carbon in the form of deteriorated phytoplankton sank to the sea floor over a

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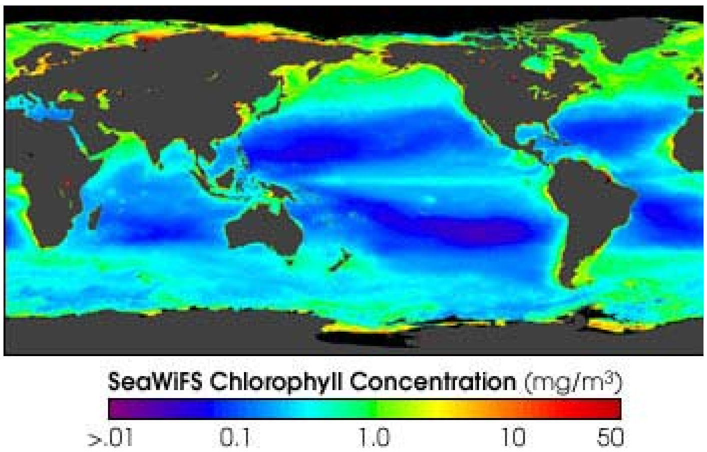
given period of time. With the cooperation of scientists from many institutions, the Moss Landing researchers placed sediment traps all across the North Pacific to measure the amount of carbon settling to the sea floor. They then compared their measurements to the phytoplankton growth levels on the surface. The project became the blueprint for nearly every future large-scale effort to measure the role of phytoplankton in the Earth's carbon cycle such as the Joint Global Ocean Flux Study (JGOFS) program.



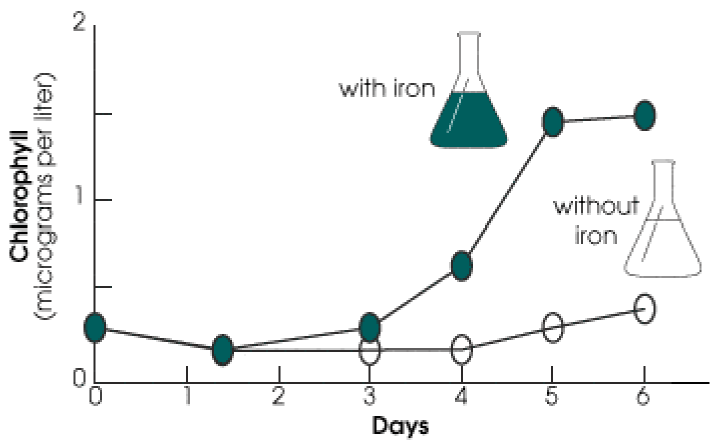
The distribution of phytoplankton in the ocean is largely governed by the availability of nutrients. However, vast stretches of ocean are almost devoid of phytoplankton, despite the presence of adequate phosphorous and nitrogen (the same nutrients in garden fertilizer). Martin discovered that the missing ingredient was iron—a trace element in the waters of the open ocean. The above image shows the concentration of chlorophyll from phytoplankton, compiled from 3 years of data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). Purple and blue indicate low chlorophyll levels, and green, yellow, and red indicate high levels. (Image courtesy the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE.)

It was also through his work in VERTEX that Martin came to the iron hypothesis for which he is so well known. While examining the growth levels of phytoplankton in the Earth's oceans, Martin decided to revisit one of the oldest, greatest mysteries of oceanography concerning “the desolate zones.” Formally dubbed HNLC (high-nutrient, low-chlorophyll) zones, these enormous tracts of water in the sub-arctic North Pacific, the equatorial Pacific, and the Antarctic Ocean contain very little phytoplankton, or for that matter any other type of marine life, despite high levels of nutrients. Lacking a solid explanation, most scientists believed that hungry zooplankton populations kept burgeoning phytoplankton levels low.

Again, Martin's instincts told him that there was something amiss with this textbook explanation. The phytoplankton in the HNLC zones behaved as they did in areas of the ocean where the levels of the standard nutrients were low. He was sure there was something else that caused the absence of phytoplankton in these areas other than low nitrogen or phosphorus levels. In the 1930s, Joseph Hart, an English scientist, speculated that these HNLC areas might be due to an iron deficiency. Though iron is typically not a key ingredient in phytoplankton growth, they do need some to grow.

Previous measurements, of course, turned up no iron deficiency. Using the lab he developed at the Moss Landing, Martin measured the iron levels in seawater collected from these regions again and found that they were exceedingly low or non-existent. He came up with the hypothesis that iron acts as a sort of micronutrient in phytoplankton reproduction, and therefore the lack of iron was the sole cause for such low phytoplankton levels in HNLC waters. He reasoned that the seas only get their iron from the dust originating in windswept lands, and that wind currents weren't carrying enough iron to these “desolate zones."

To test his hypothesis, Martin sent his team to Antarctica where they collected clean water and added iron to some samples and left others untreated. The samples were placed in baths on the deck of the ship. The phytoplankton in the iron-dosed jar flourished after a few days.



The above graph shows the amount of phytoplankton in two flasks of ocean water, one seeded with iron, the other untreated. After several days, the phytoplankton population in the flask with iron had exploded, while that in the other flask remained stable. (Graph courtesy U.S. Joint Global Ocean Flux Study, based on data from K. Johnson and K. Coale.)

With these results in hand, Martin then went a step further and claimed that the iron levels could in part be responsible for past ice ages. During an ice age much of the fresh water on the continents is locked up in the ice caps, and the exposed landmasses become drier than they are today. If large amounts of iron were swept off these arid landmasses by wind and dumped into the ocean's "desolate zones," the resulting growth of phytoplankton would effectively pump vast amounts of carbon dioxide from the atmosphere deep into the seas. The lower levels of carbon could, in turn, prolong the ice age. In 1989, Nature magazine published the results of Martin's experiments as well as his speculations on climate change. Within months the news had reached all the major science magazines and the press wires and even landed Martin on Good Morning America, CNN, and the United Kingdom's BBC.

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As is often the case with great scientific ideas, Martin's iron hypothesis met with every reaction but complacency. Some believed his bottle experiments were not accurate representations of marine conditions as they did not contain those zooplankton that fed on the phytoplankton. Some scientists couldn't see how a simple trace metal such as iron could possibly affect aquatic life so profoundly.

On the other hand, many large commercial interests and governments now embrace Martin's hypothesis. They view iron fertilization as a way to remove carbon dioxide from the air and bring themselves within compliance of the proposed Kyoto Protocol. The idea is that the carbon drawn down by the iron fertilization could offset excess emissions from coal-burning power plants and other carbon sources. By drawing down enough carbon, they believe they can trade "carbon credits" under the Kyoto Protocol and avoid costly renovations to plants and factories. Nearly all scientists are concerned that if private companies or governments use Martin's research for wholesale fertilization of the HNLC zones, disaster could ensue. Poisonous algae blooms could be created, methane—a greenhouse gas 30 times more

"Martin saw iron fertilization as a possible solution to our climate woes only if all our other efforts to regulate greenhouse gases fail."

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potent than carbon dioxide—could be released, and entire aquatic ecosystems could be thrown out of whack.

A more timid researcher may have shut himself in a lab and refused to answer phone calls. Martin, however, accepted this controversy willingly. He endured the media onslaught and even claimed on more than one occasion that we may be able to reverse the warming effects of greenhouse gases by littering the ocean with iron. At the same time, he emphasized to those overzealous about the idea that further tests would have to be performed before we start dumping iron into the oceans.

The people who were close to him knew Martin was a scientist at the end of each day. Coale explains that while Martin was a bold thinker, he saw iron fertilization as a possible solution to our climate woes only if all our other efforts to regulate greenhouse gases fail. “I think he brought this out in the open to bring attention to the work at Moss Landing and to the oceanographic community as a whole,” says Penny Chisholm, a friend of Martin’s and an oceanographer at the Massachusetts Institute of Technology. Marlene Martin said his greatest concern was that his findings would be misused.

John Martin planned on following up these initial tests by fertilizing a small patch of HNLC ocean in the central pacific near the Galapagos Islands. If the phytoplankton populations shot up with the addition of iron, then his hypothesis would be proven correct. In 1991, however, Martin began having back pains. Medical tests revealed he had prostate cancer that had spread into other parts of his body. For the next two years he underwent chemotherapy and radiation treatments.

His colleagues and friends did not want to see him or his work die. They especially didn’t want to allow those naysayers who doubted his work to get the final word. Marlene Martin says that his friends, family, and colleagues were around him constantly during his final weeks in the hospital. They’d stay with him throughout the day, sometimes spending the night on a cot in his room. John Martin died on June 18, 1993.

After his death the scientists at Moss Landing

Rachel Carson
Benjamin Franklin
Robert Goddard
Samuel Langley
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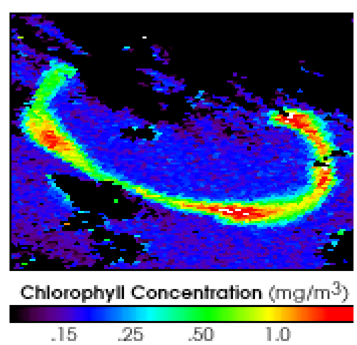
Several experiments in the open ocean confirmed Martin’s iron hypothesis. During the 1993 Iron Enrichment Experiment (IRONEX), researchers dumped iron into a 64-square-kilometer area and measured the resulting phytoplankton bloom. The photograph above shows researchers at the Naval Postgraduate School preparing iron to be dumped in the sea.



The results of the Southern Ocean Iron Enrichment Experiment (SOIREE) experiment in 1999 were captured by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). The bright comma in the above image indicates phytoplankton growth stimulated by iron added during the course of the experiment. (Image courtesy Jim Acker, Goddard Distributed Active Archive followed his vision tirelessly. “We immediately stepped into the leadership position when he left,” says Coale. Dick Barber of Duke University and Kenneth Coale and Ken Johnson at Moss Landing carried out Martin’s first campaign, known as “Ironex I.” For this experiment the scientists dumped a truckload (445 kg) of iron over a 64-square-kilometer patch of clear, blue, nearly phytoplankton-free ocean near the Galapagos Islands. The experiment was a success in that phytoplankton levels increased threefold.

Center, the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE

Kenneth Coale launched Ironex II in 1995 and corrected for a few problems found in the first experiment. This time the researchers sprinkled an area roughly the same size as the first with iron several times over three days. The phytoplankton populations bloomed so rapidly that the researchers claimed they could smell it growing. The iron increased phytoplankton levels to 30 times greater than normal, producing essentially the same biomass as 100 redwood trees, and the phytoplankton drew down more than 2,500 tons of carbon.

These results changed the field of oceanography forever and vindicated Martin. But, as Coale explains, Martin’s work goes beyond his iron hypothesis. “He showed that no longer is life in the ocean determined solely by the standard nutrients, but minute trace metals are involved too,” says Coale. This knowledge could have far reaching consequences for oceanography that go well beyond the iron hypothesis.

But in the end, perhaps Martin didn’t give as much importance to his own iron hypothesis as the rest of us. After Martin’s death, a list was found on Martin’s computer wherein he had written what he most wanted to live for. His top three priorities were spending more time with his wife, his two sons, and his dog. After that he wanted to finish rebuilding a lab that was destroyed in the 1989 earthquake. “Proving the iron hypothesis was sixth or seventh. Certainly not at the top of the list,” says Marlene Martin.

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