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WHAT GOES UP

THE GLOBAL ASSAULT ON OUR ATMOSPHERE

INTRODUCTION

What we have here is a failure to communicate!

Picture a young scientist working in the lab late one night, a dedicated researcher who after months of dogged effort suddenly runs his last series of calculations and finds himself eyeball-to-eyeball with a "monster": If his findings are valid, some long-accepted product or societal practice he has been studying actually constitutes a major threat to mankind—and to his career.

Such a discovery would be galvanizing and momentous of course, but in the place of warm thoughts about Nobel Prizes and professional accolades, cold panic begins to grip the pit of his stomach, steadily encompassing the young Ph.D. with the reality of what probably lies ahead. His head swimming, he sits back heavily, his professional future flashing in horrific images before his eyes. For a brief moment he even considers stuffing the genie back in the bottle—slamming the lid on the Pandora's box before him—rather than face the business community with the conclusion that yet another commodity or activity propelled by the massive inertia of modern society is in reality dangerous to life as we know it on Planet Earth.

They will not take it well, and neither will he—his potential "reward" the role of a pariah, the messenger scorned for the temerity of delivering the message.

He knows the precedents, and those who have made such discoveries before him—chemists such as Harold Johnston of Berkeley, Sherwood "Sherry" Rowland, and Mario Molina of U.C. Irvine for instance—soldiers of science who dutifully reported their discoveries about things that gobble the Earth's ozone layer only to find themselves paying a heavy personal and professional price for their trouble. Given their trials and tribulations, our frightened young Ph.D. knows instinctively that he'd better reveal his galvanizing new discovery with the caution of an infantryman lifting his helmet on a stick from the depths of the foxhole, gauging the odds of personal survival by the number of bullet holes he pulls back in.

He knows too that the bullets he'll have to dodge will come first from his fellow scientists, their numbers in direct proportion to the seriousness of his findings. His colleagues will snort, harrumph, niggle, question, retest, deplore, and perhaps decry his conclusions in writing, behind his back, and even in person, and if his "finding" is radical and dangerous enough, they'll fire at him frantically over their shoulders while racing back to their labs like a band of routed Indians in a Western movie—shaken scientists desperate to validate or disprove the "findings" for themselves.

That, of course, is the scientific method of peer review at work, and it does keep science honest. But the process also breeds and licenses human jealousy and professional rivalry, producing at least a few so-called colleagues who will snipe at his work for the pure joy of cutting him down, whether the finding is eventually confirmed or rejected by the overall scientific community.

But he can survive that. As a scientist—a Ph.D. in some scientific field—he's trained to survive the rough-and-tumble world of professional scrutiny. What worries him in the cusp of his midnight discovery is what lies in wait beyond the boundaries of the scientific community, and what happens professionally to those who venture there.

What if there's no one to help him sound a *public* alarm? What if no one outside the scientific community understands the danger and the momentous decisions that must be made by the policymakers representing all of society? What if *he* ends up the one who must go into perpetual motion, abandoning the comfort of quiet scientific research for the glaring lights of public scrutiny, sailing with his findings like the ancient mariner wearing his albatross, trudging from TV stations to Capitol Hill, trying to speak like a scientist with caveats and limitations peppering and ameliorating his statements of alarm, yet trying to trigger responsible action—trying to move the policymakers to value judgments of their own.

Scientists have a hard time speaking the language of the layman when it comes to their work, and the layman has a worse time understanding. If scientists could only be clear, they moan. Is it or isn't it a problem? "When you guys get your act together and agree on something, come back and talk to us."

If Paul Revere had been a scientist, there would have been no armed patriots awake that seminal midnight to meet the British troops. Not even the Minutemen would have understood the cry of a man riding through darkened, rural Massachusetts yelling with appropriate scientific caution:

> I have anecdotal indications that the British may be coming, but I caution that this warning is subject to potential observational error and may be explainable by other phenomena. More research will be necessary before we can state with assurance that the British are, in fact, coming!

And even if a scientifically correct Paul Revere had made himself understood, he would then face the rage of the scientific community for his incautious and unabashed advocacy of a position taken without adequate peer review.

A scientist who takes his findings before the public or Congress runs the risk of being considered professionally biased and suspect. One who dares draw conclusions or value judgments as to how society should respond becomes a radical, and one who crosses the Rubicon to become a visible, vocal advocate for change, may become an outcast—especially if he commits the ultimate sin of publication-by-media (which *is* usually deplorable because such announcements are not tempered by peer review). The purists in science believe their colleagues should state their findings only in cold, detached fashion, drawing no societal conclusions, and making no value judgments or recommendations as to how society should react. But even that is too much for the dwindling number of scientific elitists who believe that scientists should speak *only* to other scientists and then in professional papers, accepting virtually no responsibility for what use (if any) their less-well-educated brethren on this planet make of their findings.

Science, however, is never pursued in a vacuum of total detachment from the messy realities of the real world. After all, even the ivory towers run on money, and for that money society expects answers in a language it can understand. Pure science and quiet publication is never enough. As life becomes more technological and science more important in every aspect of civilization, we demand ever more loudly that the scientific community come down from their ivory towers every now and then and speak to the common man—and the common politician.

By the same token, the politicians, policymakers, and public have to make a genuine effort to understand the language and the methods of science, if we're to understand their warnings in time.

It took thirteen long, lonely years of sometimes-vicious battles fought by a small cadre of scientists before the world began to limit the ozone-destroying manufacture of CFC's (chlorofluorocarbons). The initial "midnight discovery" was made by two scientists in 1973, yet it wasn't until 1987 that the principal nations of the world reluctantly agreed that the elegant, inert, stable, and highly useful CFC's are indirectly dangerous to mankind.

"But that's a reasonable process," says one respected atmospheric chemist, "when you realize that what we were listening to for all that thirteen-year period were the messy sounds of democracy in action—especially in the United States."

True, yet while that democratic process roared on (and while the CFC industry spent millions vitriolically denying as unproven the scientific worries that their products could be a threat to the ozone layer), millions of tons of additional CFC's were pouring into the sky, threatening additional damage. Time, in other words, is not always on the side of those who would rely on the normal half-life of scientific arguments and the glacial response of political and policy change.

In the end, the argument was resolved as much on the basis of skillful negotiating by a handful of rare and talented scientists and diplomats as by any compelling understanding of the nature of the warning. As the reality of chemical damage—the discovery of the Antarctic "Ozone Hole"—was coming to light, the international community finally acceded to the one truth they couldn't avoid: whether or not ozone depletion *had* occurred in significant amounts, if ever it *did* occur at some point in the future, we would be powerless to stop it for half a century, because the CFC's put in the air today will take fifty to sixty years to even reach the upper atmosphere. There had been far more compelling facts that should have spawned a worldwide ban of CFC production immediately in 1975, but such findings were largely swept aside because the scientific community was not "certain."

Even today the international response is wholly incomplete, and CFC's continue to waft skyward. The messy sounds of democracy in action may be joyous in theoretical debates, but when we're fouling our own nest, we may not have the luxury of waiting out the process to see what happens.

It has taken forever, it seems, for governments and politicians and the chemical industry to realize that as simple as it sounds, what goes up must go somewhere, and that somewhere in this case is the atmosphere that keeps us alive. And logic alone, it would seem, would tell us that blind, wholesale alteration of that gaseous soup can't really be a good idea, especially when we don't fully understand the consequences now and for the future.

The Chlorofluorocarbon/Ozone battles involved a single family of man-made gases, which can be replaced. The far more serious global threat that has taken its place in media attention—the so-called Global Warming caused by The Greenhouse Effect—is a monster of a different temperament. The gases involved are many, and stem from the very essence of modern society: the production of energy for human use. There are no obvious and simple methods of turning off or turning down the worldwide overproduction of carbon dioxide, methane, and nitrous oxide (and other trace gases), and there is major uncertainty over the consequences of ignoring the problem, or being too slow to act. Do we have another thirteen years for *this* debate? No one knows as yet, and the answer may be a shocker.

In the unusually hot summer of 1988 in the United States a single scientist touched off a worldwide firestorm of publicity and scientific recrimination by expressing a personal conviction: that we were already beginning to pay the wages of atmospheric sin—increasing greenhouse gas emissions over the past one hundred years—through the sizzling temperatures and Midwestern drought conditions. A massive scientific catfight erupted as a result, a battle that has obscured and twisted the basic message: Whatever the eventual effect on the climates of the world and the levels of the oceans, no credible member of the atmospheric science community disagrees with the evidence that we *have* altered our atmosphere rather dramatically (in terms of the mixture of gases), and we face uncertain consequences as a result.

In many respects the Global Warming/Greenhouse Effect debate is at the same crossroads occupied by the chlorofluorocarbon debate in 1974—scientific uncertainty fueling societal and political reluctance to act. In the process, a monstrous hurricane of sound and fury has obscured the real messages coming from the scientific community, and no one is really communicating. The public and the media have been watching a play-by-play account of a controversy that really isn't significant, focusing on a side-show battle over whether or not we are already experiencing measurable global warming. Was the summer of 1988 the opening round? Was the decade of the eighties the hottest one in a thousand years? The fact that those questions don't really matter has been temporarily lost in the noise of stories and articles reacting to the slightest cooling trend with headlines questioning whether the Greenhouse/Global Warming alert is a false alarm.

It isn't, yet we've missed the point. The important question does not depend on whether or not the climate has begun to change. The important question is simply this: Just how far *should* we go in permitting continued uncontrolled experimentation with the life-giving atmosphere of our home planet—the only habitable planet we know of in this or any other galaxy.

Compared with the size of the Earth that nurtures us all, an individual human seems insignificant. How could such tiny creatures as we affect in any material way such a huge planetary body?

Yet we *have* affected it. Untold billions of free chlorine atoms now float in the stratosphere for the first time in Earth's four-billion-year history, and 25 percent more carbon dioxide now occupies the gossamer-thin atmospheric envelope than existed a mere century ago. Billions of human beings—our numbers growing by the minute—spew chemicals and gases indiscriminately into the sky, and only within the past two decades has anyone seriously questioned the long-term consequences.

"I can't go home and dump my garbage in my neighbor's backyard," says atmospheric chemist Dr. Susan Solomon, "the police would arrest me in five minutes. But I could take a tank of chlorofluorocarbons, put it in my backyard, turn it on and let it go into the atmosphere all day long, and no one can stop me! Somehow that's very wrong."

The point is that mankind faces for the first time the need to make some very weighty policy decisions for all of society. And yes, those decisions depend on what the scientific community believes to be true.

But here's the problem: If we can't understand each other, if we can't decipher the warnings, we simply argue before a Tower of Babble, flailing our arms in animated debate delivered in a foreign language beyond the comprehension of our fellow debaters, accomplishing nothing—while the hot sun gets hotter above us.

There will be future midnight discoveries. It's up to all of us within and outside the scientific community to learn to speak with a common tongue when we face such threats.

PROLOGUE

A faint glow of reddish-orange brushed the eastern horizon where moments before only darkness could be found. With each passing second as the planet turned inexorably to the east, more of the wildly scattered rays of light from the distant sun pushed through the thin lens of Earth's atmosphere, forming a slight line of ruddy color, heralding the impending sunrise. It would be minutes before the mighty solar engine of electromagnetic energy would be fully exposed, and before the incoming radiation from ninety-three million miles away could have a straight shot at a tiny puff of oxygen that floated in the frigid Antarctic darkness. It was an impossibly small formation of identical molecules in a sea of stratospheric gases at sixty thousand feet above the southern ice cap, adrift in a soup of floating molecules sitting like a carefully constructed amalgam of dry tinder and twigs among logs and planks, waiting for a spark to turn it into a raging bonfire of chemical reactions—a spark now approaching over the eastern horizon in the form of sunlight in various wavelengths. The submicroscopic community of oxygen atoms had long since bonded together in threes, becoming part of a vast atmospheric reservoir of similar molecules called ozone—a gas at once poisonous to humans yet indispensable for human life. And, for the first time in tens of millions of Earth years, an endangered species.

These particular oxygen atoms had traveled a great distance together, beginning two years before at the southern tip of New Zealand as they percolated into the sunlight through the cells of an aspen leaf. They had come out in pairs, two oxygen atoms clinging to each other to form a molecule known as O_2—the stuff of carbon-based life itself. Each of the tiny pairs had once been married to a carbon atom, but the sunlight and the strange inner workings of the aspen leaf had stolen the carbon and pushed them into the open to float up and away in a sea of fellow oxygen molecules and nitrogen gas, eventually drifting toward the southern pole.

And it had been a year since the ultraviolet sunlight had come over the eastern horizon on a similar morning, energizing an age-old process: breaking the bonds holding many of the tiny pairs of oxygen atoms together. In untold numbers they had begun to split into single atoms, which then floated in aimless solitude until bumping into a surviving pair whose bonds had not yet been torn away. When such collisions occurred, the pair would attach in a microsecond to the single atom, and the three of them would spin off in another direction, now with the different characteristics that come with forming O_3—the pale blue gas known as ozone. Hour after hour, day after day, the cycle continued, the ozone molecules absorbing a special wavelength of ultraviolet light, UV-B, which would break the bond holding the three together and cause them to split off a single oxygen atom which then promptly attached itself to an O_2 molecule, once again forming an ozone molecule.

There was a beautiful symmetry to the delicate molecular dance, a self-regulating system that kept the gossamer veil of ozone in proper supply; there were always enough free oxygen atoms to reform the ozone that continually sacrificed itself to the cause of absorbing ultraviolet energy.

Now, however, something new and threatening had joined the atmospheric community, something lurking in man-made abundance as the sun's rays cascaded over the eastern horizon, ending the six-month Antarctic night. Chlorine atoms, untold trillions of them, unnatural, foreign interlopers in the stratospheric equation, rapidly became energized by the rising level of sunlight, and began their own catalytic dance. In accelerating numbers, each chlorine atom would rip away a single oxygen atom from an ozone molecule and transform itself into a molecule of chlorine monoxide (one chlorine and one oxygen atom bonded together). What had been an ozone molecule now became an O_2 molecule again.

But the process was just beginning. The chlorine monoxide molecules now began a complex and unique metamorphosis, pairing off to form two ClO molecules together—a "dimer"—mutating eventually to end up as single Cl atoms on one hand and stable O_2 molecules on the other. The net result in each cycle left each chlorine atom just as it had been at the start, but for each ozone molecule caught up in this strange polar catalytic cycle, there would remain only stable O_2 molecules which would split no more, and form no more ozone.[1]

As the sun rose higher, the unnatural collection of chlorine scavengers began moving faster, each one destroying ozone molecule after ozone molecule, endlessly repeating the same cycle as more of the ultraviolet radiation filtered deeper and deeper through the stratosphere toward the unprotected surface of the Antarctic ocean twelve miles below—fewer numbers of ozone molecules left to intercept the damaging frequencies. Day after day the process proceeded until by mid-

October—the Antarctic spring—nearly 80 percent of the ozone molecules had been destroyed in a slice of the stratosphere between sixty thousand and one hundred thousand feet above the south polar region.

Nothing like it had happened before in such magnitude, and in the silence of space overhead, a man-made satellite took careful note of the disappearance and the deepening "hole," digitalizing what it saw into long strings of radioed binary messages sent back to the United States to a high-speed computer—data strings that painted a picture of ozone concentrations so ridiculously low that the computer did precisely what it had been programmed to do: It rejected the data as obviously incorrect.