FIXING GLOBAL WARMING

The Iron Hypothesis

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John Martin's idea was simple and brilliant: Iron controls the growth of tiny ocean plants. If that's true, then fertilizing the sea with iron might cool the climate. A ship of friends went to sea to find out if Martin was right.

by Caroline Dopyera

Courtesy Tim Stanton/Naval Postgraduate School

The *Columbus Iselin* was still a ways off when Ken Johnson saw it pass through the Panama Canal and chug toward him. He tensed with a feeling of desperation. The ship was supposed to carry the ocean experiment of the decade, one that could revise textbooks. But to Johnson, the *Iselin* looked more like a ship that would take the Beverly Hillbillies to sea than a sophisticated research vessel.

A portable laboratory and huge plastic tanks were lashed to the deck. A crane towered near the ship's center. Barrels of blue-green iron granules crammed the ship. For six weeks, 23 of the world's top ocean scientists would work in a lab the size of a subway car. It was an enormous mission for such a small ship.

How are we going to do this? Johnson wondered.

The researchers would attempt to prove that by seeding the ocean surface with iron, they could make tiny marine plants called phytoplankton bloom dramatically. When phytoplankton grow, they absorb carbon dioxide dissolved in the water, which in turn draws the gas out of the air. Done on a very large scale, iron fertilization might cool Earth's climate. The concept was simple, the consequences incalculable.

If the scientists succeeded, they might discover a way to remedy global warming, the heating of Earth's atmosphere caused by excess carbon dioxide and other greenhouse gases. At minimum, they would amend what scientists believe about the ocean. And they'd be remembered as the first researchers to turn the sea into a field laboratory, pioneers of a new research method.

Traditionally, marine research had been limited to observation and "bottle experiments." Oceanographers would collect seawater and conduct experiments on it in a laboratory to learn how the ocean works in nature. On the iron expedition, they'd try to chemically alter a patch

The Columbus Iselin sets sail in 1993 to test John Martin's iron hypothesis on the open ocean. Inset: This diatom and other tiny ocean plants use sunlight to make food from water and carbon dioxide gas. According to Martin's iron hypothesis, seeding the ocean surface with iron should make diatoms multiply dramatically.

Doug Allan/Science Photo Library/Photo Researchers

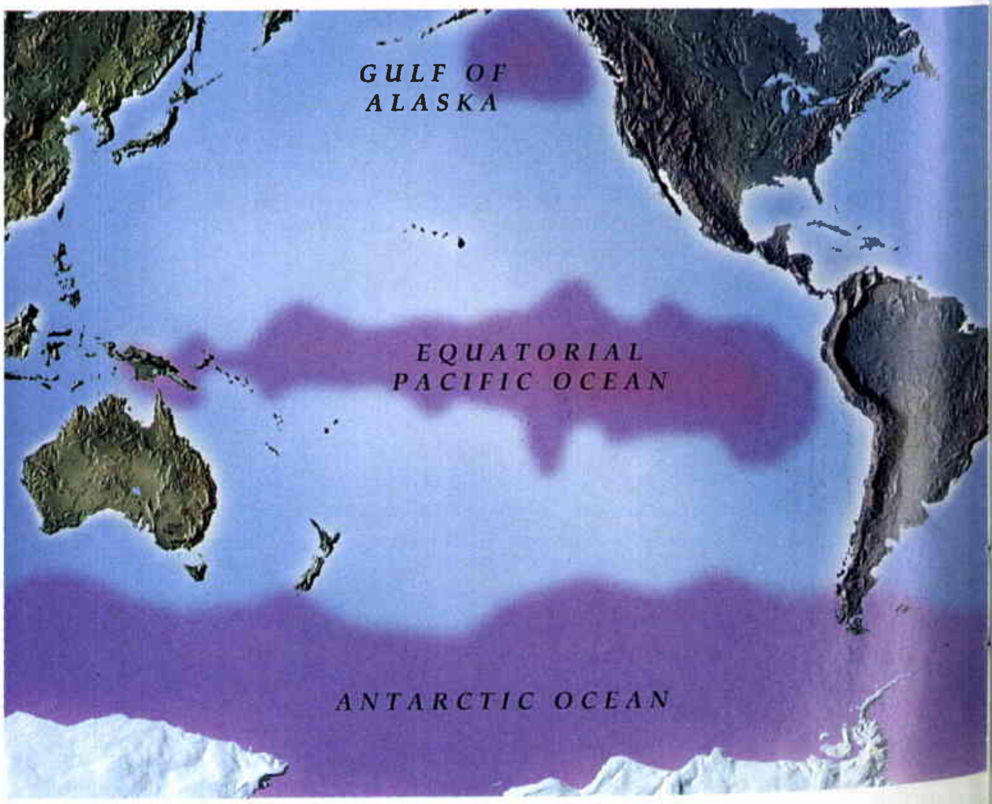
of ocean water and observe the effects — a first.

If the scientists failed in their experiment, they'd fail a friend. Johnson and his partner, Dick Barber of Duke University, had promised John Martin that they would test his final, brilliant idea. They didn't want the world to remember him as a scientific quack or, worse, to forget him. They had to make his experiment work.

The iron hypothesis, as it came to be called, was pure John Martin. It was wild, maverick and simple. If true, it could make a difference to everybody on the planet. It was also elegant from an engineering standpoint, because a small amount of iron could have a huge effect on the atmosphere. "Give me a half a tanker of iron and I'll give you the next ice age," Martin once said jokingly.

He planned the iron experiment, recruited scientists and collected $1.5 million in research funding to pay for two expeditions. But the iron hypothesis was controversial. Just that one quip about using iron to bring about the next ice age, Barber recalls, was enough to make "500 oceanographers grab their calculators to prove that he couldn't be right." In the press, Martin was dubbed Johnny

Beneath the ice off Signy Island in Antarctica, a research diver works in water unclouded by tiny ocean plants called phytoplankton. Here in the Antarctic Ocean, and in the equatorial Pacific Ocean and Gulf of Alaska (see shaded areas on map, below), phytoplankton populations are relatively low despite adequate sunlight and nutrients. John Martin set out to prove that a lack of dissolved iron in the water in these areas keeps ocean plants in check.

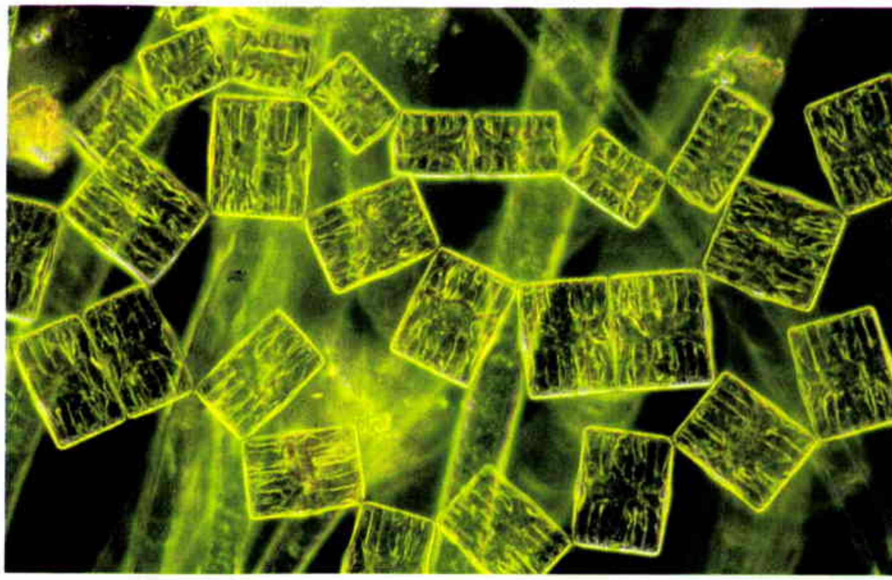


EARTH: Elisabeth Rowan

Ironseed and the Iron Man. Those who thought his idea might yield a giant ecological disaster called it irresponsible — even dangerous.

No one ever expected Martin to go to sea to test the theory that had landed him on front pages and TV talk shows. Crippled by polio when he was 19, Martin, a scientist at Moss Landing Marine Laboratories in California, didn't have the sea legs for the trip. But everyone expected he'd be around to see the results of the experiment. Then, three months before the *Columbus Iselin* set sail, Martin died of prostate cancer.

In October 1993, while they were still mourning their friend, Barber and Johnson went to sea, trying to finish what Martin could not. *John Martin would have pulled this off,* Johnson thought as the ship approached. *Where are you now that you've gotten us into all this trouble? Where are you now that we really need you?*



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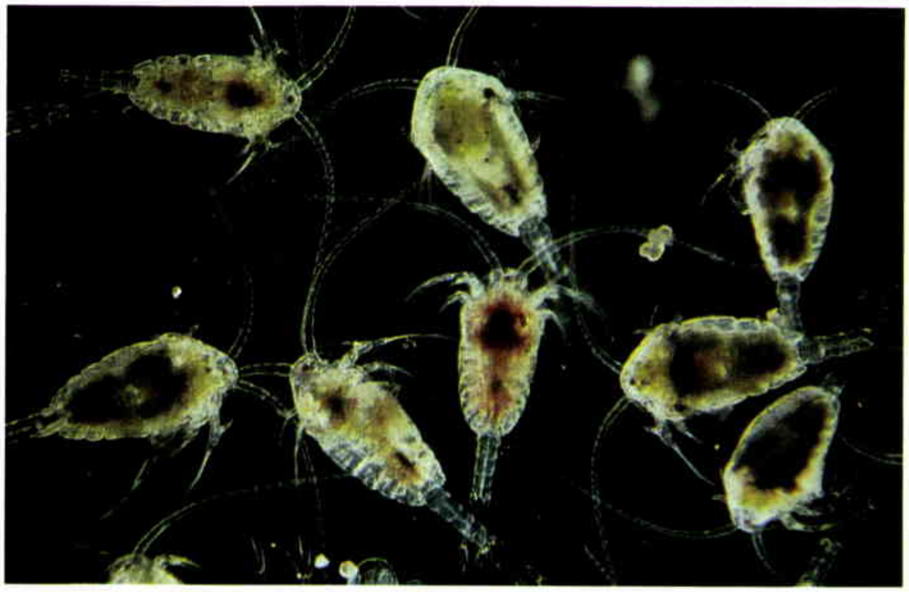

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Why don't tiny marine plants called phytoplankton (top) flourish in some parts of the ocean? For a long time, scientists thought that marine "grazers" such as copepods (bottom) ate the phytoplankton faster than they could reproduce, thus keeping their numbers in check.

Martin's iron hypothesis traced to an academic squabble in 1986. A colleague, Bruce Frost of the University of Washington, was at a scientific meeting discussing one of the great mysteries of oceanography: Why are phytoplankton populations so low in certain parts of the ocean, even though they seem to have plenty of sunlight and nutrients? These tiny plants are present in the water, but they never bloom into huge colonies.

Frost offered the conventional explanation: Grazing by marine creatures called zooplankton keeps the ocean plants in check. Just like cows constantly trimming the grass in a meadow, the creatures eat the phytoplankton and prevent them from becoming too populous.

For decades, scientists had suspected that this explanation was flawed. Some had proposed that the parts of the ocean where phytoplankton failed to bloom lacked a key nutrient — perhaps iron. However, none of them had the evidence to prove it.

Martin, who had spent his career measuring trace metals in the ocean, thought he had that evidence. So when Frost finished speaking, Martin challenged him, saying, "Aw, baloney! It's just iron deficiency!" He was half kidding, but he realized he had a good idea.

Martin had found that iron was present only in very low concentrations in the waters of the Antarctic Ocean, the equatorial Pacific and the Gulf of Alaska. The only iron in these areas, he believed, comes from dust carried out over the oceans by the wind. In these places the phytoplankton never bloom.

It occurred to Martin that during the last ice age, when ice sheets trapped vast amounts of water that might otherwise rain on the continents, Earth was a drier, dustier place. With iron-laden dust blowing continuously onto the ocean surface, perhaps phytoplankton bloomed on a mass scale and drew down carbon dioxide. Falling levels of the gas, Martin proposed, helped cool the climate during glacial periods.

Phytoplankton controlling climate? It seemed outrageous. But perhaps it was true, Martin thought.

In 1989, he set out to test his idea. He sent three lab technicians on a research cruise to the Antarctic Ocean for a small-scale experiment. They filled plastic bottles with phytoplankton and seawater. To some they

David Vaughan/Science Photo Library/Photo Researchers

During past glacial periods, masses of ice like this one, the Perutz Glacier in Alaska, covered vast areas of the continents. Along with the global cooling came a drier, dustier climate. Martin proposed that during the ice ages, iron-rich in dust blew off off the continents and fertilized the ocean. This triggered plankton blooms that drew carbon dioxide out of the air, which contributed to further global cooling.

"Give me a half a tanker of iron and I'll give you the next ice age."

— John Martin

Courtesy Marlene Martin

added iron. To others they added nothing. Then they set them in the sunlight and waited.

In six days phytoplankton clouded the iron-enriched seawater, feasting on the iron until they consumed all the nutrients. The phytoplankton without iron stayed the same. Martin had found what he hoped he would.

Several months later, Martin published his results in the influential science journal *Nature*. Within a week, he and his maverick idea were broadcast on radio and TV and in newspapers all over the world.

The response was overwhelming. Martin's iron hypothesis excited some ocean scientists, who appreciated his fresh, bold approach. But others found it alarming. They said fertilizing the ocean would be treating the symptom, not the cause, of global warming.

Some scientists took aim at Martin's bottle experiments. They said the bottles excluded the very thing that controlled the growth of phytoplankton — animal grazers. What happened in a bottle wouldn't necessarily happen in the ocean, they argued. Martin knew that to quiet these critics he would have to do an open-ocean experiment. He would have to turn the ocean into a laboratory.

But the iron hypothesis spurred a controversy so large that Martin feared he'd never get the grant money to test it. It pitted him against environmentalists and many scientists he admired. They said widespread global tinkering could end in a catastrophe worse than the projected global warming. It could knock the oceans out of balance and wipe out many species.

"I will never advocate shooting-from-the-hip iron fertilization without the detailed research to understand it," Martin wrote to one worried critic. But adding a little iron to the ocean would be a lot better than allowing the climate to heat up, he said. "I agree that the ideal would be to have the average American get out of his car; have the Chinese not develop their coal resources; have the Brazilians not cut down the rain forest," he wrote. "However, we don't live in an ideal world."

Critics worried, too, that if the iron hypothesis were proven, politicians might use it as an excuse to abandon clean-air policies. Why go through all that trouble when science could provide a quick fix to global warming?

Two influential research groups — the National Research Council and the American Society of Limnology and Oceanography — held national meetings to hear both sides of the iron debate. Either group could have decided that Martin's idea was unethical or that it lacked scientific merit. If they did, Martin would have been denied funding to test the iron hypothesis.

But at each meeting, held in 1989 and 1991, Martin's idea received resounding support. The scientists concluded that the iron hypothesis should be tested. More important, they decided a small-scale test wouldn't threaten the environment.

"Here was a bold, new idea that purported to explain many of the things we've had trouble explaining," Barber recalled. "Was anybody going to stand up and say we shouldn't find out if it's right?"

In March 1991, just as the critics were retreating and funding for the experiment looked secure, Martin's back began to ache constantly. The pain persisted, and in May doctors found tumors in his back and neck. They said he had prostate cancer that had spread into the rest of his body. Once that happens, men under 60 have a slim chance of surviving, his doctor said. Martin was 56. After chemotherapy failed to help him, John Martin died on June 18, 1993.

On a clear October morning the research vessel *Columbus Iselin* left Miami with a crew of scientists, many Martin's close friends. They'd have to finish the job that Martin could not.

So much equipment loaded down the vessel that the crew had to dump fresh water from the holds to keep the ship from listing. No problem: They could get more in Panama. So what if the water there might make them sick? Everyone had crammed the ship with spare parts and extra equipment, enough for two expeditions. They were determined to complete the mission.

How are we going to do this? Ken Johnson wondered as the cluttered, shopworn ship approached.

The iron expedition was Johnson's first time in the public eye. Years earlier, he had gone to Moss Landing as a young ocean chemist specifically to work with Martin, and he now had his own funding and an active research program. Johnson thought he was in a no-win situation. If the experiment failed, he worried, other scientists might blame him for not doing it properly. And if it succeeded, only Martin would be praised.

Where Johnson was tense and irritable, Barber was calm. His scientific standing was solid and he had a prestigious position at his university. The results wouldn't change his career either way. But Barber was honored to be on board.

"I wouldn't have been happy with any other person looking after this part of John's legacy," Barber says. "I had the right mixture of appreciation of his ideas and detachment." He'd pay tribute to his friend by conducting a clean test of the iron hypothesis.

With everyone on board, the ship headed southwest toward the Galapagos Islands. In the coming days, they would lay a 25-square-mile patch of iron crystals dissolved in seawater and track it to see whether it made the ocean bloom. Martin had predicted a repeat of the bottle experiments. He thought that within six days the amount of chlorophyll in the water would increase by twelvefold.

Courtesy Tim Stanton/Naval Postgraduate School

Crew members and scientists on the *Columbus Iselin* dumped crystallized iron into plastic tanks, where it dissolved in seawater. The iron-water slurry was then pumped out the back of the ship to create a patch on the ocean surface. Plankton bloomed dramatically in response to the iron fertilization, proving John Martin's theory.

Chlorophyll is the green pigment in photosynthetic organisms (like phytoplankton) that enables them to capture sunlight to make food from carbon dioxide and water. The scientists would measure chlorophyll levels in the water to track the effect of iron fertilization on phytoplankton.

Johnson started a chlorophyll pool, taking bets on how much the phytoplankton would grow. Barber wrote down a conservative threefold increase. Johnson, who had cast his lot with Martin, was taken aback. "If you don't believe in John's ideas, why are you here?" he asked.

"The best tribute to John is to do the best science you can do," Barber replied. "You don't pay proper tribute to any scientist by trying to fudge any issue."

Martin knew the hardest task would be to lay a uniform patch of