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WHO'S AFRAID OF MARY SHELLEY?

by

Barnett Rosenberg, Ph.D
Professor of Chemistry
Michigan State University
President/Director
Barros Research Institute

As a scientist I have grown weary at the crescendo of reports in the newspapers and on TV of the terrible things science and technology are doing to the world. Some of these are true, but slanted; others are partly true and exaggerated; most are patently false. I would like to try to put these in a more balanced perspective.

Let me illustrate with some examples of each of these categories.

I'm sure you've heard your TV commentator intone somberly: There are enough nuclear warheads controlled by major powers to kill earth's population ten times over, and nuclear proliferation will surely put some of these in the hands of less responsible leaders of smaller countries. The Chernobyl accident threatens the whole of eastern Europe. Chemical pollution pushes an ever-increasing number of living species to the brink of extinction, and Love Canals blight our cities and landscapes.

The protective ozone layer in the atmosphere is being depleted and the harmful ultra-violet rays of the sun are leaking through. Even the return to burning fossil fuels as a safe alternate to nuclear power, is after all, not so safe. The increasing load of CO₂ creates a "greenhouse effect" that will melt the polar ice pack and inundate our coastal plains. Our foodstuffs are spiked with cancer-causing chemicals despite the Delaney Clause in our federal law. Handing a rosy apple to a rosy cheeked child makes us soul mates of the wicked Queen in Snow White and the Seven Dwarfs.

We live precariously if we put saccharin in our coffee, have high cholesterol eggs for breakfast, eat nitrite-laden bacon and frankfurters, charcoal broil our steak and fry our hamburgers.

And for the final indignity, when we seek to allay our by now frazzled

nerves, and lower our too high blood pressure, popping a reserpine pill is a no no. If we turn to the films to relax we find, for the umpteenth time, Baron Frankenstein resurrecting his monsters--still with the criminal brain and still because Igor has clumsily dropped the jar containing the good man's brain. Would that one time he doesn't.

But that is Mary Shelley's story -- not mine.

These things are the grim fairy tales of our time, more frightening because they do contain an element of truth. If these are the fruits of science and technology run rampant, then why do we not put an end to them all? Call a halt to science; cut off the tax monies that support scientists in their university and government laboratories. End clinical experiments with animals, let alone, humans. Let us have a breather while society catches up with science and makes up its mind where it wants to go and what it wants to do.

The list of horror stories grows almost daily. Were we not wiser, we might almost believe that the news media report them with glee, along with the accidents, murders and fires that so easily fill the nightly news reports. Is it any wonder that sleep comes slowly and nightmares ride through what little we get?

But is this what science is all about? Is science evil? Is immorality immanent in its very workings?

I don't believe so and I shall try to tell you why. I will very likely fail, but it is certainly worth the effort. I have been what is commonly called a dedicated scientist all of my life, and I can hardly be considered a disinterested party. You may, therefore, wish to dilute or disregard what I have to say, but I urge you not to do so, for I am an optimist, and I offer an honest balm for soothing irritated fears.

All of you graduating here today have been exposed, in the pursuit of your education, to a number of courses in science. I do not doubt that for many of you they have been discomfoting experiences. They were full of worlds you had never met before and hope never to again -- the mathematical perplexities of physics, the seemingly endless and illogical memorizations of chemistry (to say nothing of its foul odors), and an uncomfortable intimacy with the innards of dead animals in the biology laboratories.

But to some of you, it has also let you glimpse a universe of logical laws that deepen your understanding of that strange and delightful sense of beauty you feel when you watch the night sky over your heads, or feel the cool sands beneath your feet. You can know what they are and why they are. We are born willy nilly into a world already old at our birth. We are ignorant, but we learn.

And what science teaches us is that the world is knowable. We fear many things when we are young, but when we learn, we fear less. Knowledge is better than ignorance. This is what science is about. It is why some of us can love it so, and fear it not at all.

I can cull one example of its logical simplicity and profound beauty from something which happened to me in my early years, and which was later responsible in part, for my passage from physics to biophysics.

Almost forty years ago, I was a graduate student of physics at the Federal Technical Institute in Zürich, Switzerland. At that time a small book, written by Erwin Schrödinger, one of the creators of quantum mechanics, was published. It is called "What is Life?" It excited us all, physicists and biologists alike, because it provided a simple explanation for a great mystery -- the nature of the genes that control what we are and what we become. Schrödinger postulated that the gene is nothing more than a single molecule in

the nucleus of the cell -- a molecule we now know as DNA.

We debated this for long hours even after the coffee houses closed at midnight. What a marvelous thing it was, that by logical reasoning from some simple laws of physics, Schrödinger could explain the stability of the Hapsburgh lip over many generations. This is due to the stability of the molecular structure. And he could explain the mutations that allowed us to evolve from a primordial slime to become creators of this beautiful university. These are the rare, small changes in that molecule.

How far we have come from those days, when many biologists wrote that we would never know this "mystical entity" called the gene, to these days when, at any number of companies that line Silicon Valley, people are busily punching instructions into little boxes, which, after a short spell, pop out a custom-made gene that can incorporate a new heredity into various organisms. This is quite a revolution, and there are many lessons to be learned from it.

Let me first sort out what is science here and what is technology. Certainly Schrödinger's book is science -- in the noblest tradition of a noble art. I use the word "art" deliberately, to connote those inner feelings and emotions, mental states of beauty and pleasure, aesthetics if you will. These mental states are fully as significant in science as they are in music, literature or painting. Because these inner feelings cannot be taught, for many of you, science will always be unsatisfying. But take the words of this practitioner, if not the words of Keats: There is beauty in truth. Schrödinger's argument that the gene is a molecule is elegant and beautiful -- and it is true.

But how do we know it is true? Because time after time we have put it to a test in the natural world, and each time we correctly predicted the outcome. Of all the worlds man may weave in flights of fancy, only those that closely

touch the external world into which we are born can become the subject of science. Science is a necessary amalgam of the joy of mental creation and a test for truth in the objective world. Thus, science is the most meaningful and satisfying way we have discovered to know the world. And, society, in its need to know, has established a social contract with us; it provides the means to do research, and in return, we submit the fruits of that research.

Note that in all of this I have nowhere mentioned morality. The reason for this omission is simple: There is no moral value in a new scientific fact or theory -- It is simply true, partially true (as most are) or false. That the hereditary substance is a molecule of DNA is a fact. It has no connotations of good or evil about it. It was reported, verified, and incorporated into our knowledge, where it is irreversibly embedded. We cannot take it back.

So much for science. But what about those people pushing buttons on the gene generators? Why are they there and why do we pay them? It is because knowledge implies powers -- powers to change our world. This is the role and the realm of technology. Because these powers may be used for good or for evil, technology does have moral values. If we custom-make genes, as we now do, then we can use this knowledge to do many things, some good, some bad. For example, we now foresee an end to genetic diseases. Who would not want to eliminate Down's Syndrome or Sickle Cell Anemia?

But how few of us would desire to modify an innocuous intestinal bacteria into a deadly carrier of toxins. If this latter could become a weapon of war, then those to whom we delegate the responsibility for such decisions, the political and military minds of our country, must, in good conscience, consider these possibilities. And we as citizens must be knowledgeable enough to exert a control on their decisions, and say yea or nay to them.

This is the nature of the moral dilemmas posed by technology. It could create fearsome weapons of war, or it could, as fire and steam ~~has~~^{have} change the human condition from the "nasty, short and brutish existence" of the middle ages, to the passably comfortable and pleasant world of today's western technologies, where famine is almost forgotten and pestilence is under increasing control. Where I do not fear every summer, as my parents did, waves of polio crippling or killing my children; and where I do not fear, as my grandparents did, recurrent plagues of smallpox, for we have in these past few years wiped the smallpox virus off the face of the earth.

Did you hear any hosannas in the press to celebrate this momentous success? This was a brilliant triumph of science, technology and society, that will soon save more lives than were lost in all the wars of history. Some among you of a more pessimistic turn of mind may consider this a not unmixed blessing that only exacerbates the population explosion (another current scare phrase). I personally find such reasoning detestable, for, by an extension of this logic, why not have World War III and really reduce the population! Instead, can we not use science and technology to find humane solutions? I think we can and should and will.

I have said that the applications of science through technology leads to moral problems. Could not scientists be bright enough to anticipate such problems and do something to check the potential inhumane use of the creations of humane minds? Not always -- since we cannot see the future clearly -- but it has happened sometimes. I will illustrate with two particularly significant cases.

Case I: In the early 1940's it had become obvious to many physicists that a nuclear bomb of unprecedented power could be constructed. These scientists voluntarily put in place a tight security lid on their work, and,

through the intervention of Einstein, made President Roosevelt aware of the potential military use of such a bomb and the fact that the Nazi government of Germany was already taking steps to implement it. In the context of World War II and the quite real fears of a future world dominated by Hitler, I cannot fault the decisions to develop the bomb. What other decision could they make? Thus, the Manhattan District Project, the military security, the ultimate decision by President Truman to use it to end the war with Japan, and the present nuclear stalemate that is so troublesome today. But could this be worse than Nazi hegemony of the world?

Did we choose wrong? I don't know. But I do know that the development of nuclear sources of energy was inevitable, given the irreversible advances of knowledge. The physical world and the methods of science, are there for all to study. Nuclear energy has yet to produce the good promise of limitless and free energy to make the deserts bloom, but that may be because we have only a poor grasp of the economic forces at work in our culture. If we do choose to go with nuclear power, and that decision has not yet been made, is a Three Mile Island or a Chernobyl accident a price we have to pay? Probably. Then should we decide to forego nuclear power, close off our nuclear energy plants and demolish our nuclear bomb arsenal? This is for you to determine, using all your powers of reason and your votes, as is proper in a democratic society. But at least you must become knowledgeable to the best of your ability before you decide and act. Scientists, as scientists and not as citizens, cannot be asked to decide for you -- they are not competent to do so.

Case 2: Even more recently, when the techniques of gene transfer (recombinant DNA) became clear, the involved scientists again voluntarily banded together, and this time, publicly, debated the hazards and the benefits

of this new technology. Out of many such open discussions, a set of government-enforced guidelines for containment of potential experimental hazards was forged. As it turned out, none of the horrors envisaged by the most pessimistic scientists could happen; but then, neither have any of the great social benefits envisaged by the most optimistic yet been realized. I am hopeful, however, that some such benefits may be available soon, and that those people pushing the buttons on the gene generator boxes may be our future heroes.

These are two examples where scientists have voluntarily intervened in the usual courses of events leading from scientific discovery to social use. In the first case we chose to go forward. In the second case, it turned out not to be necessary to impede progress. The first case was a horror, with at decision time, some redeeming social qualities; while the second case, after due caution, turned out to be no horror at all.

These stories do not make a sufficient case that scientists are men of good conscience, but they should give pause to the too easy assumption that we are all lesser Baron Frankensteins.

Now I must come to the balm for soothing irritated fears that I promised earlier. It will be, as many modern medicines are, a combination therapy. I prescribe a healthy dose of skepticism, compounded with a knowledgeable (in contrast to naive) optimism.

Skepticism is a virtue in science; it is a state of suspended belief until firm evidence is at hand. What is a skeptical approach to the doomsday criers? I would ask: Are their results confirmed by other scientists? Is the study correctly done? Are the conclusions warranted? Is there controversy over the results? Until we are reassured on these points, would it not be wise to refrain from acting? If we have our finger on the destruct

button, shouldn't we be sure it is not a self-destruct button?

The second ingredient in my prescription, is a knowledgeable optimism. Knowledge, of course, can be learned, but it is likely that optimism cannot. It is possible that optimism or pessimism is something hard-wired in our brains at an early age, and it remains a characteristic mood for the rest of our lives. The horror stories can take on a different coloration when perceived by an optimist rather than a pessimist.

Perhaps a simple analogy will help here. Consider a marble sitting on top of an inverted bowl. It is in a state we would call metastable, because even a slight push in any direction will send it plummeting downward. Now, turn the bowl over and put the marble inside. It is stable; a small or even a large push may move it upwards slightly, but it will return on its own to the bottommost level. The pessimists look upon the world as though it were perched on the inverted bowl and any change is bad. The optimists look upon the world as situated at the bottom of the bowl. We may perturb it somewhat, but there are natural restoring forces at work to return it to the stable state.

Catastrophes may, and do occur, but they are healable. The damage is not irreversible, or we should not be here today. Predictors of doom have always been with us. They play a significant role in our social evolution. And we should not tamper with their rights. Besides, considering the terrible burden of foolishness that mankind has accumulated in our long history, the pessimists are probably right more often than they are wrong. But what a hard way it is to live!

Let me cite two relevant examples from the past where public fears were roiled unnecessarily by pessimists. In the first decade of this century, Paul Ehrlich discovered Salvarsan (606), a chemical which was specific in curing

syphilis. This was the beginning of chemotherapy. It was a laudable feat. Yet many voices were raised against him in fear that a cure for venereal disease would stimulate promiscuous behavior and that the moral fabric of society would dissolve. Sound familiar? Remember this was 80 years ago.

For our second example we turn to perhaps the most notorious pessimist in history, Thomas Robert Malthus. In 1778 he proposed the doctrine that infinite human hopes for social happiness were in vain, for population would always tend to outrun food production. This is pessimism personified. Today, over 200 years later, it is very likely that, at least in the western world, more people die of overeating than undereating. Could modern technology not do the same for the poorer countries of the world? I believe it can and will.

Penultimately I would like to try to allay your fears of this sea of cancer-causing chemicals we appear to be swimming in. It is just not so that these are the causes of our cancers. Despite many attempts, we have never succeeded in transforming a single normal human cell into a cancer cell by exposing it to the strongest chemical carcinogens. Some have attributed 80-90 percent of human cancers to environmental pollution; the best scientific evidence suggests that no more than 1-2 percent could so be caused. I do not know of any evidence to suggest that the total rate of all cancers in our world has changed in the past 80 years, during which time most of the industrial pollution occurred. But cancers are still with us (for still unknown reasons), so what can we do? We can try to cure them, and cure them we are. Perhaps not as fast as we would like, but we are making progress.

We come, finally, to the last case of a soothing balm. It is also the latest battle cry of the pessimists - the greenhouse effect. Apparently humanity's dependence on fossil fuels to drive our civilization adds almost eight billion tons of carbon dioxide to the atmosphere each year - which, if

not abated, will increase the global temperature to unlivable levels. Many scientists, the EPA included, have argued that in order to survive we must decrease this source, even at the price of giving over things of great social value, and at an enormous cost. Truly, a draconian solution.

Unlike my brethren, I am not appalled by the greenhouse effect. Instead, I find it to be one of the most optimistic things we have discovered about the world we live on. For if the global temperature, in the long or short run, was determined by changes in the output of the sun's energy - or if it depended upon the wobble of the earth's axis - or changes in the rate of heat rising from the earth's core - then Mark Twain was right, there isn't anything we can do about it. But, if running the heat engines of the world is the source of increasing the global temperature, then we can exert a degree of control over it. We can in a sense, put a thermostat on the world. And, it is easy to do so. We do not need to choke off the source of the carbon dioxide, we only need to create a sink which can remove eight billion tons of carbon dioxide out of the air each year. How can we do this? Probably in a number of ways, but let me describe my favorite.

We start with a simple fact; the Pacific Ocean is blue and clear, while the Atlantic Ocean is grey and turbid. This grey turbidity is caused by enormous numbers of single cell plants, phytoplankton, in the Atlantic Ocean. The Pacific is blue and clear because it contains little or no phytoplankton. At 64 million square miles in area it is the largest desert in the world. Why? The answer comes from another simple fact - the coast of Chile (the eastern border of the Pacific) - is one of the great fisheries of the world - rich in plankton, and the food chain these support. This anomaly is caused by the local upwelling of cold, mineral rich bottom water. This upwelling cannot occur over the major expanse of the Pacific basin. No nutrients - no life - a

desert!

All living things require carbon, nitrogen, hydrogen, and oxygen. Photosynthetic plankton which fix nitrogen from the air, obtain the needed carbon from the carbon dioxide of the air; while the hydrogen and oxygen come from the splitting of the water molecules in photosynthesis by the absorbed sunlight. These nutrients then are freely available in the Pacific and, therefore, are not the limiting nutrients. But living systems also require minerals, such as sodium, potassium, calcium, phosphorus and a much smaller amount of others.

My personal experience, and the evidence of others, suggest phosphorus is the limiting nutrient in the Pacific Ocean. I will tell you why. At my home, there is a large pond surrounded by grass lawns. Twice a year the lawns are fertilized - and twice a year the pond fills rapidly with many tons of unsightly green and brown algae. Eventually it became clear even to me that here was a cause and effect relation. On advice from experts, I changed to a fertilizer that had no phosphorus. The algae blooms ceased. I was delighted, and then, amazed. For how can a few tens of pounds of phosphorus cause the growth of many tons of algae? It is because living cells require only one part of phosphorus for every hundred parts of carbon. Here indeed was a living, powerful amplifier.

Therefore, to make the Pacific Ocean bloom, we need only seed it with the most appropriate nitrogen fixing photosynthetic plankton and fertilize it with the missing nutrients. To fix eight billion tons of carbon dioxide per year we would need 83 million tons of calcium phosphate rock per year, (this is just twice as much as we currently put on our lawns and farms and only a tiny part of what is available).

Now we only need to know the size of this mid Pacific oasis. Simple

calculations from known algae growth rates shows that the area needed is a square about 320 miles on a side. This is only about one thousandth of the total area of the Pacific basin.

All the dead and dying plankton fall into the abyss and remove the carbon more or less permanently from circulation. However, it would be a pity if we did not capitalize on this new protein source or use it to support a fishery to feed the world's hungry. To the extent that we do so, however, we need to increase the size of the oasis. By slightly increasing or decreasing the amount of phosphate rock added each year, we can indeed control the carbon dioxide content of the atmosphere and, therefore, the global temperature. The oasis is the thermostat on the world.

As a final deeply pleasing bit of poetic justice, we can convert the soon to be unused whaling ships of the world to sow the fertilizer; a watery version of beating swords into plowshares.

You would be right to be skeptical of such an easy solution to the problem. That's fine. For it is out of the conflicts of many good minds, and diverse good experiments, that knowledge grows, and the powers to control our fate become possible.

Now you are responsible citizens of the world. You are leaving this insulated life at the university to go out into the world to strike for the levers of power. Use them well. Be knowledgeable, be skeptical and be optimistic. I wish you all the best.