The Iron Hypothesis

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
he 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.
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
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?

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
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 dust blew 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

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 shootin', 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 Galápagos 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.

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
iron on the moving, churning ocean surface. Indeed, some scientists said it couldn’t be done. But Tim Stanton, a physicist on the expedition, devised a way to lay down the iron using a floating buoy as a guide. As the buoy drifted along with the moving surface of the ocean, the ship would follow it, laying down a square patch of iron-rich water around it.

On October 23, the ship was 250 miles southwest of the Galapagos Islands. Now the crew had to find an area where the ocean was calm and the salt and nutrients were distributed evenly. By fertilizing a patch of ocean with known chemical properties, the scientists would be able to see the effect of the iron clearly.

Stanton watched his computer screen as a long, bobbing electronic sensor — a towyo — dragged behind the ship, gathering information about the temperature and salinity of the water. Within minutes, a red graph on his screen indicated the right conditions. This was the spot.

Three of Martin’s technicians used the ship’s crane to lift the barrels of iron crystals and empty them into a 250-gallon plastic tank of seawater. They added acid to dissolve the iron and a colorless chemical that would help them track the patch. They then switched on the pumps. The iron brew flowed out just above the propeller, leaving a green, bubbly wake.

The ship moved back and forth in a zigzag course around the shifting buoy. Every two hours the technicians dumped three more barrels of iron into a plastic tank and began the long process of dissolving the iron. Every four hours they switched from one iron tank to the other.

The Sun came up and went down again. After 24 hours and with the seventh tank-load emptied, the patch was finished. Twenty one barrels of iron, a total of nearly a thousand pounds, had been spread across the ocean. The ship turned around. Had the patch stayed together for even a few minutes?

British scientist Andrew Watson saw a bright red graph flash across his computer screen, displaying information from a chemical sensor testing the water beneath the ship. “We’re coming into the patch!” he shouted. The screen indicated that the five-mile-square patch of fertilized water was spread out before them.

Before they went to bed, Martin’s technicians returned to their post on the back of the boat one final time. “Here’s to you, John,” Craig Hunter said, raising his duct-taped plastic cup. “We got it in the water.” They drank the spirits and went to bed.

Barber slept in his clothes, like most days on the busy expedition. Just before dawn, he woke up and went out on deck, eager to see if anything had happened. After 29 years of scientific expeditions, he trusted his seafarer’s senses.

In the muted light, he saw that the water was a different color. The change was subtle, something only a mariner would see.

Small waves lapped at the ship. Reflected light shattered the seascape into an Impressionist canvas. Barber watched the sea surface, waited, sniffed. There was something different. With one last turn through the patch, the ship arrived back at her starting point. A familiar scent hung in the air. Barber scanned his memory and made a match.

Newly mown hay.

“I could smell the phytoplankton growing,” the mariner recalled later. The iron had made the plankton grow. John Martin was right.

During the iron experiment, scientists drew water from the fertilized patch and from clear seawater. The cloudy green jar (right) contains thriving plankton from the fertilized water.
They tracked the iron patch for nine days. With the added iron, the chlorophyll levels in the water had increased three times. Not as high as Martin had hoped, but just as Barber had predicted in the chlorophyll pool.

The relatively weak response of the ocean to fertilization seemed to imply that using iron to "cure" global warming would be impractical. Iron would have to be dumped repeatedly on a vast scale to have a significant effect on climate. "The iron hypothesis is proven," Johnson said after the first iron expedition, "But the link to climate is not proven. The idea is if Mother Nature blows dust on the ocean, she does it all the time." To prove that plankton can affect climate, the scientists would have to go to sea again and fertilize a patch of water more than once.

So in June 1995, Johnson, chief scientist Kenneth Coale (also of Moss Landing) and 35 other researchers embarked on a second expedition — this time on the National Science Foundation’s premier research vessel, the R/V Melville. The team reapplied iron twice and the results were dramatic. This time the surface of the water turned a deep, cloudy pea-green. "You didn’t have to be a scientist or a seaman to see it," Johnson says. The scientists observed a 30-fold increase in chlorophyll levels, well beyond Martin's prediction of a 12-fold increase. "John won the chlorophyll pool," Johnson notes.

Clumps of phytoplankton filled the fertilized patch. Of all the types of phytoplankton in the water, diatoms grew the most — to 85 times their normal number — and consumed an estimated 367 tons of carbon dioxide. To honor Martin, the most abundant diatom in the mix was dubbed Nitschia martini.

During the expedition, Johnson discovered something that seemed to make the iron solution to global warming seem more feasible than it had after the first experiment. Iron needs to be exposed to sunlight to stay in solution and to remain available to phytoplankton. On the first expedition, a lens of less-dense water had moved in over the comparatively dense iron patch. This layer blocked sunlight, causing the iron crystals to fall out of solution and sink. As a result, the plankton stopped growing.

"After the first experiment we said global engineering wouldn’t work because you’d need to keep adding iron," Johnson explains. "If one fertilization might be enough as long as most of the iron stayed near the surface. "In some sense it’s bad news for those who don’t want iron fertilization to work," Johnson says. "It says maybe iron fertilization will work. It puts global engineering back in the more feasible category." But of course, Johnson points out, you still have the practical challenge of spreading a huge amount of iron over a large region of the ocean.

Ocean scientists may not remember John Martin for his controversial proposal to remedy global warming with iron. His more lasting legacy is likely to be the new way of studying the ocean he and his colleagues pioneered. Thanks to Martin’s iron experiment, scientists now know it’s possible to transform the sea into a controlled laboratory and use it to learn how oceans work. It is now up to others to determine the wisest use of what Martin’s colleagues learned when they put the iron hypothesis to the test.

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