A CONVERGENCE OF CRISES AND A GLIMMER OF HOPE

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Classical physics was the paradigmatic science for the 19th and early 20th centuries. It was based on the study of a relatively small number of kinds of things, each with enormous number of replicates. It bequeathed to all of science a reductionist strategy that presumed that the smallest objects are in some sense most "fundamental" and that things can reasonably be isolated from their contexts to study under controlled conditions without doing too much violence to their natures, so that when you have understood the parts well you can reinsert them into the bigger world and understand the whole from the laws governing the parts. It projected an aesthetics of simplicity and symmetry. It asserted the need to quantify and left us with a sense that quantitative methods are superior to qualitative, the sign of the maturing of a science. I think it was Rutherford who said that something exists if I can measure it. Precision, an essential ingredient in solving many scientific problems, came to stand for science as such. And it was ahistorical: time enters into classical physics only as the interval between events, not as when something happened in real time. Physics also developed more general norms for science: the separation of thinking from feeling, the demand for publicly verifiable evidence, the imperative that arguments should be evaluated independently of their source. In an age of high-cost megaprojects, and military and commercial secrecy, these aspirations can no longer be implemented. That is, physics grew up with democratic aspirations that have worn thin along with the low-intensity political democracy that figures so highly in the self-praise of the dominant world regimes.

Physics was extraordinarily successful both in understanding the world of energy and matter and in providing the basis for advances in

technology. Part of its success came from the fact that the instruments of research in physics are themselves the results of physical science, creating a rich positive feedback in which the researchers build or understand thoroughly the apparatus of that research . And it had an extraordinarily fruitful relationship with mathematics. Its admiring sibling in social science was classical and neo-classical economics which also studies the world as a large collection of independent "individuals" or firms interacting in an ahistorical void with fixed rules of behavior determined outside that science. It also elaborated on mathematical methods and created an index, GDP, to stand for progress. Other fields suffered from what Joel Cohen described as physics envy and elaborated intricate schemes and techniques for creating indices, estimating them and comparing them. Biology, nourished by an influx of physicists who thought that the business of physics had been completed, also went reductionist. Systematic biology languished, and many a doctoral student examined tissue homogenates in flasks without ever seeing the organism it came from in nature. Whole departments "went molecular". One Nobel laureate stated that biology is genetics and biochemistry, all else is stamp collecting.

But the paradigm of physics as a model science also misled. The great errors of applied science came from a reductionist mode of work that posed problems too narrowly, removed contexts, and abstracted away too many essential ingredients. In the 1970's, epidemiology adopted the doctrine of the epidemiological transition that asserted that as countries develop infectious disease would disappear and be replaced by chronic disease. It extrapolated from the recent history of Euro-North America to predict a future for the whole world. It ignored the longer sweep of history, the waxing and waning of epidemics. It did not notice what was happening with animal and plant disease. It ignored ecology, how for example deforestation or the expansion of irrigation create the habitats for mosquito reproduction. It ignored evolution, both the rapid acquisition of resistance to pesticides and antibiotics that thwarted the anti-malaria campaign of the 1950's, and longer range evolutionary processes by which microbes invade new hosts, especially such widespread and abundant hosts as we are. The alternative to the "epidemiological transition" is the proposition that every change in the ecology, land use, vegetation, economy, demography and politics is also in principle a change in the epidemiology.

The Green Revolution was another effort at high power innovation with a very narrow focus. It promoted an industrial model

for agriculture with high doses of expensive inputs, widespread use of irrigation, chemical fertilizers and pesticides, mechanization, selection of high-yielding varieties that replaced local genotypes, and support for the richer farmers at the expense of the poor. It responded to criticism by comparing the yields of the Green Revolution to yields if you do nothing. Therefore it resulted in increased yields per hectare, at least initially, but new pest problems; increased deforestation (and malaria) and soil degradation; reduced diversity of crops; increased disparities between rich and poor in the countryside; promoted rural-urban migration; and undermined the economic independence of women. None of this fit within the scope of traditional plant breeding or agronomy.

The paradigmatic sciences of the 21st century will be evolutionary ecology and organismic biology, including neurobiology. They arise out of a realization that the major problems we face now, both in understanding the world and in improving upon it, are intrinsically complex. They depend on insights from many disciplines on different levels of organization none of which can be reduced to any other. They evolve in time, and when things happens is important. Development in 21st century Africa cannot be a replay of 18th century England. For one thing, there is nobody left to enslave and plunder.

The great errors of public health, agriculture, water management and development came about from construing problems too small, too static, removed from context and from history. The sources of these errors are three-fold. First, they come out of the internal development of science, the reductionist philosophy that has dominated its development in the West since its origin in the 17th century. From this perspective we could study these errors as intellectual history, how new experiences and observations intersected with changing intellectual climates to support some approaches and dismiss others, to accept some new research claims and arguments readily and subject others to the most exquisite scrutiny or simply rule them out of order.

A second perspective is institutional. The sciences are divided into disciplines under different chairpersons or deans. Schools of medicine are separated from schools of agriculture geographically and culturally. Their practitioners go to different meetings and read different journals with very little overlap. Despite all the service to interdisciplinary, transdisciplinary, or non-disciplinary scholarship, the structure of promotions rewards and funding requires people to stay within narrow guidelines. Students are encouraged by accumulating

debt and uncertain employment to choose a thesis which may be a subcontract of their advisor's work. Therefore it is difficult for academics to step outside of the bounds that the fields have already defined. At a national level, reviews of the state-of-the-art are entrusted to those who created the fields as they are and are therefore least likely to encourage radical departures. University presidents consult the recognized leaders in a few in a field in order to choose their priorities. Therefore the best that we usually see our programs in the vanguard of the conventional.

Another view is from the perspective of political economy. It asks the question, how and why is science produced, who owns it, who is allowed to do it, how is science rewarded or punished? Then we see that the dominant philosophy is consistent with the knowledge industry as commodity production. As with all commodities, objects produced for sale, there is no necessary relation between the exchange value of a commodity and its usefulness. For instance not all ideas about health or pest control are equally marketable. As chemicals they can have an unlimited market, but ideas such as natural pest management or social determination of disease cannot be packaged into pills or sprays that have to be repurchased every year. Some truths have a good market because they are congenial to the owners of the knowledge industry and support existing prejudices, while others get you into trouble. Disputes about environmental impacts are clashes of interests discussed as questions of ecology and physiology. Legislation about science and funding for science follows the interests and concerns of the owners of legislatures.

Thus the need for a more complex approach to problems is impelled both by the internal development of the sciences and by the need to solve urgent problems, but is resisted by the prevailing philosophical biases and power interests.

The reductionist, instrumentalist view of science is challenged from two quite different perspectives. The pre-capitalist views of the world tended to be holistic. Their proponents were repelled by "fragmentation" of what had been a coherent universe, the separation of thinking and feeling, of fact from morality. It was a hierarchical holism, with a place for everything and everyone, and everyone and thing in their place. It was also static. Origin stories explained how things came to be the way they finally are. Even the more dynamic variants seen in Hinduism, Taoism, and Buddhism emphasize change

but in a sort of steady state and in any case not especially concerned with the natural world. This feudal and tributary version of holism was also expressed in the romantic movement in Europe. It spiritualized nature, gloried in seeing connections everywhere, condemned the "coldness" of a science that would reduce love to fluxes of molecules. In biology it looked to vitalism, the doctrine that living things could only be understood as matter infused with some "*élan vital*" to set it in motion. This conservative holism is the ideological choice of right wing Hindu nationalism and Christian fundamentalism that seek to make use of modern science without absorbing its secular rationalist and skeptical spirit. Nazi ideology also advocated a special holism, the unity of the *volk* with the land in a mystical unity of blood and soil which automatically excluded those who had never been allowed access to the soil. Nazi romanticism coexisted with a cold modernism and claims to ultra-scientific rationality.

One Third World variant of anti-science is Third World-ism. It begins with the truth that Euro North American science came to the colonies providing the tools of conquest, the means of exploitation of the colony, the justifications for ruling and the assertions of superiority. It then goes on to claim that the criticism of traditional beliefs and practices is racist and calls for the defense of national science and culture. In doing so, it fails to examine the conflicting worldviews in the light of history: how are the beliefs of different societies and classes within those societies created, how do the conditions of production of knowledge influence the content of that knowledge, the patterns of knowledge and ignorance and obfuscation present in all systems of thought? What determines which ancient ideas are preserved and granted the aura of wisdom? It takes cultures as the subjects of history without recognizing the heterogeneity of each society not only now but also in the past as the defenders of India's indigenous philosophy present Brahmanic Hinduism as if it were the only ancient intellectual tradition of India and its defense obligatory for anti-colonialism.

A materialist approach rejects both the scientism of Euro America and the obscurantist reactionary nationalism. The struggle for science against the Bushite attack on reason is a twofold struggle against both scientism and mystification. By scientism I mean the illusion that all questions can be solved by employing some universal scientific method that is fundamentally different from all other ways of gaining knowledge, but that knowledge is evidence-based and therefore true,

while opposing views are just theory or ideology, and that only numbers derived from measurement really matter.

Post-capitalist holism is quite another story. With roots in Marxism, feminism, and ecology it emphasizes wholeness, context, and change. The notion of integrative levels of existence—processes of atomic, molecular, cellular, organismic, ecosystemic and social levels—presumes both the relative autonomy of each level and reciprocal determination. A "thing" is a snapshot of a process maintained temporarily as it is through the provisional balance of opposing forces. But its significance depends very much on its context. Therefore we always have to ask about things and two fundamental questions, why are things the way they are instead of a little bit different, and why are things the way they are instead of very different? The first is the question of self-regulation, homeostasis, and control. The second is the question of evolution, development and history. And then we ask also about our asking, aiming our dialectical perspective at ourselves, our own ideas, why some questions are now on the agenda and others are dreadfully uninteresting to mainstream science, in what sense can theory capture reality. The two critiques of reductionist science sometimes get mixed up together. In a world of so much uncertainty, a critical view of science sometimes spills over into anti-science.

Thus the new wave of interest in complexity. If the dominant errors today come from construing the world too narrowly, abstracting away from context, the world is more complex than we had imagined. Complexity has become a new buzz word. There are books on complexity, symposia on complexity, even whole institutes devoted to the study of complexity. And there is talk about a "new science of complexity." Of course there is not really a new science of complexity. There is a heightened awareness of the complexity of the world, warnings about the errors that arise from not taking it into account, appeals for inter-disciplinarity or non-disciplinarity or trans-disciplinarity, and elegant research into the mathematics of non-linearity.

There is also a widespread interest in "chaos", an unfortunate term to describe some interesting non-linear phenomena. "Linear" has two quite different meanings. It may refer to a unidirectional sequence of causal steps, A→B→C→D. Then we can use familiar statistical techniques, making A an independent variable and the others successively dependent on it. The opposite of this kind of

linearity is a network with feedback, in which A can act on B but B also acts on A. The familiar two-species predator/prey interactions are examples of this non-linearity (figure 1). As soon as we take the feedback loop rather than unidirectional causation as our object of study, several very powerful conclusions become almost obvious: First, predator and prey have different structural positions in the system. It can be understood as follows: suppose that a pesticide poisons both predator and prey. Then the predator is harmed by two pathways: the direct effect of the pesticide and the indirect effect of having its food poisoned. But the prey species is harmed by direct poisoning and benefits indirectly from the poisoning of its predator. These pathways conflict. Therefore pesticides have a stronger impact on the predator, while the prey may actually increase. This result has been observed often. It is not that predators are more sensitive to pesticides but that the predator species is in a more vulnerable position in the community structure. A second observation is that if environmental impact of any kind varies geographically it generates correlation between predator and prey. If it impacts directly on the prey then it changes the abundance of the two species in the same direction (increases in the prey increase the predator, decreases in the prey decrease the predator.) But if the environment impacts directly on the predator, an increase in the predator decreases the prey. This generates a negative correlation between the two species. Thus the same causal network can give either positive or negative correlations (or even zero!) depending on where the environment enters the system. Slightly more complicated networks give even more unexpected results. Impacts may accumulate in variables far from the point of entry, a variable which is impacted directly may not change at all, a variable may change in the opposite direction from what common sense would suggest. All of this is apparent from the qualitative examination of the network of interactions without having to know the exact equations for their interactions, just their structural relations.

The second meaning of non-linearity refers to the kind of equation. If a relation is linear in this sense, the distributive law of arithmetic holds: c(a+b)= ac+cb. If equations are of this type all sorts of easy conclusions can be derived. But if the equation is non-linear once again there are surprises. If a process is bounded between limits, as all finite processes are, then a process may lead to an equilibrium in which a population remains the same size because births exactly balance deaths, production balances consumption, etc. The first complication is that there may be more than one equilibrium, depending on where you

start from. In one range a species may not be abundant enough to persist and goes to extinction, but beyond some threshold it can persist. An illustration of multiple equilibria is as follows: suppose that you are dropping tennis balls on a peaked roof of a house. The balls land on the roof and roll off to one side or another depending on which side of the roof they landed on. The peak of the roof is an unstable equilibrium while there is a stable equilibrium on the ground on each side of the roof.

But not all processes lead to equilibrium. A second outcome of a process may be periodic motion and this motion may be rapid or slow, and with big or small amplitude. The variable may oscillate periodically as does the moon or the menstrual cycle. These are the normal outcomes of the processes that were familiar. But something else could happen. Edward Lorenz , working at MIT, set up three equations on his computer representing atmospheric conditions. He set it to calculating in the expectation that the variables would reach an equilibrium. But they didn't. He went to lunch and returned. The calculations hadn't finished. He left the computer on over night, and the next the variables still hadn't reached equilibrium. They were not even oscillating in a regular way. And if he started it over again from a different initial state it still oscillated, but not in quite the same pattern. Even if the initial conditions were similar, the outcomes diverged quickly. Li and Yorke (1976) analyzed difference equations. They found three characteristics that occur together in some equations: the equation has periodic solutions of every period; it has non-periodic solutions, and it shows extreme sensitivity to initial conditions. They gave this phenomenon the unfortunate designation of "chaos". Extreme sensitivity to initial conditions can be understood as follows: Returning to the balls dropped on a roof, if two balls start near each other on the same side of the peak then they end up near each other on that side run. But if they are on opposite sides of the roof, no matter how close, they will diverge. Now imagine a crazy roof with peaks, turrets, domes and spires all over the place so that any two points are always on opposite sides of some peak. Then there will be the "extreme sensitivity to initial conditions".

The discovery and publication of mathematical chaos was a bombshell in the scientific community. Extreme sensitivity to initial conditions meant that no matter how precise your measurement of the state of a system, you are always a little off and that means that predictions will be way off after a short time. Peter Carruthers, an

astronomer, said on National Public Radio that chaos overturned the whole basis of science. Deepak Chopra used chaos and nonlinearity to identify a spiritual domain below the "Newtonian table", where chaos, quantum leaps and irrationality hold sway. The idea of science as giving us progressively more precise prediction collapsed. The unexpectedness of some of the outcomes of non-linear processes is really their deviation from linear expectations. They demand respect for the complexity of dynamics in order to study it not to despair.

Nowhere is a complex view of things more important than when you look at the ecosystem and the dangers to it. Ecology is intrinsically a science of complexity, and all the complexities of ecosystems, geological cycles, evolution, and human activity come together in the eco-social distress syndrome.

The Eco-social Distress Syndrome is a multidimensional pervasive dysfunctional relation between our species and the rest of nature, and between members of our species. All of us are familiar with some of the manifestations of that crisis:

Decline in the major life support systems for our species (agricultural land, forestry, fisheries and rangeland);

Exhaustion of non-renewable resources;

Pervasive pollution of our environment, with more than 100,000 historically new molecules released into a moist medium and energized by sunlight to open up possibilities for recombining in zillions of new ways with still unimagined consequences for life;

Disruption of our relations with the microbial world leading to the emergences of new infectious disease and the reemergence of some such as malaria, tuberculosis and cholera that were thought to have been conquered;

Destruction of ecosystems and loss of biodiversity;

Global warming and changing climatic patterns with increased variability;

Growing gap between rich and poor both within and among countries;

War, previously regarded as an anomaly, has become a more normal mode of existence, with much ingenuity and resources invested in developing more tools for killing and controlling people;

Nationalist (mis-described as ethnic or racial) conflicts;

An imbalance between the immensity and urgency of the problems we confront as a species and the incapacity or unwillingness of our science to confront them;

Widespread corruption and the crisis of governance.

This last one requires some explanation since superficially there seems to be an extension of democracy in the world. However much of this is illusory. While formal electoral democracy is widespread it is undermined in several important ways. More and more decisions affecting our lives are taken out of the hands of elected bodies and a settled within the boardrooms of private corporations. Others are passed to non-elected international bodies such as the IMF, WTO, and the World Bank. Within governments, power passes to nearly royal executives who bypass the legislative bodies in the public sphere and will boast of taking their countries into war despite the opposition of the public. The right of government to lie, repress, spy on citizens, and ignore its own legal framework is praised as statesmanship and world leadership. Government office is increasingly a commodity and investment in future plunder or access to influence. Thus corruption represents both the deviation from the social norms and their extreme expression.

This crisis is one more of many in the history of humanity but is more profound than the previous ones. It reaches higher into the atmosphere and deeper into the crust of the earth. It affects more aspects of our life. It is more widespread geographically so that we cannot evade the problems by moving someplace else.

The individual elements of this crisis are by now familiar to all of us. But it is useful to examine how they fit together, the network of feedbacks that give the whole a temporary persistence and threatening instability.

When non renewable resources are depleted, the search goes on for more distant and inaccessible deposits that require greater expenditure of energy and leave greater residues of pollutants.

Once renewable resources are diminished, their economic value increases, encouraging a more frantic race to exhaust them before somebody else does.

Erosion increases the demand for fertilizer and irrigation, both increasing energy demand and pollution load and intensifies the factors of climate change.

More energy-efficient means of transportation would encourage longer distance commuting and make it easier to ship goods

to and from the furthest reaches of the earth. But in order to reduce the increased use of energy it would be necessary to reduce commuting by locating residents closer to employment. However this would cause greater health hazards unless we also transform the production process to eliminate pollution. It would also increase traffic congestion. As long as human settlement patterns are determined by real estate values, energy-efficient cars will not protect our atmosphere. Until we reduce the wage disparities between the capitalist heartland and the periphery the incentives will remain for the long-distance shipping of raw materials, partly finished, and finished goods.

As long as the status of women is determined in the labor market that alternately lures them into remunerated employment and pushes them back into unpaid domestic employment, and as long as the allocation of women's labor between production and reproduction is determined in the marketplace, the equality of women will remain an epiphenomena of commerce. An aging population in the industrial countries creates a labor shortage, and this is ameliorated by luring workers from the periphery and urging women to have more babies. Then the media push a culture of family values, the joys of staying at home, and sexist divisions of labor. An alternative solution to an aging population might be to extend the working years of people. But this would be inhuman unless work were redesigned to become life fulfilling.

The undermining of job security increases people's mobility and undercuts the formation of community. Isolated individuals then seek purely individual goals either through aggrandizement or religious fundamentalisms or both.

At one level, the eco-social distress syndrome is a generic crisis of the human species that has emerged almost instantaneously in the evolutionary time framework from a local omnivorous primate of East Africa to a worldwide colonizing and dominant species. Perhaps we are a weed, a successional species that is already destroying the conditions for its own persistence. Perhaps in that case we should set up a nominating committee to interview potential successor species. But since most of the processes of the EDS have emerged during the last few centuries of capitalism, it is more particularly a crisis of world capitalism as a successional stage in our social evolution.

Every kind of society has its own ecology, its own patterns of relations with the rest of nature and internally with itself. Therefore we have to examine the ecology of capitalism.

Most production of goods and services under capitalism takes the form of commodities, that is, things made for sale, and the exchange of economic values. This is so obvious and widespread that is taken for granted. But it has tremendous consequences for our lives and in particular for our ecology. There is no necessary relationship between the usefulness of a commodity and its economic value. The long-term trend is for more and more kinds of things to become commodities: knowledge, art, emotional support, other organisms of all kinds, healing care, violence, body parts, or public office, or recreation turned into entertainment. Once things are commodities the question of what is produced, how much of it is produced, how it is made, where it is manufactured, by whom, with what technology, and where it goes to are determined not by any decisions about usefulness, need, or potential harm but only by profitability. The freer the market, and the easier it is for investment to move from one activity to another, the more commodities are interchangeable. It is a matter of indifference to a company whether it produces grain, educational materials, soft drinks, porn, computer games or cars, or runs a chain of nursing homes or sports teams. They all meet and are measured against each other at the bottom line. Since other companies can also move in on anything that looks profitable, there is a race for competitiveness. Each enterprise strives to improve profits by controlling resources, squeezing the workers more, hiding harmful impacts on the environment or human health, creating new needs and convincing people to buy them, expanding into new markets and buying up existing companies. Some innovations in production may actually be beneficial to the environment, but these are side effects. An honest logo from a corporation would be "profit is our only product". Land may be uncultivated even in the face of hunger, markets may be open next door to perfectly satisfactory existing markets, research may be suppressed or announced with fanfare according to how it might affect profits. It is a matter of indifference whether money is invested in more efficient engineering, union busting, researching new products, electing or renting a Senator, increased sales effort and public relations, or hiring lawyers to delay the removal of products from sale when dangerous effects on people's lives, water quality, or the ozone layer can no longer be hidden. A particularly noxious growing industry is the manufacture of consent. Another option is that companies may step away altogether from production of any sort and trade in financial papers.

Business is and must be insatiable. Individual entrepreneurs may be concerned about people or the environment, but once they are successful enough the big boys move in and the personal concerns of the founders of an enterprise are erased in the impersonal imperatives of the corporate and financial world. Ben & Jerry's, Horizon dairies, Cascadian and Muir Glen organic foods have all been swallowed up by the giant food corporations, starting at their green tails and eventually leaving only the ecological grin behind. People are also increasingly treated as things, human capital, investments to be rented and discarded as the market dictates. The competitive individualistic mode of existence of business becomes a model for all of life, isolating people from each other, reducing living to relations with things and quest for individual meaningfulness. Thus, despite efforts such as antitrust laws, a competitive market evolves toward monopoly and with the power. Crime and corruption in every society are caricatures of their respective virtues and therefore are both condemned and tolerated. Of all of its defects, it is the insatiability of capitalism that in the long run makes it incompatible with sustainability.

As a species we confront the dilemma that a rising standard of living is incompatible with sustainability and equity as long as we interpret that rising standard of living as an unlimited increase in the consumption of matter and energy. But if we understand the rising standard of living to mean improvement in the quality of life, the care of people, and the creation of opportunities for people to develop a full capacity, then a whole new range of possibilities open up. The trouble is that these are incompatible with commodity production. We can bribe, coerce, and con industries into doing the decent thing as far as some recycling technologies, energy efficiency or even alternative energy is concerned; we can promote organic foods and establish national parks. But sooner or later we come against the immovable stone wall of the imperative to expand. It is here that ecology movements must confront the reality that commodity production is at least equal in environmental importance as global warming in threatening our survival. The refusal to do so has led to the death by domestication of the German Green party and those environmental movements that draw back from finger-pointing.

This awareness is spreading in the world. We see the bumper stickers: Food for people not for profit! Health is a right not a privilege! Owls do not destroy jobs, greed destroys both! The demands

of indigenous peoples for the control of their own natural resources is also a demand to nurture those resources and to protect them from that cost/benefit calculation which can decide when using up a species or a habitat is more profitable than keeping them alive for the long haul. We see conflicts between real estate values and humane habitats, between educating children for rich lives as active citizens and training them for docile performance in the new industries. In Latin America especially we see movements against the privatization of water and energy and for community level control of what happens in the community, and the invention of new forms of participatory grassroots democracy derived from the traditional forms of consultation still surviving in the indigenous cultures. In the world social forum we see a glimmering of convergence of these various movements. What is still missing is a coherent program. Many of the ingredients are already present but often in different movements. What makes this scary is that if we put it all together and insist that goods are produced only insofar as they enhance life and the rest of nature, if we value all human lives and offer opportunities for their fullest development, if we insist that people be treated as intrinsically valuable rather than as human capital, if we treat governing as a moment in the division of labor where we pool our brains to solve shared problems, if we evaluate the total impact of our activities on ourselves and on the future in making decisions, then whoops! That would be socialism! Perhaps we had better convene that nominating committee.