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Chaos Theory

Dialectical materialism, elaborated by Karl Marx and Frederick Engels, was concerned with much more than political economy: it was a world view. Nature, as Engels in particular sought to demonstrate in his writings, is proof of the correctness of both materialism and dialectics. "My recapitulation of mathematics and the natural sciences," he wrote, "was undertaken in order to convince myself also in detail…that in nature amid the welter of innumerable changes, the same dialectical laws of motion force their way through as those which in history govern the apparent fortuitousness of events…" (16)

Since their day, every important new advance in scientific discovery has confirmed the Marxian outlook although scientists, because of the political implications of an association with Marxism, seldom acknowledge dialectical materialism. Now, the advent of chaos theory provides fresh backing for the fundamental ideas of the founders of scientific socialism. Up to now chaos has been largely ignored by scientists, except as a nuisance or something to be avoided. A tap drips, sometimes regularly, sometimes not; the movement of a fluid is either turbulent or not; the heart beats regularly but sometimes goes into a fibrillation; the weather blows hot or cold. Wherever there is motion that appears to be chaotic—and it is all around us—there is generally little attempt to come to terms with it from a strictly scientific point of view.

What then, are the general features of chaotic systems? Having described them in mathematical terms, what application does the mathematics have? One of the features given prominence by Gleick and others is what has been dubbed "the butterfly effect." Lorenz, had discovered on his computer-simulated weather a remarkable development. One of his simulations was based on twelve variables, including, as we said, non-linear relationships. He found that if he started his simulation with values that were only slightly different from the original—the difference being that one set were down to six decimal places and the second set down three places—then the "weather" produced by the computer soon veered wildly from the original. Where perhaps a slight perturbation might have been expected, there was, only after a brief period of recognisable similarity, a completely different pattern.

This means that in a complex, non-linear system, a small change in the input could produce a huge change in the output. In Lorenz's computer world, it was equivalent to a butterfly's wing-beat causing a hurricane in another part of the world; hence the expression. The conclusion that can be drawn from this is that, given the complexity of the forces and processes that go to determine the weather, it can never be predicted beyond a short period of time ahead. In fact, the biggest weather computer in the world, in the European centre for Medium-range Weather Forecasting, does as many as 400 million calculations every second. It is fed 100 million separate weather measurements from around the world every day, and it processes data in three hours of continuous running, to produce a ten day forecast. Yet beyond two or three days the forecasts are speculative, and beyond six or seven they are worthless. Chaos theory, then, sets definite limits to the predictability of complex non-linear systems.

It is strange, nevertheless, that Gleick and others have paid so much attention to the butterfly effect, as if it injects a strange mystique into chaos theory. It is surely well established (if not accurately modelled mathematically) that in other similarly complex systems a small input can produce a large output, that an accumulation of "quantity" can be transformed to "quality." There is only a difference of less than two per cent, for example, in the basic genetic make-up of human beings and chimpanzees—a difference that can be quantified in terms of molecular chemistry. Yet in the complex, non-linear processes that are involved in translating the genetic "code" into a living animal, this small dissimilarity means the difference between one species and another.

Marxism applies itself to perhaps the most complex of all non-linear systems—human society. With the colossal interaction of countless individuals, politics and economics constitute so complex a system that alongside it, the planet's weather systems looks like clockwork. Nevertheless, as is the case with other "chaotic" systems, society can be treated scientifically—as long as the limits, like the weather, are understood. Unfortunately, Gleick's book is not clear on the application of chaos theory to politics and economics. He cites an exercise by Mandelbrot, who fed his IBM computer with a hundred year's worth of cotton prices from the New York exchange. "Each particular price change was random and unpredictable," he writes. "But the sequence of changes was independent of scale: curves for daily and monthly price changes matched…the degree of variation had remained constant over a tumultuous 60-year period that saw two world wars and a depression." (17)

This passage cannot be taken on face value. It may be true that within certain limits, it is possible to see the same mathematical patterns that have been identified in other models or chaotic systems. But given the almost limitless complexity of human society and economics, it is inconceivable that major events like wars would not disrupt these patterns. Marxists would argue that society does lend itself to scientific study. In contrast to those who see only formlessness, Marxists see human development from the starting point of material forces, and a scientific description of social categories like classes, and so on. If the development of chaos science leads to an acceptance that the scientific method is valid in politics and economics, then it is a valuable plus. However, as Marx and Engels have always understood, theirs is an inexact science, meaning that broad trends and developments could be traced, but detailed and intimate knowledge of all influences and conditions is not possible.

Cotton prices notwithstanding, the book gives no evidence that this Marxist view is wrong. In fact, there is no explanation as to why Mandelbrot apparently saw a pattern in only 60 years' prices when he had over 100 years' of data to play with. In addition, elsewhere in the book, Gleick adds that "economists have looked for strange attractors in stock market trends but so far had not found them." Despite the apparent limitations in the fields of economics and politics, however, it is clear that the mathematical "taming" of what were thought to be random or chaotic systems has profound implications for science as a whole. It opens up many vistas for the study of processes that were largely out of bounds in the past.

Διϖισιον οφ Λαβουρ

One of the main characteristics of the great scientists of the Renaissance was that they were whole human beings. They had an all-rounded development, which enabled, for example, Leonardo da Vinci to be a great engineer, mathematician and mechanician, as well as an artist of genius. The same was true of DühPer, Machiavelli, Luther, and countless others, of whom Engels wrote:

"The heroes of that time were not yet in thrall to the division of labour, the restricting effects of which, with its production of one-sidedness, we so often notice in their successors." (18) The division of labour, of course, plays a necessary role in the development of the productive forces. However, under capitalism, this has been carried to such an extreme that it begins to turn into its opposite.

The extreme division, on the one hand, between mental and manual labour means that millions of men and women are reduced to a life of unthinking drudgery on the production line, denied of any possibility to display the creativity and inventiveness which is latent in every human being. At the other extreme, we have the development of a kind of intellectual priestly caste which has arrogated to itself the sole right to the title of "guardians of science and culture." To the degree that these people become remote from the real life of society, this has a negative effect on their consciousness. They develop in an entirely narrow, one-sided way. Not only is there an abyss separating "artists" from scientists, but the scientific community itself is riven with ever-increasing divisions between increasingly narrow specialisations. It is ironic that, precisely when the "lines of demarcation" between physics, chemistry and biology are breaking down, the gulf which divides even different branches of, say, physics has become virtually unbridgeable.

James Gleick describes the situation thus:

"Few laymen realise how tightly compartmentalised the scientific community had become, a battleship with bulkheads sealed against leaks. Biologists had enough to read without keeping up with the mathematical literature—for that matter, molecular biologists had enough to read without keeping up with population biology, physicists had better ways to spend their time than sifting through the meteorology journals."

In recent years, the advent of chaos theory is one of the indications that something is beginning to change in the scientific community. Increasingly, scientists from different fields feel that they have somehow reached a dead end. It is necessary to break out in a new direction. The birth of chaos mathematics, therefore, is a proof as Engels would have said, of the dialectical character of nature, a reminder that reality consists of whole dynamic systems, or even one whole system, and not of models (however useful) abstracted from them. What are the main features of chaos theory? Gleick describes them in the following way:

"To some physicists, chaos is a science of process rather than state, of becoming rather than being."

"They feel that they are turning back a trend in science towards reductionism, the analysis of systems in terms of their constituent parts: quarks, chromosomes, or neutrons. They believe that they are looking for the whole."

The method of dialectical materialism is precisely to look at "process rather than state, of becoming rather than being." "More and more over the past decade, he'd begun to sense that the old reductionist approaches were reaching a dead end, and that even some of the hard-core physical scientists were getting fed up with mathematical abstractions that ignored the real complexities of the world. They seemed to be half-consciously groping for a new approach—and in the process, he thought, they were cutting across the traditional boundaries in a way they hadn't done in years. Maybe centuries." (19)

Because chaos is a science of whole dynamic systems, rather than separate parts, it represents, in effect, an unacknowledged vindication of the dialectical view. Up to now, scientific investigation has been too much isolated into its constituent parts. In pursuit of the "parts" the scientific specialist becomes too specialised not infrequently losing all sight of the "whole." Experimentation and theoretical rationalisations thus became increasingly removed from reality. More than a century ago, Engels criticised the narrowness of what he called the metaphysical method, which consisted of looking at things in an isolated way, which lost sight of the whole. The starting point of the supporters of chaos theory was a reaction against precisely this method, which they call "reductionism." Engels explained that the "reduction" of the study of nature to separate disciplines is to some extent necessary and inevitable.

"When we reflect on nature or the history of mankind or our own intellectual activity, at first we see the picture of an endless maze of connections in which nothing remains what, where and as it was, but everything moves, changes, comes into being and passes away…

"But this conception, correctly as it expresses the general character of the picture of phenomena as a whole, does not suffice to explain the details of which this picture is made up, and so long as we cannot do this, we are not clear about the whole picture. In order to understand these details we must detach them from their natural or historical connection and examine each one separately according to its nature, special causes and effects, etc."

But as Engels warned, too great a retreat into "reductionism" can lead to an undialectical view, or a drift to metaphysical ideas.

"The analysis of nature into its individual parts, the division of the different natural processes and objects into definite classes, the study of the internal anatomy of organic bodies in their manifold forms—these were the fundamental conditions for the gigantic strides in our knowledge of nature that have been made during the last four hundred years. But this has bequeathed us the habit of observing natural objects and processes in isolation, detached from the general context; of observing them not in their motion, but in their state of rest; not as essentially variable elements, but as constant ones; not in their life, but in their death." (20)

Now compare this with the following passage from Gleick's book:

"Scientists break things apart and look at them one at a time. If they want to examine the interaction of subatomic particles, they put two or three together. There is complication enough. The power of self-similarity, though, begins at much greater levels of complexity. It is a matter of looking at the whole." (21)

If we substitute the word "reductionism" for "the metaphysical mode of thought," we see that the central idea is identical. Now see what conclusion Engels drew from his criticism of reductionism ("the metaphysical method"):

"But for dialectics, which grasps things and their images, ideas, essentially in their interconnection, in their sequence, their movement, their birth and death, such processes as those mentioned above are so many corroborations of its own method of treatment. Nature is the test of dialectics, and it must be said for modern natural science that it has furnished extremely rich and daily increasing materials for this test, and has thus proved that in the last analysis Nature's process is dialectical and not metaphysical.

"But the scientists who have learnt to think dialectically are still few and far between, and hence the conflict between the discoveries made and the old traditional mode of thought is the explanation of the boundless confusion which now reigns in theoretical natural science and reduces both teachers and students, writers and readers to despair." (22)

Over one hundred years ago, old Engels accurately describes the state of the physical sciences today. This is acknowledged by Ilya Prigogine (Nobel-prize winner for chemistry 1977) and Isabelle Stengers in their book Order Out of Chaos, Man's New Dialogue with Nature, where they writes the following:

"To a certain extent, there is an analogy between this conflict (between Newtonian physics and the new scientific ideas) and the one that gave rise to dialectical materialism…The idea of a history of nature as an integral part of materialism was asserted by Marx and, in greater detail, by Engels. Contemporary developments in physics, the discovery of the constructive role played by irreversibility, have thus raised within the natural sciences a question that has long been asked by materialists. For them, understanding nature meant understanding it as being capable of producing man and his societies.

"Moreover, at the time Engels wrote his Dialectics of Nature, the physical sciences seemed to have rejected the mechanistic world view and drawn closer to the idea of an historical development of nature. Engels mentions three fundamental discoveries: energy and the laws governing its qualitative transformations, the cell as the basic constituent of life, and Darwin's discovery of the evolution of species. In view of these great discoveries, Engels came to the conclusion that the mechanistic world view was dead." (23)

Despite all the wonderful advances of science and technology, there is a deep-seated feeling of malaise. An increasing number of scientists are beginning to rebel against the prevailing orthodoxies and seek new solutions to the problems facing them. Sooner or later, this is bound to result in a new revolution in science, similar to the one effected by Einstein and Planck nearly a century ago. Significantly, Einstein himself was far from being a member of the scientific establishment.

"The mainstream for most of the twentieth century," Gleick remarks, "has been particle physics, exploring the building blocks of matter at higher and higher energies, smaller and smaller scale, shorter and shorter times. Out of particle physics have come theories about the fundamental forces of nature and about the origin of the universe. Yet some young physicists have grown dissatisfied with the direction of the most prestigious of sciences. Progress has begun to seem slow, the naming of new particles futile, the body of theory cluttered. With the coming of chaos, younger scientists believed they were seeing the beginnings of a course change for all of physics. The field had been dominated long enough, they felt, by the glittering abstractions of high-energy particles and quantum mechanics."

Χηαοσ ανδ Διαλεχτιχσ

It is as yet too early to form a definitive view of chaos theory. However, what is clear is that these scientists are groping in the direction of a dialectical view of nature. For example, the dialectical law of the transformation of quantity into quality (and vice versa) plays a prominent sole in chaos theory:

"He (Von Neumann) recognised that a complicated dynamical system could have points of instability—critical points where a small push can have large consequences, as with a ball balanced at the top of a hill."

And again:

"In science as in life, it is well known that a chain of events can have a point of crisis that could magnify small changes. But chaos meant that such points were everywhere. They were pervasive." (24)

These and many other passages reveal a striking resemblance between certain aspects of chaos theory and dialectics. Yet the most incredible thing is that most of the pioneers of "chaos" seem to have not the slightest knowledge not only of the writings of Marx and Engels, but even of Hegel! In one sense, this provides even more striking confirmation of the correctness of dialectical materialism. But in another, it is a frustrating thought that the absence of an adequate philosophical framework and methodology has been denied to science needlessly and for such a long time.

For 300 years, physics was based on linear systems. The name linear refers to the fact that if you plot such an equation on a graph, it emerges as a straight line. Indeed, much of nature appears to work precisely in this way. This is why classical mechanics is able to describe it adequately. However, much of nature is not linear, and cannot be understood through linear systems. The brain certainly does not function in a linear manner, nor does the economy, with its chaotic cycle of booms and slumps. A non-linear equation is not expressed in a straight line, but takes into account the irregular, contradictory and frequently chaotic nature of reality.

"All this makes me feel very unhappy about cosmologists who tell us that they've got the origins of the Universe pretty well wrapped up, except for the first millisecond or so of the Big Bang. And with politicians who assure us that not only is a solid dose of monetarism going to be good for us, but they're so certain about it that a few million unemployed must be just a minor hiccup. The mathematical ecologist Robert May voiced similar sentiments in 1976. 'Not only in research, but in the everyday world of politics and economics, we would all be better off if more people realised that simple systems do not necessarily possess simple dynamical properties.'" (25)

The problems of modern science could be overcome far more easily by adopting a conscious (as opposed to an unconscious, haphazard, empirical) dialectical method. It is clear that the general philosophical implications of chaos theory are disputed by its scientists. Gleick quotes Ford, "a self-proclaimed evangelist of chaos" as saying that chaos means "systems liberated to randomly explore their every dynamic possibility…" Others refer to apparently random systems. Perhaps the best definition comes from Jensen, a theoretical physicist at Yale, who defines "chaos" as "the irregular, unpredictable behaviour of deterministic, non-linear dynamical systems."

Rather than elevate randomness to a principle of nature, as Ford seems to do, the new science does the opposite: it shows irrefutably that processes that were considered to be random (and may still be so considered, for everyday purposes) are nevertheless driven by an underlying determinism—not the crude mechanical determinism of the 18th century but dialectical determinism.

Some of the claims being made for the new science are very grand, and with the refinement and development of methods and techniques, may well prove true. Some of its exponents go so far as to say that the 20th century will be known for three things: relativity, quantum mechanics and chaos. Albert Einstein, although one of the founders of quantum theory, was never reconciled to the idea of a non-deterministic universe. In a letter to the physicist Neils Bohr, he insisted that "God does not play dice." Chaos theory has not only shown Einstein to be correct on this point, but even in its infancy, it is a brilliant confirmation of the fundamental world view put forward by Marx and Engels over a hundred years ago.

It is really astonishing that so many of the advocates of chaos theory, who are attempting to break with the stultifying "linear" methodology and work out a new "non-linear" mathematics, which is more in consonance with the turbulent reality of ever-changing nature, appear to be completely unaware of the only genuine revolution in logic in two millennia—the dialectical logic elaborated by Hegel, and subsequently perfected on a scientific and materialist basis by Marx and Engels. How many errors, blind alleys and crises in science could have been avoided if scientists had been equipped with a methodology which genuinely reflects the dynamic reality of nature, instead of conflicting with it at every turn!