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Paul Prew, "The 21st Century World-Ecosystem: Systemic Collapse or Transition to a New Dissipative Structure?"

According to the classical view, there was a sharp distinction between simple systems, such as studied by physics or chemistry, and complex systems, such as studied by biology and human science. . . . Over the last decades, we have learned that, in non-equilibrium conditions, simple materials. . . can acquire complex behavior. This opens the way to new channels for transferring of knowledge from physics and mathematics to a variety of other fields (Prigogine 1985:19).

INTRODUCTION

Social science has thrown itself wholeheartedly at an attempt to apply the Newtonian paradigm of the physical sciences to scientifically verify and predict social reality. [1] As positivistic statistical procedures of the social sciences become more complicated and advanced, the physical sciences have once again leaped ahead of most social scientists in their efforts to understand reality. Many of the researchers in sociology cling to the notions of equilibrium and stability. The work of Talcott Parsons and Emile Durkheim remain popular to this day. Sociologists who follow the structural-functionalism of Parsons are convinced that structures exist because they are functional. Social systems operate within an equilibrium, only to be disturbed, momentarily, by dysfunctional phenomena until the dysfunctional is absorbed into the functional system. Durkheim, fascinated by the consensus in social order, spent a great portion of his career studying the perturbations to that order, namely anomie and deviance. Although equilibrium has not disappeared from our reality, the new buzzword in the sciences is "chaos." If social sciences are to advance, they must relinquish their hopes of scientific credibility in their quest for the holy grail of linear causality and begin reorienting research to include the ideas being generated in what has been called the "new sciences." [2]

The new sciences have developed over time in a variety of locations, somewhat simultaneously. One significant marker in the development of this body of insight was the discovery of the "butterfly effect" by Edward Lorenz in the early 1960's (Capra 1996: 134). Ilya Prigogine and Isabelle Stengers also conducted pioneering work in this area. They strove to shed light on how order could be generated despite the countervailing tendency toward disorganization or entropy. As a resolution to this apparent contradiction Prigogine and Stengers argued that the flow of entropy could actually create higher states of order in what they call "dissipative structures." According to their thesis, dissipative structures operating "far from equilibrium" may diverge unpredictably onto new paths of development. Not only did these notions challenge the accepted canon, Prigogine and Stengers (1984: 8) contended that "irreversibility and randomness are the rules" and "non-equilibrium is a more usual source of order" (Wallerstein 1983a: 31). In other words, capitalism must maintain a constant flow of "energy" through the system to maintain its order. This flow is not only historically situated, it follows a specific geographic pattern.

I am convinced that the geographic relationships of dissipative flow are best understood using world-system analytic tools. I would be remiss, however, if I did not also mention the origin of the ideas of a geographic contradiction tied to the environment developed by Marx and recently illuminated by the work of John Bellamy Foster and Paul Burkett. This chapter will attempt to develop some theoretical links between the new sciences, Marx's conception of the relationship between capitalism and nature, and world-system analysis.

DISSIPATIVE STRUCTURES: AN INTRODUCTION

To understand how capitalism as a social system leads to environmental degradation, it is first necessary to outline the basic processes governing the production of life itself. One of the most important "laws" governing natural systems is the second law of thermodynamics, entropy. According to the law of entropy, "any isolated, or 'closed,' physical system will proceed spontaneously in the direction of ever increasing disorder" (Capra 1996: 47). This law can be observed as perfume disseminates throughout a room and the odor diminishes. Another example would be "chaotic" nature of the area around my desk as neat stacks of books begin to spread out and become covered in numerous journal articles that used to occupy space in my file cabinet.

The concept of entropy is not limited to a mere increase in disorder, but it also is meant to describe the depletion of "useful" energy. In the known universe, the amount of energy and matter remain fixed and, therefore, cannot be created nor disappear (first law of thermodynamics). But, the amount of useful energy or energy that can perform work is reduced when matter or energy is used (second law of thermodynamics). In other words, as matter or energy is used, it changes form into something no longer useful to people, i.e. waste. Entropy is the increase in matter and energy that is no longer useful (Altvater 1993: 194). In this way, many authors have used the concept of entropy as a new way to study the social and ecological problems faced by the world today.

Elmar Altvater (1993) argues that capitalism increases the environmental entropy because of the logic of accumulation and expansion inherent to the system. For Altvater, the capitalist system demands that energy use increase to meet the demand of accumulation and expansion of the system. Jeremy Rifkin and Ted Howard (1989) also argue that entropic processes reduce the available energy in the environment. Efforts to reverse the entropy process, according to Rifkin and Howard (1989: 51), only result in "increasing the overall entropy of the environment." [3]

Although many authors have described entropy and attempts to reverse it, the concept of entropy only explains part of the story. The increase in entropy is intimately connected with the creation of order and complexity. Similarly, capitalism, although destructive, produces its own form of order such as social arrangements and technological gadgets. Even Karl Marx and Friedrich Engels (1964: 65-66), in the *Communist Manifesto*, acknowledged the power of capitalism to produce technological improvements. William Greider (1998: 11), in his book *One World, Ready or Not*, described capitalism as a machine that "throws off enormous mows of wealth and bounty while it leaves behind great furrows of wreckage." How is it that capitalism can create at the same time it is argued to be so destructive? There appears to be a contradiction if we cannot describe capitalism solely on the basis of its destructive impacts, but must also acknowledge its "creative" abilities. How can a system be, at the same time, both creative and destructive? Although Rifkin and others allude to the solution, by arguing that attempts to reduce entropy increases overall entropy, the answer to these questions can be found in the concept of "dissipative structure."

The very basis of life is dependent on a counter tendency to the second law, otherwise complex life-forms could not exist. If entropy were truly the overriding logic of reality, development of the basic building blocks of life would have been impossible because the law of entropy would demand that matter, organic or otherwise, become less complex, not more. In order to evolve and survive, living organisms must find a way to combat entropic forces that would break them down before development and organization could take place.

Research into these questions of how order can evolve from chaos (or entropy) has lead scientists to the conclusion that order can be created by increasing the entropy flow in the surrounding environment. In other words, order can be created, but it comes at the expense of greater entropy in the long run. In terms of living organisms, Erwin Schrödinger (1985: 121) argues that life "feeds on a 'negative entropy flow.'" Organisms are able to exist because the production of entropy in living organisms is compensated by entropy flow from the surrounding environment (Prigogine and Stengers 1997: 63). Thus, organisms continue their existence through a continuous flow of energy, absorbing matter and energy from the environment and dissipating waste back into the environment (Capra 1996: 189). Prigogine (1989: 398) gives the term "dissipative structures" to the continuous flow of energy and the dissipation of waste in a complex structure. According to Prigogine (1989: 398), "increase in entropy is not an increase in disorder, for order and disorder are created simultaneously." Thus, order and entropy are intimately linked, and dissipative structures are a counter tendency to entropy.

The notion of dissipative structure arose as Prigogine and Stengers (1984) investigated the conflict between the old Newtonian paradigm that is characterized by "*lawfulness, determinism* and *reversibility*" (Prigogine and Stengers 1984: 60, italics in original) and new discoveries in quantum mechanics and thermodynamics. What Prigogine and others had discovered was a world where outcomes were not determined by a universal set of physical laws, but were subject to chance and not reversible. Uncertainty, irreversibility and far from equilibrium conditions became primary concerns of Prigogine and Stengers (1984). Typical Newtonian physics dealt with near equilibrium systems where any perturbation only momentarily disturbed the system before returning to equilibrium conditions. Prigogine and Stengers (1984: 140-1) were concerned with the development of stable states and order in systems that were far from equilibrium. Instead of returning to an equilibrium position, far from equilibrium systems tend to be driven by fluctuations. At far from equilibrium, "certain fluctuations, instead of regressing, may be amplified and invade the entire system." This fluctuation and subsequent amplification may lead to new states of order qualitatively different, and more complex, from the initial state. At far from equilibrium these new states of order increase the production of entropy (Prigogine and Stengers 1997: 64, 67).

In this way, the level of complexity rises as the generation of entropy, or dissipation, increases, hence the name dissipative structures. According to Prigogine, "dissipative structures not only maintain themselves in a stable state far from equilibrium, but may even evolve. When the flow of energy and matter through them increases, they may go through new instabilities and transform themselves into new structures of increased complexity" (Capra 1996: 89). The generation of disorder in a dissipative structure is directly tied to the creation of higher states of complexity. In this sense, order arises out of disorder, and increased complexity necessarily results in increased entropy in the surrounding environment.

The generation of waste and greater complexity generated by the flow of energy through a system is the primary concern of this chapter, especially as it relates to capitalism. The laws of dissipative structures govern the very development of life. Increasing complexity witnessed by Darwinian evolution as well as the so-called "development" of the industrial world comes with a price tag of increased entropy production. Capitalism, as a dissipative structure, has a logic that is, at its core, environmentally destructive. In addition, the effects of entropy production have become de-localized as complexity and order are concentrated in the core and the production and concentration of waste tends to occur in the periphery. The benefits of capitalism have tended to be concentrated hundreds, if not thousands, of miles away from the periphery where its worst effects are felt.

CAPITALISM AS A DISSIPATIVE STRUCTURE

Capitalism operates as a dissipative structure. However, this statement means little if we do not examine it historically. [4] To argue that capitalism is a dissipative structure does not distinguish it from other historical modes of production. All social systems, and all organic life for that matter, are dissipative structures. Fritjof Capra (1996: 159-61) uses the concept of dissipative structure defined by Ilya Prigogine as the key "structure" in a living system. My argument that capitalism is a dissipative structure is not a significant conceptual breakthrough. Thus, the trick is to keep in mind that capitalism is a dissipative structure while investigating how it is that capitalism, as a dissipative structure, "undermin[es] the original sources of all wealth -- the soil and the worker" (Marx 1977: 638). For the answer to this question (specifically how capitalism is environmentally destructive), we must look at the defining logic of the system of production during the historical epoch to be considered.

Since all social systems are dissipative in nature, they share a commonality with capitalism. It is not as important to understand that capitalism "dissipates" energy to maintain the order of its system as it is to understand *how* capitalism dissipates energy. Each social system, more specifically mode of production in Marxist terminology, has a particular manner in which it organizes production from material nature, a "metabolic interaction between [people] and the earth" (Marx 1977: 637). In this sense, a dissipative structure can be thought of as a historical constant, an abstraction, and capitalist production is the historically specific realization of that abstraction.

In the *Grundrisse*, Marx (1973) not only recognized historical constants, but integrated abstract concepts with historically specific analysis. He states, "However, all epochs of production have certain common traits, common characteristics . . . Still, this *general* category, this common element sifted out by comparison, is itself segmented many times over and splits into different determinations. Some determinations belong to all epochs, others to only a few" (Marx 1973: 85 italics in original). But, Marx (1973: 105) was careful never to allow abstractions to become reified into concepts outside of their historical specificity. "This example of labor shows strikingly how even the most abstract categories, despite their validity -- precisely because of their abstractness -- for all epochs, are nevertheless, in the specific character of this abstract, themselves likewise a product of historic relations, and posses their full validity only for and within these relations." Indeed, the concept of dissipative structure is a general category that applies to all historical epochs. Likewise, I think it is appropriate to use the concept of dissipative structure to help understand the operation of the capitalist system, but the use of dissipative structure must be in relation to the historical specificity of the capitalist mode of production. By accepting the fact that all social systems are dissipative and attempting to understand the particular manifestation of capitalism as a dissipative structure, it may be possible to shine some light on the ecologically destructive nature of capitalism and attempt to create more ecologically sound relationship with our material environment.

How is it then that this process is necessarily exploitative of nature? Although all dissipative structures create order from the flow of energy and capitalism is no different, the unique nature of capitalist flows demands goals that are wholly unconcerned with sustainability and renewability. All systems create and maintain their order by using energy to convert their material surroundings into the means to their existence. In this process, energy must flow through the system, and entropy, or waste, must be generated even if it is only the creation of unusable radiated heat. Each society must maintain their order by the dissipative flow of energy through the society itself. In order to maintain this flow, people must engage in a "metabolic interaction" with nature to facilitate the continued existence of the society. [5] People under capitalism must engage in the same metabolic interaction with their surrounding environment, converting raw materials into the necessities of life. Under capitalism, the transformation of nature into use value takes the form of commodities. This particular mode of meeting human needs is the present source of environmental degradation.

The origin of the environmental problem with capitalist production can be linked to the end goal of its central logic. Capitalism is based solely on the logic of ceaseless accumulation of capital (Marx 1981b: 352-3; Marx and Engels 1964: 63; Wallerstein 1983b: 17-8, 1999: 78). Accumulation is the engine of dissipation. For capitalism, accumulation is the mechanism that orders the social world. It is the process around which the rest of the relations are organized. To argue that accumulation is the engine of dissipation is not to say that accumulation is unilinearly determinate, but the logic of capitalism, accumulation, is the singular process that all other relations are somehow forced to conform. The way in which accumulation occurs, or the speed at which accumulation takes place, etc. may be changed by social relations, but the logic remains the same -- accumulate greater sums of wealth at the end of the working day than the capitalist had at the beginning. Although the logic of capitalism orders our existence, it at the same time is also the very same mechanism that generates tremendous amounts of entropy and waste. The amount of entropy generated by the capitalist system must, by its very logic, increase as a result of accumulation. Accumulation is not the accumulation of a steady state of materials and wealth, a finite pie so to speak. It is an ever increasing accumulation. The pie must always expand.

Capitalism as a system must expand its operations if it is to survive. The very accumulation logic central to capitalism necessitates this. The valorization of commodities is dependent on their production from materials in the physical environment. The production process under capitalism, like all other systems of production, necessitates a metabolic interaction with nature. However, the accumulation logic of capitalism necessitates that these material elements of nature are transformed into commodities in an *ever expanding rate*. The stability of the capitalist order as a dissipative structure is dependent on the continued accumulation in a cycle of never-ending expansion. Because the systemic logic is based on the expansion of accumulation, and accumulation is dependent on the valorization of commodities in the marketplace whose surplus value arises from labor-power, and the production of commodities necessitates materials from the natural environment, it follows that more and more materials of nature must be consumed in the process of production. The inputs to the dissipative flow of capitalism must necessarily increase, because the very logic of capitalism demands that it continue to expand.

According to Marx (1981a: 431), the use of natural resources occurs at a rate that can be more intensively and extensively exploited by labor-power. “The natural materials which are exploited productively (and which do not form an element of capital’s value) i.e. soil, sea, mineral ores, forests, etc. may be more or less severely exploited, in extent and intensity, by greater exertion of the same amount of labor-power, without an increase in the money capital advanced.” Marx’s analysis can be broken down into a time component (intensive exploitation) and a geographic element (extensive exploitation). It is then possible to study how capitalism quickens the use of the material elements to production and how capitalism also expands geographically to incorporate more environmental resources into production.

Intensive exploitation attempts to more quickly and thoroughly use the natural products and processes of the earth to increase the productivity of labor. One of the means to increase the productivity of natural materials is to utilize the waste generated during the production process. Although capitalist production processes are inherently wasteful, since they produce for exchange value not use value, capitalists are aware of the necessity to economize inputs to the production process. Marx (1981b: 196-7) describes the inefficient nature of Irish flax production, condemned by English manufactures. Whenever possible, capitalists will attempt to stretch their raw material inputs to gain the greatest productivity from the labor power applied to them. In addition whenever possible, capitalists will attempt to use the waste products of production. In terms of the use of waste in the production, Marx (1981b: 196-7) described the use of rags in the making of woolen garments and also the use of the byproducts of the chemical industry. However, the overall tendency for capitalist production, "for all its stinginess, . . . make[s] it very wasteful of material resources, so that it loses for society what it gains for the individual capitalist" (Marx 1981b: 180). What cannot be readily reincorporated into the circuit of production is cast off as an externality. The use of refuse in production does not significantly reverse the trend toward wastefulness of production. [6]

Another means to more intensely use the natural inputs to production is to speed up the processes of their development. Marx (1981a: 316; Marx 1981b: 213-4) discussed the interruptions in the production process necessitated by nature. "Winter corn needs nine months or so to ripen. Between seed-time and harvest, the labor process is almost completely interrupted. In the raising of timber, once planted and the preliminary work connected with this is completed, the seed may need 100 years to be transformed into a finished product; during this whole time, only a relatively very insignificant intervention of labor is needed." At present, timber companies are "factory farming" trees such as the eucalyptus. Because of the effect of these trees on the environment and the livelihood of the people in the surrounding area, indigenous peoples are uprooting and cutting down groves of quick growing eucalyptus trees (Shiva 1989: 79-82). The use of hybridization and the application of petrochemicals have led to shorter growing periods for many crops. Bioengineering and the green revolution have increased the number of crops per season, speeding the depletion of the soil and other inputs such as water. The increase in turnover rate not only applies to plants, but also to living organisms such as chickens and other livestock.

The accumulation logic of capitalism necessitates that not only shall production utilize natural elements more intensely, it shall also expand production on a greater scale. Marx (1981b: 214) states, "The more capitalist production is developed, bringing with it greater means for a sudden and uninterrupted increase in the portion of the constant capital that consists of machinery, etc., and the more rapid the accumulation (particularly in times of prosperity), the greater is the relative overproduction of machinery and other fixed capital, the more frequent the relative overproduction of plant and animal raw materials . . ." There are limits to the amount of production that can be increased through the more intense use of resources, and many times it is more easy to expand production. The expansion of production, however, has the unfortunate consequence of more quickly exhausting readily available inputs to production.

As natural elements are exhausted, capitalists must seek new stores of resources. As the fur-bearing mammals of Europe were hunted to near extinction, colonial powers depended greatly on the early incorporation of the indigenous groups of the Americas, such as the Cherokee, to procure the needed furs (Dunaway 1994). The depletion of the soil Marx (1977: 637, 1981b: 216, etc.) discussed in *Capital* led to the scavenging of bones from the Napoleonic battlefields to provide fertilizer for core-region agricultural fields (Foster 1994: 64). Necessities of geographic expansion have led capitalists to colonize islands for the sake of guano fertilizer (Skaggs 1994), develop offshore floating oil platforms and contemplate extra-terrestrial mining. Without this expansion, capitalism, as a dissipative structure, would find its dissipative flow restricted, threatening the very viability of the system so dedicated to ever expanding accumulation.

WORLD-SYSTEM ANALYSIS AND GEOGRAPHICAL DISSIPATION

Although Marx and others were able to satisfactorily explain why the capitalist world-system would need to expand in order to survive, world-system analysis is able to more clearly elucidate how this expansion occurs. In addition, world-system analysis provides a foundation for understanding the development of inequality within the capitalist system and the resulting relationships of hierarchy between the various poles of the system.

The expansion of the capitalist system is not haphazard, but is based on a geographic system of hierarchy and a systematic flow of goods, resources and energy from one region to another. [7] According to Wallerstein (1983b), the capitalist world-system operates through a set of inequitable geographic relationships where certain regions are able to consistently retain greater value in exchanges, leading to the enrichment of one participant and the impoverishment of the other.

One researcher to apply these relationships to the environment is Stephen Bunker (1985). Interested in the environmental and social impacts of resource extraction, Bunker (1985: 20) studied how the core's demand for raw materials leads to deleterious results for the peripheries where the resource extraction takes place. Bunker argues there are flows of energy from extractive to productive economies that act differentially on the development of the various regions. The transfer of value in the form of natural raw materials from the extractive economy to the productive economy constrains the former's ability to develop while promoting the latter's economy. "The differences between the internal dynamics of modes of extraction and of modes of production create unequal exchange not only in terms of the labor value incorporated into products but also through the direct appropriation of rapidly depleted or nonrenewable resources" (Bunker 1985: 22). For Bunker, the process of unequal exchange results in a flow of energy value from the periphery to the core.

The notion that a flow exists from the peripheries of the world-system to the core fits well with world-system analysis. In fact, the very terms core and periphery are derived from the geographic structure of economic flows from one region to another (Wallerstein 1983b: 32). From the very beginning of incorporation, a flow begins from the point of incorporation to the center of the incorporating power. This is not to argue that goods, energy etc. do not move back and forth between the regions, however core regions tend to accumulation the benefits of the relationship.

By virtue of the accumulation of the benefits of this unequal exchange, the core is able to “develop,” or increase its complexity, due to the flow of energy it receives. Bunker (1985: 33) states, “Accelerated energy flow to the world industrial core permits the social complexity which generates political and economic power there and permits the rapid technological changes which transform world market demands.” The flow from the periphery to the core is the spatial manifestation of the accumulation logic, and gives the dissipative structure of the capitalist world-system its geographical dimension. The order and complexity of the core are direct beneficiaries of the global capitalist flows. Bunker (1985: 21) continues to describe the relationships between the core and periphery by arguing that the order in the core comes at the expense of peripheral complexity. “The flow of energy from extractive to productive economies reduces the complexity and power of the first and increases complexity and power in the second.” According to Bunker (1985: 34), the peripheral region becomes “increasingly simplified” as a result of this relationship. The extraction of raw materials from the peripheral region diminishes its ability to become more complex.

Although the relationships Bunker describes certainly occur, the concept of dissipative structures would tend to suggest that in addition to the depletion occurring in the periphery, order should also be created. The capitalist system, acting as a dissipative structure, not only creates order in the core where the vast majority of benefits are concentrated, it also creates order in the periphery. The capitalist world-system must be understood in its entirety, as a single dissipative structure. By examining the world-system as a whole, the peripheral regions could be understood as nodes within the system. As a part of the capitalist world-system, the peripheral regions perform specific functions for the necessary maintenance and expansion of the whole. It follows then that the periphery must develop order and complexity. However, this complexity is very specific to its role within the world system, which is extraction and primary goods production. Thus, peripheral regions develop, but they develop in historically specific ways as a result of the relationships established to maintain the flow of energy and resources in the system necessary to maintain the order of the system.

Energy may flow away from the periphery, but this flow also creates order in the periphery, a very historically specific order. The very process of incorporation and the degree to which the social, political, economic etc.

infrastructures are ordered to meet the needs of the incorporating power conditions the historical “development” of the various peripheries. Depending on the opportunity for other types of development and the level to which external forces control the types of production developed, the peripheral nation may see very different “paths of development.” Within dissipative structures, the initial conditions are not “forgotten” and have a significant effect on the further trajectories of the system. Likewise, the initial conditions at incorporation, and the manner in which the region is incorporated will set the stage for its further development. In some cases, situations may allow the possibility for the development of infrastructure that allows endogenous development, but for the majority of peripheral regions, they are subject to the whims of development according to logic of incorporation. [8]

It is worth pointing out that the order in the periphery generated by the operation of the capitalist world-system is necessarily the result of the creation of greater entropy in the region. Thus, there is a spatial organization to the inequality of the world system that takes place at the regional level as well as the global level. Peripheral complexity and order are the result of greater entropy regionally just as the complexity and order of the core are the result of greater entropy for the system as a whole. Not only do global relationships of inequality maintain the system of capitalism, regional systems of inequality persist to maintain order and complexity locally. The relationships of inequality at the various levels of the world-system assume a “fractal” nature, repeating themselves but never in exactly the same way.

The notion of fractals comes from Benoit Mandelbrot who discovered that nature and certain mathematical equations were able to create a self-similarity across various scales. A fractal object is strikingly similar at different degrees of detail. Some fractal images such as the “Koch curve” look exactly the same under high magnification as in a normal view. For mathematical fractal images, “the self similarity is built into the technique of constructing the curves- the same transformation is repeated at smaller and smaller scales” (Gleick 1987: 103). Another mathematical computer image, the “Mandelbrot set,” not only displays a level of self-similarity, it also contains within it various other images of complexity (Capra 1996: 151). Although the Mandelbrot set contains within it miniature replicas of itself at various levels, the set is filled with multitudes of complex shapes that are similar at ever finer views.

Caution should always be used when making comparisons between the scientific world and the social world especially when it comes to simple iterative process, such as the Koch and Mandelbrot sets. Still some comparisons can be drawn between fractal geometry and the operation of the world-system. Relationships in the world-system are similar at the regional level to the relationships at the global level, but the regional relationships are imbedded in the global processes, described above, that lead to a particular development of peripheral regions. Peripheral regions tend to have centers of complexity and external regions of entropic flow, just as the relationships at the global level. In fact, core regions tend to exhibit these same relationships at the regional level. Even though the relationships appear similar at various levels, they do not operate in exactly the same fashion. In other words, peripheries are not small-scale cores, nor will they follow a unilinear development path.

A clear conceptualization of the structural relationships between the periphery and core at these various levels lays the groundwork for new lines of inquiry about environmental degradation in the capitalist production process. The relationships of inequality occurring at various "fractal" levels lead to what Marx (1977: 472) described as a division between town and country. For Marx (1977: 637-8), the division between town and country was fundamentally responsible for the "metabolic rift" (Marx 1981b: 949) that developed between people and nature. The metabolic rift is the cleavage in the cyclical processes of nature as people interact with their environment to produce their daily needs. Marx demonstrated the metabolic rift by describing the increasing division of capitalist agriculture from the consumption of its products in urbanized areas.

Like the concept of metabolic interaction, John Bellamy Foster (1997: 284-5, 1999, 2000) argues the notion of metabolic rift is central to understanding Marx's view of nature. [9] As Foster (1999: 381) describes, Marx's analysis of capitalist agriculture was embedded in his views "constituting the complex, interdependent process linking human society to nature." According to Foster (1999: 380), Marx felt the growth of large-scale industry and capitalist agriculture led to the depletion of agricultural soils. At the same time, the productions of the fields were reduced to a monstrous human waste that pollutes the environment (Marx 1981b: 195). The cycle was broken as the materials that would enrich the soil became concentrated in the urban areas in the form of human waste. [10] Because the natural cycle of returning biodegradable waste to the earth is broken, the metabolic rift of capitalism establishes a relationship with nature that is inherently environmentally destructive.

In addition, the metabolic rift creates further problems because of the geographic separation of the costs and benefits of production. At both the local and the global level, disastrous effects of resource extraction are de-localized from the benefits that accumulate in the core. The people who benefit from the complexity and order generated from the entropy of resource extraction do not have to witness or live with the negative consequences of their actions. According to Wallerstein (1999: 81), capitalists are able to avoid internalizing many of the costs of production, including environmental damage. Other than the social pressure of resistance to environmental destruction, there are few incentives to acting in an environmentally responsible manner. Naturally, capitalists tend not to soil their own beds and environmental decay tends not to concentrate where people have the resources to fend off environmentally unsound practices.

The worst of capitalist environmental destruction is concentrated mainly in the peripheral regions of the world. The resource extraction on Native American reservations (Hall 1996), the location of toxic waste dumps in poor neighborhoods (Hamilton 1996), the lead in the Amazonian streams from gold mining (Hecht and Cockburn 1989) and numerous other examples can be found to demonstrate the capacity of capitalist production to toxify and destroy the natural environment. Since the peripheral regions are de-localized from the centers of capital accumulation, people in the core who benefit from this relationship tend not to experience the immediate negative consequences of capitalist production.

Besides being de-localized, capitalist production is extremely mobile especially when natural resources become depleted or too costly in one region. The peripheral region where extraction takes place tends to be oriented toward that extraction (Bunker 1985: 30) and the environment is considered only for its ability to produce the raw materials necessary for capitalist production. Unlike other systems of production that were more or less rooted in a geographical location, capitalism has always been, and will always be, a global phenomenon that is inherently mobile. It may cause terrible environmental destruction in one location, but the process of accumulation is unaffected if resources are abundant elsewhere. Capitalists readily seek out new regions of incorporation. The cores serve as the fluid, but rather stable centers of complexity, while peripheries tend to be the location of much more transient extraction. Centers of accumulation are relatively stable while zones of extraction are highly volatile, depending on the life span of the resources being extracted. Because cores can maintain rather stable accumulation while shifting regions of peripheral extraction, the resources can be depleted and the renewable resources extracted beyond reproductive rates or renewable capacity. Once the resources are depleted or become too costly, the capitalist will seek out other sources of inputs to production. The capitalist is not tied to the ecological bioregion and does not have an interest in its long term viability, only its short-term production of inputs.

Although this dissipation of natural energy maintains the order of the capitalist system by facilitating its expansionary accumulation, it is at the same time creating crisis. The destruction of the environment in the periphery first creates crisis for the ecosystems that are exploited. In some cases, regeneration can occur to a certain point until the land becomes infertile. But ecosystems are not dependent entirely on the fertility of singular patches of soil, but are complex systems. For example, small tracts of deforested land within the rainforest may regenerate, but as the areas become larger and less surrounded by rainforest, the ability to regenerate reaches a point of instability. Once ecosystems surpass this level of instability, they may never regrow as the same biotic community. The local ecosystem may collapse and never effectively recover from the incorporation into the capitalist world-system.

CONCLUSION

Why choose the notion of dissipative structure to analyze our relationship with nature? First, social systems are always dissipative because social order cannot be created without consuming energy and expending waste in the form of entropies. The natural ecosystem has evolved over billions of years to maintain a "flowing balance." However, people through their social systems have subverted the flowing balance of nature, sometimes resulting in societal collapse. Any social system based on a logic that demands energy and resource use beyond renewable sources cannot sustain itself. Some may ask "if capitalism switches to renewable energy and material inputs, will it be sustainable?" Since it is structurally impossible for capitalism to limit its inputs to renewable levels (Foster 1997), we cannot possibly construct reliable explanations if we focus our theoretical explorations on that question. By shifting the discussion to technology and the means of production, we lose sight of relationally-oriented Marxian analysis. Although capitalism must expand both extensively and intensively, our earthly biosphere is finite. Capitalism requires centers of accumulation and regions of extraction. The flow of energy and materials tends to occur geographically from the peripheries to the core while the waste tends to be concentrated in the peripheral regions. This flow tends to create a division between town and country. However, that very expansion so necessary to the logic of capitalism poses limits to the development of these polar relationships. The peripheries develop complexity at the same time that values are depleted, but peripheral regions must develop complexity in a certain fashion to serve the needs of the core. So called "development" is not possible for all regions of the world because of the polarization of the capitalist world-system and the very logic of capitalism.

World capitalism now faces two ecological options. Do we proceed with capitalism until we reach an ecological bifurcation point that leaves the habitability of the earth in question for the vast majority of the population? Or will we reach a bifurcation point that leads toward an alternative system of production that is dissipative, but less threatening to the flowing balance of nature? To accomplish the latter, we must begin to nudge the trajectory of the current social system of production in the direction of a more harmonious relationship with nature. To seek short term solutions or reforms to the current system may help increase the instability of the capitalist system necessary for its eventual transition, but a "reformed" capitalism is not sufficient to salvage our relationship with nature. This new alternative system must nurture a metabolic interaction with its natural environment, and it must ground its logic of production in renewable sources of energy and a diminution of the entropies that will generate ecological crisis.

NOTES

1. Many thanks to Wilma Dunaway, Don Clelland, Brett Clark, John Bellamy Foster, Larry Carter, Michael Dreiling, Tony Leiserowitz and others who have given me insights and inspiration.

2. For a similar discussion, see Lee (1998).

3. Others such as Nicholas Georgescu-Roegen (1971) and Juan Martinez-Alier (1987) also discuss the role of entropy and the loss of available energy for human use.

4. Others have also likened capitalism to a dissipative structure, for example see (Bunker 1985; Harvey and Reed 1994; Straussfogel 1997; Wallerstein 1983a, 1996).

5. The notion of metabolic interaction is a more developed discussion of people's material relationship with nature as described in Marx's (1971, 1998) earlier works such as *The German Ideology* and *The Economic and Philosophic Manuscripts of 1844*. Metabolic interaction is an integral part of Marx's (1973: 489, 1977: 133, 283, 290, 637-8, 1981a: 226, 1981b: 195, 949, 959) discussion of capitalism and can be found in his core texts. John Bellamy Foster (1999, 2000) illuminates Marx's notions of metabolic interaction and has been largely responsible for demystifying the criticisms of Marx's analysis of ecological concerns by both non-Marxists and Marxists alike. Paul Burkett (1999) also does an excellent job of addressing the perspectives of Marx's ecological critics such as Ted Benton (1989) and James O'Connor (1998). Benton and O'Connor's work appear to be based more on the commonly held misperceptions of Marx than a close reading of his published texts, while Foster and Burkett's work have restored the core nature of Marx's thoughts on the environment to the rest of his analysis.

6. For a discussion of the costs associated with the externalization of capitalist waste in production, see (Wallerstein 1999).

7. Wallerstein (1983b:30) states, "Now commodity chains have not been random in their geographical directions."

8. The distinction I make here could be compared to Bunker's (1985:24) notion of extreme peripheries where

relationships with the rest of the world system are based almost exclusively on "the exchange of extracted commodities."

9. Foster (1997, 1999, 2000) not only sheds light on Marx's ideas surrounding metabolic interaction and metabolic rift, he has also brought these ideas to bear on contemporary issues.

10. The division between town and country is not only expressed at the local level, but is also evident, for Marx, at the global level. For Marx, ecological resources and the productions of nature were appropriated from the colonized regions by their colonizers (Foster 2000:164).

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