

Energy and Culture

EUGENE E. RUYLE

Man, like all other forms of life, depends directly on the flow of energy through the biosphere. Recognition of this has led to a variety of attempts to apply thermodynamic concepts to the analysis of sociocultural systems. Broadly speaking, thermodynamic analyses of human societies fall into two categories. First, there is ecological energetics, which attempts to analyze the relationship between the population as a whole and the environment. Second, there is the labor theory of value, which attempts to analyze the social relations between individuals and between classes in thermodynamic terms. The present paper represents an attempt to synthesize what is useful in each of these two approaches. To do so, it is necessary to discuss their strengths and weaknesses.

Ecological Energetics

Much of the inspiration for the application of thermodynamic concepts to the analysis of cultural systems comes from the work of Leslie White (1949, 1959). White's energy theory of cultural evolution, adopted from earlier writers such as Ostwald (1907) and Lotka (1922, 1945; for a more complete bibliography, see White 1959:33-57), sees the evolutionary

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process as essentially a process of harnessing increasing amounts of energy from the environment, with a concomitant evolution of increasingly complex biological and cultural systems.

Though the non-biotic universe, in conformity with the Second Law of Thermodynamics, is running down thermodynamically, life processes represent a transitory reversal of this process, a building up of thermodynamic systems. To accomplish this, both biological and cultural systems must capture free energy from the environment and the "struggle for existence" is, above all, a struggle for free energy, with natural selection favoring those systems "whose energy-capturing devices are most efficient" (Lotka 1945:185, quoted by Leslie White 1959:37).

As energy-capturing devices become more efficient and more energy is harnessed, this increased energy is organized into increasingly complex systems, hence the evolution of social structures from simple to complex, from bands through tribes and chiefdoms, to states and larger, more modern nations (Service 1962). White's ideas on evolution have exerted considerable influence on general anthropology and have contributed strongly to the reemergence of evolutionary thought in anthropology (see, for example, Cohen 1968; Hoebel 1972).

Another source of thermodynamic concepts for cultural analysis has been E. P. Odum's framework (1971) for describing the flow of energy through ecosystems. Energy enters the system as sunlight, is harnessed by the primary producers, green plants, and passes through successive levels of consumers — herbivores, carnivores, and decomposers. Energy is dissipated at each level, so less energy is available at the higher trophic levels (see Figure 1).

These basic concepts have been used to describe human subsistence patterns and other aspects of ecosystems containing human populations (Parrack 1969; Lee 1969; Rappaport 1971). Such studies demonstrate that the principles, concepts, and operations used by anthropologists to describe sociocultural phenomena in human populations need not be basically different from those used by ethologists to describe animal populations (cf. Vayda and Rappaport 1968:494). Further, such studies provide firm scientific data for the examination of such problems as the evolutionary distinction between man and other primates (Lee 1969:48) and the relationship between religious ideas and ritual and ecological adaptation (Harris 1966; Rappaport 1967).

Mention should be made of H. T. Odum's ambitious attempt (1971) to develop an energy language to illuminate various historical and contemporary problems in the complex interaction between man and nature. Much of Odum's book is tantalizing, but one doesn't know exactly

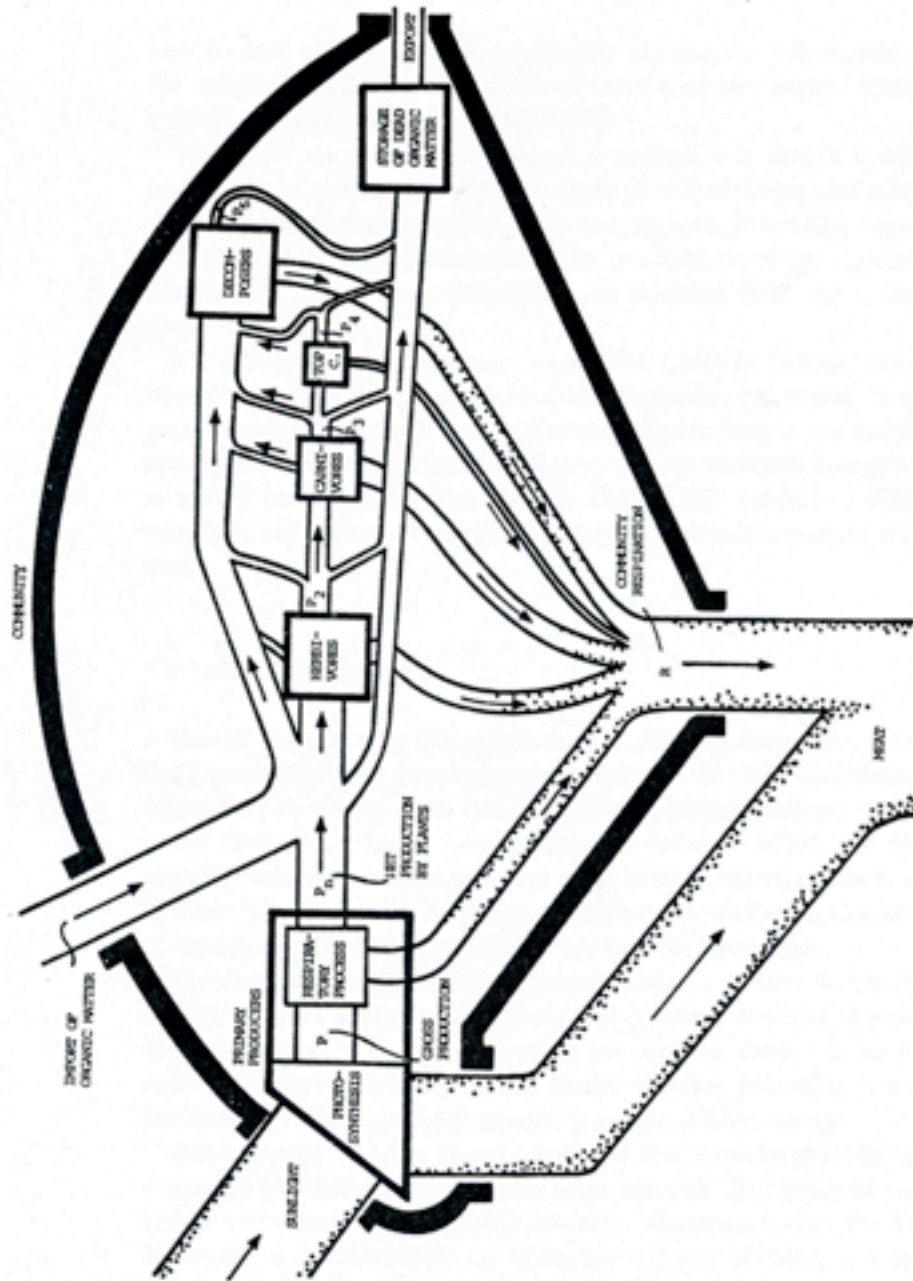


Figure 1. Flow of bioenergy through ecosystem (from E. P. Odum 1971:65)

how to deal with some of it, specifically his chapter, "Energetic basis for religion" and his "Ten commandments of the energy ethic for survival of man in nature" (1971:236-253).

The major shortcoming of ecological energetics is that it treats the population as a whole and does not attempt to deal with social relationships in a thermodynamic way. As a consequence, it sees the causes of cultural phenomena mechanistically, as resulting from the man-nature relationship, rather than dialectically, as resulting from the sphere of social relations.

The individual does not appear as a causal factor in history, and class struggles are seen as a product of cultural evolution, rather than as a primary source of historical change. A related shortcoming is the failure to distinguish between man's somatic energy and extrasomatic energy which is merely used by man. The two are distinct and subject to different principles and ecological energetics simply ignores this important distinction.

The Labor Theory of Value

Although not generally recognized as such, Marxist economics is essentially concerned with thermodynamic concepts. In the labor theory of value, the commodity is the focus of analysis. Distinctions are made between three properties of commodities: *use-value*, or utility, the ability to satisfy some human need or desire; *price*, or exchange value, the amount of money the commodity will bring on the market; and *value*, the amount of socially necessary labor required to produce the commodity.

The last two properties are thermodynamic in nature. Value is the amount of labor energy, usually measured in hours, required to produce the commodity. Price is measured in money, but money is simply a symbol for energy, a claim on the energy of other people, a means of facilitating exchanges of labor energy, or a store of labor energy.

One aspect of the labor theory of value is that it relates price to value: prices are ultimately determined by value through the agency of supply and demand (see Sweezy 1956:47, 109-130).¹ However, this aspect is only incidental to the more basic use of the labor theory of value, as a means

¹ Marx's passage in *Value, price, and profit* (quoted by Sweezy 1956:47) helps dispel much of the confusion propagated by orthodox economists (e.g. Samuelson 1970) on this point: "At the moment when supply and demand equilibrate each other, and therefore cease to act, the market price of a commodity coincides with its real value."

of analyzing social relationships.² The exchange of commodities, which appears in fetish form to the actors themselves as an exchange of use-values, is also an exchange of human labor. In analyzing this exchange between producers and consumers, and between capitalist and worker in value terms, Marx provides us with a thermodynamic approach to the analysis of social structures.

The difficulty with Marxist economics, for anthropologists at least, is that it is only in capitalist society that most use-values take the form of commodities so that the analysis of economic exchange in precapitalist societies, where markets are relatively limited in scope, requires somewhat different conceptual tools. Further, energy expended in non-productive ways, such as warfare, politics, and wasted labor, is excluded from consideration in the model. Nevertheless, the success of Marxist economics in illuminating the nature of class relations in capitalist societies suggests that a similar approach to the analysis of class relations in precapitalist societies might be equally valuable.

THREE THERMODYNAMIC SYSTEMS

Although the evolutionist and cultural materialist approaches which are associated with ecological energetics contain large measures of crypto-Marxism, there has been little or no cross-fertilization between ecological energetics and the labor theory of value. This is unfortunate because the shortcomings of both approaches may be overcome by a synthesis which recognizes the strengths of each.

There are three analytically distinct but functionally interdependent thermodynamic systems associated with human populations. Two of these occur with all animal populations; these are: (1) the *bioenergy system*, or the manner in which the population in question articulates with the food web of the ecosystem; (2) the *ethnoenergy system*, or the manner in which somatic energy is expended by the members of the population; and (3) *auxiliary energy system*, the extrasomatic energy

² See Sweezy (1956:128-130) for a discussion of this point. Sweezy concedes that the methods of orthodox economics are perhaps preferable in price calculation, but this is not the major concern in Marxist economics. Robinson's remarks (1960:2) on the differences in outlook between orthodox and Marxist economics are perhaps relevant here: "The orthodox economists have been much preoccupied with elegant elaborations of minor problems, which distract the attention of their pupils from the uncongenial realities of the modern world, and the development of abstract argument has run far ahead of any possibility of empirical verification. Marx's intellectual tools are far cruder, but his sense of reality is far stronger, and his argument towers above their intricate constructions in rough and gloomy grandeur."

harnessed and utilized by man, including fire, draft animals, fossil fuels, and atomic energy.

Recognition of these distinct thermodynamic systems provides us with a way of charting the flow of energy not only through ecosystems but also through social structures and cultural systems, and enables us to incorporate the strengths of the two thermodynamic approaches discussed above into a single analytical framework. This paper deals primarily with the ethnoenergy system, but it is necessary to discuss the bioenergy and auxiliary energy systems in slightly greater detail before turning to our major concern.

Bioenergetic Systems

Man's bioenergy system has undergone a series of changes during his evolutionary career. The hominid line first began to diverge from the pongid when man's ancestors moved out of the forest, where they had been exploiting primarily frugivorous bioenergetic sources, onto the savanna, where energy was primarily harnessed from graminivorous sources (C. J. Jolly 1970). This in turn led to an omnivorous diet as man became the first and only primate to obtain a significant portion of his energy ration as a carnivore.

The greater part of man's evolutionary career, from at least pithecanthropine to Neolithic times, was as a hunter and gatherer, and man's hunting career has conditioned his intellect, interests, emotions, and basic social life (Washburn and Lancaster 1968).³ But as long as man was a carnivore, his bioenergetic position in the food chain necessarily made him a rare animal, and it is unlikely that his numbers exceeded a few million as late as 10,000 B.C. The Neolithic Revolution and the invention of agriculture marked a return to a lower position in the food chain, coupled with a unique degree of ecosystemic management. Man had become an ecological dominant without parallel in the earth's history.

Auxiliary Energy Systems

Major cultural evolutionary advances have been associated with the

³ Perhaps this is a sexist position. The greater part of the caloric intake of most human populations is from plants gathered by women. An interesting, although extreme and fanciful, corrective for male chauvinist thinking on human origins is *The descent of woman* (Morgan 1972).

discovery of novel ways of harnessing and utilizing extrasomatic energy (cf. Leslie White 1959; Cottrell 1955). The earliest evidence of an auxiliary energy system is seen at Choukoutien, where there is clear evidence of pithecanthropine utilization of fire about half a million years ago. Slightly later, in Spain, there is evidence of the use of fire in group hunting (Howell 1968:85-99). Only much later, during the Mesolithic, did man harness his second source of auxiliary energy, the domesticated dog, for use in hunting.

Although the earliest evidence of the beginnings of animal domestication dates from about 9000 B.C., it was several millennia before draft animals began to be harnessed as sources of auxiliary energy. By about 3000 B.C., ox-drawn plows were in use in the Near East. The harnessing of water power occurred almost simultaneously in the Mediterranean, Denmark, and China about the time of Christ, but did not become widespread for another thousand years (Lynn White 1964:84). The harnessing of energy from fossil fuels during the Industrial Revolution and, more recently, of atomic energy are thus merely the latest episodes in the long, progressive development of larger and more powerful auxiliary energy systems.

The use of auxiliary energy in technological processes permits a reduction in the amount of ethnoenergy required to perform a given amount of work, that is, it renders human labor more efficient. More importantly, it permits new kinds of work to be done. Certain soils cannot be cultivated without horse-drawn plows or tractors. Oceans cannot be crossed in any regular way without sails or steam. The moon cannot be reached by human energy alone. Thus, major cultural evolutionary advances are linked to new methods of utilizing auxiliary energy as more efficient technology permits the development of larger populations, larger surpluses, and more complex social structures.

But it is not just in the sphere of production that auxiliary energy is important. Important advances in the utilization of auxiliary energy have also come from the sphere of exploitation, especially in warfare. Waves of barbarian conquests were initiated by Near Eastern nomads after they learned to harness horses to war chariots in the eighteenth century B.C., and to ride horses in the ninth century B.C. (Lenski 1970:299).

As Lynn White (1964) suggests, the crystallization of European feudalism was a result of the diffusion of the stirrup into Europe, permitting mounted shock combat and demanding social structures capable of producing and maintaining mounted knights. The harnessing of chemical energy was accomplished first for the purpose of warfare, in Greek fire and gunpowder, and the same is true of atomic energy. Finally, the harnessing

of fossil fuels for productive purposes was a result of the exploitative aspect of capitalism, the drive for profits (see below, under Ethnoenergetic Exchange, Markets, and Capitalism).

CONCEPTS FOR THE ANALYSIS OF THE ETHNOENERGETIC SYSTEM

The bioenergy harnessed by the members of a population is actively channeled into various activities, such as spatial movement, interaction with the environment and other members of the population, and so forth. Elsewhere (Ruyle n.d.a.), I have suggested the term ethnoenergy for this outpouring of animal energy. The ethnoenergetic expenditure of all animal species may be measured and described in terms of similar data languages. This has obvious advantages if we wish to describe the similarities and differences between man and the other animals. We are in a dubious position to do so if we emphasize mentalistic differences — symbolizing, language, abstract thought, etc. — for there is no generally acceptable way of getting inside the heads of animals to find out what, and if, they are thinking. It is only when we describe human and animal behavior in a similar operational data language that we can demonstrate similarities and differences.

The simplest measure of ethnoenergy is in units of duration — seconds, minutes, hours, days, etc. — but ethnoenergy may also be measured in calories. The ethnoenergetic outflow, or the behavior stream, may be described by a variety of methods (for examples of descriptive techniques which can be applied to both animals and man, see Chapple 1940; Hess 1962; Harris 1964; A. Jolly 1972:111).

The ethnoenergetic expenditure of an animal population is patterned by the species-specific needs of that population. The satisfaction of biological needs for food, water, air, shelter, etc., requires the expenditure of ethnoenergy but since the amount of ethnoenergy is limited, the energy expended in one direction necessarily reduces the amount that can be expended in the others. There are certain functional requisites which must be met by any ethnoenergetic system. First and foremost, all animals must eat, and a portion of the ethnoenergetic flow must be directed toward harnessing sufficient bioenergy to maintain the biological functioning of individual members of the population. Over and above this, ethnoenergy is expended in a variety of ways, such as play, grooming, resting, and escape from predators (see Figure 2).

It is possible to conceptualize social interaction and social relations in

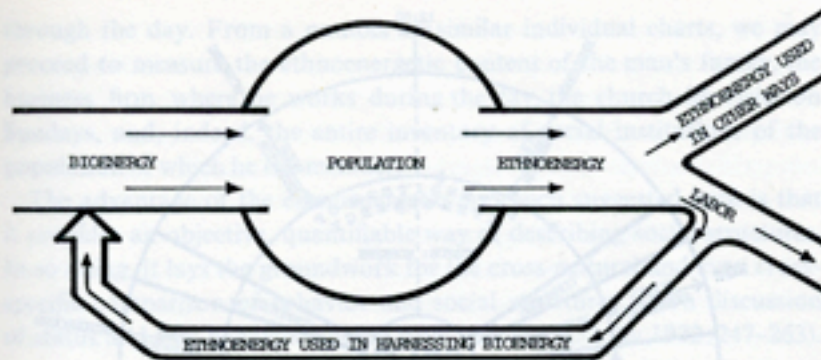


Figure 2. Ethnoenergetic harnessing of bioenergy

thermodynamic terms, thus opening the way for the thermodynamic measurement of social structures. As the individual members of a population expend ethnoenergy during the course of a day, they necessarily interact with one another. Such interactions have a durational, hence ethnoenergetic content (cf. Chapple 1940). It is possible to characterize such interactions as being either cooperative or competitive.

Cooperation is essentially a pooling of the ethnoenergetic flow of two or more individuals in such a way as to provide some mutually beneficial, or need-satisfying, result. Examples include the sexual activities of nearly all species, the group hunting of lions and wolves, the group warning systems of baboons and herbivores, and, most elaborate of all, the productive activities of man.

Competition occurs when the presence of other individuals either inhibits the ethnoenergetic outflow of an individual or reduces the efficiency of the outflow. Examples include competition for sexual access to mates, for scarce food supplies, and so on.

The ensemble of social interactions of all species includes both cooperative and competitive relations, the precise balance between the two determining such variables as spatial distribution, and dominance hierarchies (Crook 1971; Wilson 1971).

We may also speak of ethnoenergetic flow between individuals. This occurs when the ethnoenergetic expenditure of one individual, A, provides benefits to another individual, B. In such a case we may speak of ethnoenergy flowing from A to B. Examples of ethnoenergetic flow include all sorts of cooperative behavior, which are multidirectional ethnoenergetic flows, the care given to young by adults (which, in mammals, also includes a bioenergetic flow in the form of mother's milk), and the grooming behavior of primates.



Figure 3. Ethnoenergetic content of status and role (adapted from Anderson 1971:46)

The sociological concepts of status and role may also be given a thermodynamic content. A status is a position in a social structure, and the amount of time individuals spend occupying the status is the thermodynamic content of the status. Role is the behavioral component of status, the patterning of ethnoenergetic expenditure of the individual occupying the status.⁴ Figure 3 shows the hypothetical ethnoenergetic expenditure of an individual in various statuses and role behaviors over the course of a day. Beginning in the morning, occupying the status of husband, he eats his breakfast and interacts with another individual occupying the status of wife.

Later, he occupies the status of commuter and interacts with other individuals in similar statuses. At work, he occupies the statuses of employee and coworker and expends ethnoenergy in interacting with his employer and his coworkers, as well as his productive activity, and so on

⁴ Sociologists usually make a distinction between role expectations and role enactment (see Turner 1968:553). Our treatment deals only with actual role behavior, since expectations have no measurable energy content.

through the day. From a number of similar individual charts, we may proceed to measure the ethnoenergetic content of the man's family, the business firm where he works during the day, the church he visits on Sundays, and, indeed, the entire inventory of social institutions of the population of which he is a member.

The advantage of the ethnoenergetic approach suggested here is that it provides an objective, quantifiable way of describing social structures. In so doing, it lays the groundwork for the cross-cultural and even cross-specific comparison of behavior and social structures (for a discussion of status and role behavior among primates, see A. Jolly 1972:247-263).

LABOR, MAN, AND CULTURE

In the preceding section, I tried to show that a thermodynamic approach to social analysis opens the way to an objective comparison of human and non-human social behavior. Man has a variety of unique characteristics, but viewed thermodynamically, he is unique in the manner in which he appropriates environmental use-values: animals merely appropriate nature to satisfy their needs, man transforms it into culturally acceptable form, a process which requires energy. I shall argue in this section that this thermodynamic peculiarity of the human primate underlies and has caused most of the gross morphological and psychological characteristics which distinguish man from his primate relatives.⁵

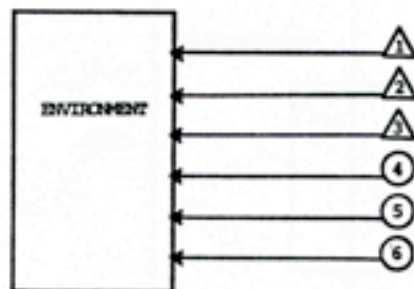


Figure 4. Ethnoenergetic flow in non-human primate populations. (1, 2, ...6 dominance hierarchy in population)

⁵ This argument has a respectable intellectual ancestry, as is seen in the following, written in 1846 (Marx and Engels 1947:7; cf. Darwin, in Washburn and Howell 1960:33; Engels 1940): "Men can be distinguished from animals by consciousness, by religion or anything else you like. They themselves begin to distinguish themselves from animals as soon as they begin to produce their means of subsistence."

Use-values are environmental objects that are able to satisfy various animal needs. These are species specific: grass is a use-value for a gazelle, but not a lion; the gazelle is a use-value for the lion. As shown in Figure 4, populations of non-human primates directly appropriate environmental use-values. Energy is expended in consuming/interacting with these use-values, but little or no energy is spent in modifying natural use-values before consuming them.

By contrast, human populations transform natural environmental resources into culturally acceptable form before they are used, as use-values, to satisfy human needs. This transformation requires the expenditure of a particular form of ethnoenergy, labor. The labor processes in human populations are characterized by first, the expenditure of energy, second, the instruments of labor, tools, and third, the transformation of raw materials into an artificial, predetermined form (cf. Marx 1965: 178). Further, in contrast to the individual food quest of non-human primates, human populations are characterized by cooperative labor activities and by sharing the product of human labor. The product of labor is not an individual product but a social product (see Figure 5).

Although man is unique in the elaboration of his labor systems and his dependence upon these systems, various forms of protolabor occur among other mammals. The great apes, for example, have been observed to make and use tools and weapons in a wide variety of contexts (A. Jolly 1972:279-294). Such protolabor among the apes, however, differs from human labor in that (1) the degree of transformation of raw

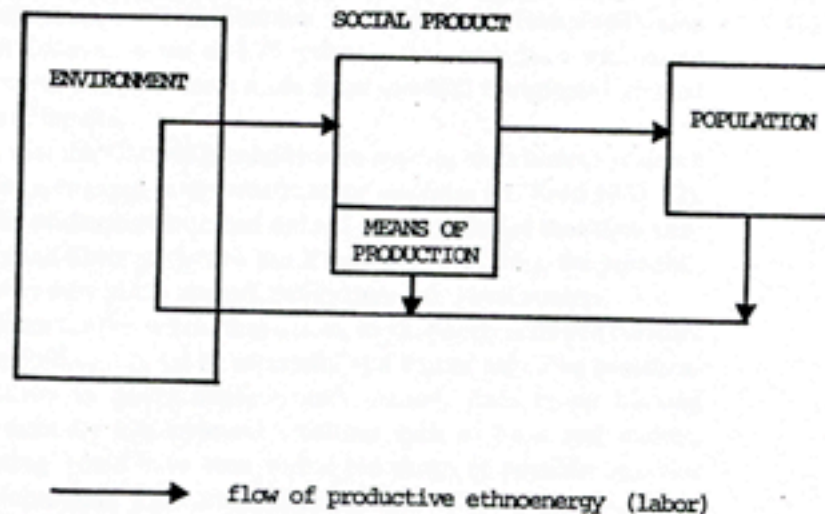


Figure 5. Ethnoenergetic flow in human populations

materials is slight; (2) the tools used, if any, are rudimentary; (3) they are individual acts, not social; and (4) they are not an essential part of the life pattern of the populations concerned — the caloric intake from termites is only a small portion of the total caloric intake of chimpanzees. Man is alone in his absolute dependence on tool use and labor (cf. Bartholomew and Birdsell 1953:489-490).

Another form of protolabor is the group hunting of lions and other predators. Here, although this is cooperative behavior, and the raw materials, living herbivores, are transformed into dead ones, and the dead prey may be transported some distance to feed the young, no tools are involved in the process. Nonetheless, all members of the population are dependent upon this pooling of ethnoenergy in the food quest, and, among African hunting dogs, at least, this has the effect of inhibiting the development of a dominance hierarchy such as that among baboon populations (see Langer 1971:322). (Significantly, when predation occurs among primates, the dominant males do not immediately appropriate the killed animal, but wait until the predator has eaten before eating the remains [A. Jolly 1972:68] — a primate recognition of the right of the laborer to his product?)

These forms of protolabor are much more rudimentary than the cooperative labor systems of even the most technologically unsophisticated human populations. The transition from the non-human to the human ethnoenergetic flow pattern was complete by the time of the Australopithecines, some two million years ago. The Australopithecine material at Olduvai, dated at 1.75 million years, includes a specialized array of quartz and lava tools made from material transported at least three miles to the site.

The fact that the Olduvai hominids were making tools is clear evidence that they were engaged in systematic labor activities (cf. Reed 1963:82). Further, the evidence of smashed animal bones indicates that they were meat eaters and likely predators. But if they were predators, the probability is that they were group hunters, rather than individual hunters.

The evidence for this is first, that a slow, weak, poorly endowed creature like Australopithecus could be successful as a hunter only if he coordinated his activity in group hunting, and, second, since group hunting occurs in mentally less endowed creatures such as lions and wolves, group hunting would have been within the range of possible behavior for Australopithecus. The earliest clear evidence of group hunting, however, is at least a million years later (Howell 1968:85-99).

The most reasonable interpretation here is that the not quite fully erect, small-brained Australopithecines had already made the decisive

transition from an animal ethnoenergetic flow pattern to a human one, in which the population is dependent upon labor to produce a social product. It follows that most of the obvious anatomical differences which distinguish man from the apes came after the incorporation of labor into the life style of man's ancestors and were a result of changed selective pressures associated with this new life style (cf. Washburn 1960).

The incorporation of labor into the life process of early man-apes is also behind the emergence of language. The labor process, like language, is hierarchical in nature, that is, it is made up of essentially meaningless elements combined in a definite order to achieve a meaningful result. Further, it imposes an arbitrary standardized form on the environment. Thus the labor process helps develop mental abilities comparable to those required in speech (cf. Critchley 1960:296-298; Lewis 1962:39-42; Pilbeam 1972:80). Further, with the development of cooperative labor in hunting the need for complex communication systems created additional selective pressures favoring the greater mental abilities required to handle the more complex systems.⁶

The incorporation of labor into the life process also had the effect of inhibiting the development of dominance hierarchies similar to those of baboons. In baboon populations, the strongest, most aggressive, most acquisitive individual is likely to be best fed, and presumably reproductively most successful. In human populations, where food is regularly shared and the individual is dependent upon the ethnoenergetic expenditure of others, the most sociable individual, the one who is given most, is likely to be best fed, and presumably reproductively most successful. The individual who is too aggressive and acquisitive is likely to be very lonely, if not dead — witness the high mortality rate among fossil man from "unnatural" causes. The human dependence on a social product thus creates pressures favoring more sociable, more cooperative individuals.⁷

EXPLOITATION AND CLASS SOCIETY

The thermodynamic peculiarity of the human primate opens the way

⁶ As Engels (1940:284) put it, "First comes labour, after it, and then side by side with it, articulate speech — these were the two most essential stimuli under the influence of which the brain of the ape gradually changed into that of man."

⁷ A number of fascinating questions have been ignored in this treatment of hominid origins. The view put forth here does not depend upon the resolution of such matters as the single vs. multiple species debate, the relationship between tool use and small canines, or predation vs. scavenging among early man. I think the labor theory of the origin of man is in accordance with the latest human paleontological thought and will stand irrespective of how these specialized issues are resolved.

for behavioral and ecological phenomena which have no parallel in the non-human world. Man, like other animals, is dependent upon the capture of free bioenergy, but in man alone is there a "struggle for free ethnoenergy." All men are dependent upon the products of social labor, and the strategy of human life is necessarily a strategy to capture ethnoenergy in the form of use-values. About five or ten thousand years ago, as human populations increased in size and as social mechanisms developed for harnessing large amounts of ethnoenergy, this led to the emergence of predacious ruling classes and to the beginnings of the class struggles which have characterized all historic civilizations.

To analyze this process, we must turn to a discussion of the general features of the production, distribution, and consumption of use-values in human populations. When material use-values are consumed by an individual, the individual is consuming not only the object itself, but also the ethnoenergy expended in the production of the use-value. One may study the outward flow of ethnoenergy from the individual, following it from its expenditure in individual or cooperative labor to its final consumer.

Conversely, one may look at the ethnoenergetic inflow of an individual, as embodied in the use-values he consumes, and trace this back to the original producers. Such an examination would show that the typical individual in nearly all human societies produces only a small proportion of the ethnoenergy he consumes, and consumes only a small part of the ethnoenergy he expends in labor. If we view the human individual as the end product of labor, it is clear that he is a social product.⁸

In analyzing the patterns of ethnoenergetic flow in human populations, we may draw upon the work of Polanyi who noted that the production and consumption of material use-values in precapitalist societies is submerged in social principles. Polanyi (1957:43-55) isolates three of these: reciprocity, redistribution, and householding (exchange and markets were relatively unimportant until the emergence of capitalism in modern Europe).

These social principles lead to three patterns of ethnoenergetic flow: symmetry, centrality, and autarchy. Householding and autarchy, of course, involve only one individual, or are within a delimited group, and are only peripheral aspects of any human society. Autarchy, with each individual appropriating for his own use, is the characteristic pattern among the non-human primates.

Polanyi, however, "deliberately disregarded the vital distinction"

⁸ As Marx (1963:317) observed, "the human essence is no abstraction inherent in the individual. In its reality it is the ensemble of the social relations."

between classless and class-structured societies (1957:52-53). By emphasizing patterns and ignoring quantities, Polanyi obscures the difference between master and slave, noble and serf, between ruler and ruled. Yet it is a simple enough matter to reintroduce these distinctions by measuring the quantity of ethnoenergetic flow as well as its direction.

When the amount of ethnoenergy flowing from one individual or group to another is balanced by an approximately equal ethnoenergetic flow in the opposite direction, we may speak of reciprocal ethnoenergetic flows. Where there is unequal ethnoenergetic flow, and where this is enforced by violence or the threat of violence, we may speak of *exploitation*. The amount by which the larger flow exceeds the smaller is *surplus*.⁹ Looking at it another way, if the amount of ethnoenergy consumed by an individual is greater than the amount of ethnoenergy he expends in production, and if he enforces this energy flow by violence or the threat of violence, then this individual, or group, is a predator, living, in part at least, on surplus exploited from the rest of the population.

As we have shown, human populations can be sharply differentiated from populations of other primates on the basis of thermodynamic structure, i.e. man alone is dependent upon labor. Similarly, a sharp distinction may be made between two types of human society on the basis of ethnoenergetic flow patterns. On the one hand, there are classless egalitarian populations in which all individuals actively participate, for much if not all of their normal lives, in the system of production through expenditure of labor energy.

On the other hand, there are class-structured, stratified populations in which at least one class participates only minimally in the labor process. The diagnostic feature of the latter sort of society is the existence of a predacious ruling class, which appropriates a disproportionate amount of the social product while participating only minimally in the productive system. There is thus a flow of ethnoenergy to the ruling class from the rest of the population.

The result is the emergence of a predator-prey relationship between ruling and producing classes similar to that existing between animal species, except that the stakes involved are not the food energy locked up in animal flesh but instead the labor energy the human animal can expend in production. Just as predation in the animal world requires the

⁹ It is to be noted that this definition of surplus follows Marx and not Adam Smith, and thus differs from the concept discussed in the "surplus controversy" (Pearson 1957; Harris 1959; Dalton 1960; Orans 1966; Mandel 1970:42-45). Perhaps it would be well to distinguish between "surpluses of appropriation," in the sense used here, and "surpluses of production" as in the surplus controversy.

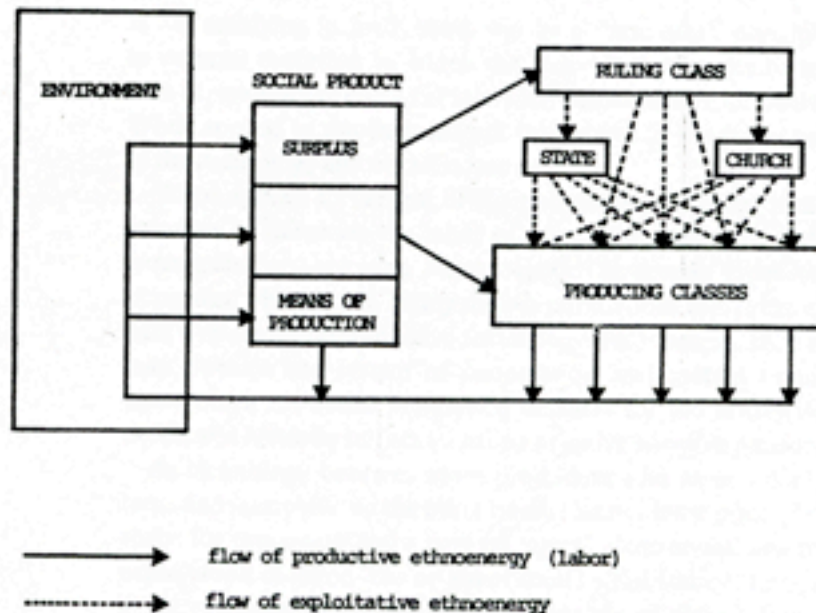


Figure 6. Ethnoenergetic flow in stratified populations

expenditure of ethnoenergy in hunting, so predation among men requires the expenditure of ethnoenergy into an exploitation system.

The elements of all systems of exploitation include:

1. The exploitative techniques themselves, the precise mechanisms — slavery, rent, corvée, taxation, etc. — by which economic surplus is pumped out of the direct producers and into the ruling class;
2. The State, which monopolizes access to legitimate violence, and which thereby physically coerces the exploited; and
3. The Church, which monopolizes access to the sacred or supernatural and thereby controls the minds of the exploited.

These institutions may be relatively discrete, as in our own society, or they may be united into a single institution, as in many of the early civilizations (cf. Leslie White 1959:303-328; and Harris 1971: 405-413) (see Figure 6).

Ruling classes, then, are populations which exist by pumping surplus out of an underlying population of producers. The subsistence technology of ruling-class populations is exploitation, and the econiche of the ruling class is different from anything existing in the animal world. But how did this situation come about? How did predation develop within the human species?

Elsewhere (Ruyle n.d.b), I have suggested that, to the extent that labor

is not satisfying in itself, there will be a "minimax" principle operating in cultural evolution in which the individual attempts to minimize his own expenditure of energy of labor but still maximize his own satisfaction. When applied to the environment this results in the increasing efficiency of the technology and organization of labor.

When applied to the rest of the population, however, it may result in attempts to substitute the labor of others for one's own and to develop techniques for exploiting human labor. In certain types of ecological situations, where small, highly mobile populations utilize the environment with a relatively unproductive technology, for example, such exploitation may threaten the system of cooperation and mutual interdependence upon which the entire population depends for the satisfaction of basic needs, and hence be subject to strong negative selective pressures.

As technology becomes more productive and as populations become large and immobile, on the other hand, this minimax principle has greater scope for expression and a new ecological niche opens, one based on the exploitation of labor. The origin of social stratification, then, can be seen as an extension of a more general principle of niche filling. The filling of this new ecological niche occurred solely because the satisfaction of the individuals entering the niche was thereby maximized in the changing ecological situation.

This theory articulates well with the latest theories of the origin of social stratification and the state. In Carneiro's treatment (1970), for example, the evolution of state structures is seen as resulting from population pressure in limited areas. As population builds up, pressure on the land leads to increased competition for land and to warfare. In expansive areas of unlimited land, defeated groups can simply move away into virgin territory, but if this option is not available, they may become subordinate groups forced to pay tribute or rent. As this process is replicated again and again in relatively restricted areas, most typically river valleys, hierarchical subordinate-superordinate systems based on military force result. Thus, the origins of the state are linked to conflicts over land.

Carneiro's theory, however, may be reinterpreted in ethnoenergetic terms. Conflicts over land arise because, with population pressure, there is less return for more effort — a reversal of the minimax principle. The result is likely to be increased dissatisfaction, perhaps witchcraft accusations, and warfare. When defeated groups are unable to move away, forcing them to pay tribute, or rent, is a reassertion of the minimax principle.

Killing the enemy would be a return to the *status quo ante*, but forcing them to pay rent or tribute, or into slavery, would increase the victors'

supply of use-values while further minimizing the expenditure of their own energy. Exploitative ethnoenergy — in warfare, raiding, collecting rent and tribute, managing slaves — is then substituted for expending energy in production in conformity with the general evolutionary principle of minimaxing.

The mechanisms suggested by Carneiro need not be the only ones at work. Preferential access to land as a result of membership in a unilineal descent group, participation in intergroup trade, or location in a redistributive system may also develop into exploitation. Elsewhere (Ruyle n.d.a.), I have suggested that one may find the following exploitative techniques in the incipient stratification system of the Northwest Coast: rent, tribute, plunder, redistribution, trade, and potlatch, as well as incipient state-church organization.¹⁰

The analysis of the complex thermodynamic systems of class-structured societies requires the development of additional conceptual tools. One such tool is the concept of ethnoenergetic field. The ethnoenergetic field of an individual is simply the ethnoenergy embodied in his property. Property is a social institution, relating not only an individual and his possessions, but also the owners and the remainder of society, such that the owner is not only guaranteed access to his possessions but is also able to deny access to any non-owner. Although there is considerable variation in the ensemble of property rights from society to society in kinds of objects which may become property and in the kinds of access which may be permitted or denied, in general there is a major contrast between property rights in egalitarian societies and in class-structured societies.

In egalitarian societies, although certain kinds of use-values, tools, weapons, clothing, household utensils, etc., are recognized as the property of an individual, no one is denied access to the strategic natural resources of the population and, typically, no one is denied access to the paramount use-value of all populations, food. In such populations the ethnoenergetic field of the individual is restricted in scope and relatively weak, including merely his own body, his clothing, such implements as he uses in his daily life (although these are typically shared with the members of the population on request).

Indeed, the development of property rights and ethnoenergetic fields

¹⁰ It is less easy to reconcile this theory with that of Fried (1967). As I understand Fried's concept of "rank society," distinctions of rank preceded the development of class exploitation (cf. Service 1962:150). If my analysis of Northwest Coast society (Ruyle n.d.a.) is correct, one of the major empirical supports for the concept of rank society disappears, and the theory is to that extent falsified.

in egalitarian societies is probably no greater than that of some animal species (Beaglehole 1931). Economic exchange, as we know it in bourgeois society, exists in only rudimentary form; instead there is a form of sharing, in which ethnoenergetic flow follows patterns dictated by various social principles, with no immediate attempt to maximize benefits or minimize costs.

It is in stratified populations that ethnoenergetic fields develop most strongly. As exploitative systems develop, increasing amounts of ethnoenergy are pumped into the ruling class and accumulate there in the form of use-values. In order to protect these accumulations, the ethnoenergetic field of the ruling class must become considerably extended and protected by strong property rights. Yet exchange, as it is known in bourgeois society, does not yet occur. The ethnoenergetic flow of surplus from ruled to ruler is patterned by social principles emphasizing hierarchy and obligation, commonly Polanyi's redistribution.

ETHNOENERGETIC EXCHANGE, MARKETS, AND CAPITALISM

Once there is the development, in stratified population, of strong ethnoenergetic fields, the possibility emerges for ethnoenergetic exchange. Exchange is a form of ethnoenergetic flow characterized by higgleggling, with each party consciously attempting to maximize his inflow and minimize his outflow. Exchange can only develop between strong ethnoenergetic fields. In egalitarian populations, where individual ethnoenergetic fields are relatively weak and small in scale, exchange is limited in scope. Flow between individuals is more properly described as sharing, with no conscious attempt to maximize inflow or minimize outflow (cf. Mandel 1970:49; Polanyi 1957:49; Harris 1971:238).

Exchange first appears in rudimentary form as barter between groups, with the local group forming a single ethnoenergetic field *vis à vis* other groups. As ethnoenergetic fields develop within populations, there is a development of barter between individuals, markets, and money. Money thus has a thermodynamic aspect as a symbol-facilitating ethnoenergetic exchange. It represents a socially acceptable claim on other people's labor.

There is a bedrock of violence underlying any exchange system. Violence, or the threat of violence, enforces the property rights without which exchange could have no meaning. Further, exchange is a form of competitive ethnoenergetic flow, occurring between hostile parties, one able to prevent access to certain use-values, the other acquiring by ex-

change that which would be too costly to acquire by force. Indeed, early trading expeditions are typically simultaneously trading and raiding expeditions, adapting their acquisitive techniques to particular situations (cf. Mandel 1970:82-85).

In populations where money exchange and markets are institutionalized there is a concomitant growth of commodity production, the production of use-values for sale in the market. It is, of course, only in capitalist economies that most use-values take the form of commodities, but commodity production undergoes an embryonic development within the womb of Asiatic and feudal societies. This embryonic development may be analyzed in three phases: simple commodity production, mercantile capitalism, and capitalist production. These phases are "ideal types" or models, and do not necessarily represent actual historical configurations.

Simple Commodity Production

Simple commodity production is an economic formation where: (1) the ethnoenergetic field of each producer includes both the means of production and his own labor; and (2) each producer is specialized, so that he sells the commodities he produces and buys other commodities on the market. In such a system, exchange occurs according to the formula:

C-M-C

Commodities are exchanged for money, and this money is then exchanged for other commodities which are consumed. Such a system is competitive, with each party attempting to minimize his effort and maximize his return, but the system operates in such a way as to prevent exploitation, provided that there is perfect competition, perfect knowledge of the system by all parties, and perfect mobility of producers in and out of various spheres of production.

Another way of saying this is to say that in a system of simple commodity production characterized by perfect competition and mobility between spheres of production, supply and demand will come into equilibrium where prices correspond to values. This may be seen if we consider the following. If a shoemaker, producing a pair of shoes in one hour and selling them for fifty cents, sees that a tailor is making a shirt in one hour and selling it for a dollar and a half, the shoemaker will stop making shoes and make shirts.

As this shift is repeated by innumerable producers, the supply of shoes

falls and hence the price rises, while the supply of shirts rises and hence the price falls, to the point where both, being produced in one hour of time, sell for one dollar. At this point, labor will have no incentive to shift to alternate spheres of production.

Of course, if there are restrictions as to skill, difficulty in acquiring tools or the mobility of labor, if the various kinds of labor are not equally distasteful, or if there is imperfect knowledge about the labor time and techniques of alternate spheres of production, the value-price ratio will be skewed. But a considerable body of ethnographic evidence confirms the tendency for labor to be exchanged for equivalent labor (see Mandel 1970: 60-65). Since equal amounts of energy are exchanged, a system of simple commodity production is basically mutualistic, not exploitative.

Of course, where there is imperfect competition and imperfect knowledge of the system, the system will become exploitative. If one man owns the only well, he can sell water at above its value, thus exploiting the buyers of water. A similar situation obtains among merchants, who hold a partial monopoly on the means of exchange, money, and knowledge of the workings of the marketplace.

Mercantile Capitalism

Implicit in the formula for simple commodity production is another, that of mercantile capitalism:

$$M-C-M$$

The merchant begins with money, exchanges this for commodities, and then exchanges these commodities for money again. Unlike the formula for simple commodity production, where the individual ends up with use-values, merchant exchange has no apparent justification: the merchant begins with money, which has no use-value, and ends with money. The sole motive for this form of exchange is if the second sum of money is larger than the first, as follows:

$$M-C-M', \text{ where} \\ \Delta M' - M = \Delta M > 0$$

In such a case ΔM is profit, a form of surplus (to the extent that the merchant is performing productive labor in transporting or storing use-values, he is functioning as a simple commodity producer; profit emerges only after such labor costs are accounted for). Capital is thus any store of value which tends to augment itself in the process of circulation. The exploitative nature of mercantile capitalism is seen when we consider

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that the outflow of energy from the merchant is M , the inflow is $M + \Delta M$.

Significantly, the surplus obtained by the merchant (and also by the usurer whose formula for exchange is simply $M-M'$) is merely transferred from elsewhere in the system (cf. Mandel 1970:84) — no new value is created by buying and selling. Mercantile capitalism is parasitic in nature; energy flowing to the merchant must come from somewhere, from either the producing class or from the old, feudal, Asiatic ruling class. There is thus a fundamental class antagonism, competitive in nature, between the rising bourgeoisie and the old, feudal, Asiatic ruling classes.

Capitalist Production

A further elaboration is seen in the formula $M-C_1+C_2 \rightarrow C'-M'$ in which a capitalist buys two kinds of commodities, C_1 , the means of production, including raw materials, and C_2 , labor. He then combines these in the labor process and creates new commodities, C' which he then exchanges for money M' . Unlike merchant capitalism, industrial capitalism does not require deviations of price from value, since the value of the commodities he produces is greater than the values of the commodities he bought. This results from the value-creating nature of one of the commodities he purchases, labor.

Labor, like other commodities, has a value, namely the amount of labor required to produce it. But labor, like other commodities, also has a use-value, namely the ability to create new value. If it requires six hours of labor to sustain a laborer and his family, this is the laborer's value, and the capitalist pays a wage equivalent to those six hours. But having purchased the labor, he wants to realize its total use-value, and therefore has the laborer work not just six hours, but a full day of ten, twelve, or sixteen hours.

Using our definition of exploitation, six hours of energy, in the form of wages, flows from capitalist to worker, but ten, twelve, or sixteen hours of energy, in the form of productive labor, flows from worker to capitalist, so that the surplus is four, six, or ten hours of energy. This surplus value is generated in the process of capitalist production itself, not simply in the sphere of circulation as is the case in merchant capitalism.

In contrast to systems of simple commodity production, prices in systems of competitive capitalism do not necessarily conform to values when the system is in equilibrium but the deviations from value follow lawful principles (see Sweezy 1956: 109-130).

As the above analysis shows, capitalism is not only a system of production but is also a system of exploitation, indeed, the exploitative aspects are the dominant ones. The motive force behind capitalist production is the drive for surplus value; if profit cannot be realized, production will cease.

Much more than precapitalist systems of exploitation which, whatever their ideological veil, are basically systems of plunder, capitalism is subtle, complex, and above all, hidden. Once money and markets become dominant in the economic life, fantastic things begin to happen. The individual in capitalist society is confronted not with naked force so much as a world of commodities and property rights, which take appearance in fetish form as use-values and prices rather than as embodiments of social relationships (cf. Marx 1965:71-83). The strength of Marxist economics lies in its ability to cut through the fetishism of the commodity world and reveal the hidden ethnoenergetic structure upon which bourgeois society rests.

It not only focuses on the reality of class exploitation, but also goes on to reveal the necessity of unemployment, of increasing exploitation, of secondary antagonisms within the working class, of periodic crises and depressions, and the ultimate transformation of the system into socialism, a return to an egalitarian ethnoenergetic system. This analysis is too lengthy to be considered here (I have tried to make a succinct statement of its most essential elements in Ruyle 1972; see also Sweezy 1956; Marx 1965). What I wish to emphasize, however, is that Marxist economics is thermodynamic in nature, a special form of ethnoenergetic analysis, albeit the most relevant form for understanding the contemporary world.

DIFFERENTIAL ETHNOENERGETIC CONSUMPTION AND SOCIAL PROBLEMS

The relevance of any theory incorporating Marxist economics to an understanding of the modern world and its problems is obvious. Nonetheless, I would like to elaborate somewhat on the importance of the study of ethnoenergetic flow patterns to the understanding of social problems.

As we noted in our introduction, all life is dependent upon the flow of energy through the biosphere. Human life is also dependent upon the flow of ethnoenergy through cultural systems. The human individual requires a continual inflow of ethnoenergy not only in the form of culturally acceptable use-values — tools, clothing, shelter, ornaments, and

artistic objects, as well as food — but also in the form of social interaction, ceremonial ritual and religious activities, and so forth. Recognition of the human dependence on this inflow leads to a recognition that a reduction of the inflow is likely to have deleterious results for the individual or aggregate of individuals affected. And indeed a considerable body of data indicates that there is a high correlation between poverty (i.e. reduced ethnoenergetic inflow) and crime, punishments for crime, high rates of infant mortality, high incidence of disease, mental disorders, and so forth.

What is true within national societies is also true on the international level. Considering the problem of economic underdevelopment, we know that for economic growth to occur, surplus must be devoted to the building up of an industrial structure and infrastructure — the construction of railroads, highways, schools, etc. (cf. Baran 1957). Yet the flow of capital, a form of ethnoenergy, has always been from the now underdeveloped world to the developed world (Marx 1965:713-774; Magdoff 1969), a process which certainly facilitated industrial growth in the advanced nations but which also led to the "development of underdevelopment" in the Third World (cf. Frank 1969).

Thus the problems of paramount concern in the contemporary world, both within national communities and in the international community are illuminated by the perspective of ethnoenergetic analysis. More than this, ethnoenergetic analysis points the way toward a resolution of these problems. If these social problems have their roots in particular patterns of ethnoenergetic flow, then they can be resolved only by a restructuring of these ethnoenergetic flow patterns.

CONCLUDING REMARKS

In this essay, I have argued that a thermodynamic approach to the analysis of sociocultural systems illuminates many of the problems of paramount concern in contemporary anthropology — the origin of man, the origin of social stratification and the state, the nature and significance of the modern world. In the course of the discussion, I have naturally taken definite stands on each of these issues, but adoption of a thermodynamic perspective does not necessarily commit one to the particular views offered here. It does, however, provide an objective, operational data language for investigating and debating these issues.

Finally, adoption of an ethnoenergetic perspective does not obviate the need for other perspectives. To appreciate the richness and complexity

of sociocultural phenomena it is essential to take a dialectical approach, to turn the subject around and view it from a variety of perspectives. The parable of the blind men and the elephant is not merely that vision is desirable in sociocultural analysis; each of the blind men, within his limits, has his own valid and important perspective on his selected aspect of the elephant and it is important that these be not lost. Ethnoenergetic analysis, I submit, is a way of looking the elephant in the face (although some might suggest that it looks up the other end) and bringing the limited perspectives of the blind men together into an integrated and meaningful whole.

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