COMMITTEE I
Unifying Principles in Science

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ENTROPY AS A UNIFYING CONCEPT

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Entropy as a Unifying Concept

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1. Introduction

The word "entropy" is currently used in a wide scope of various fields extending from thermodynamics to information theory, biology, economics, anthropology and thought. There is a critical idea against such an overuse of the notion of entropy. There are, to be sure, often some instances in which the notion of entropy is easily borrowed without any examination. However, I don't mean that all such overuses are misuses. In some cases, a new point of view has been successfully introduced in social sciences, and humanities by applying the notion of entropy.

An appropriate use of words and notions based on a clear definition must be important especially in the natural sciences. However, if the words have come to be effectively and conveniently used outside of the natural sciences (for example like "energy"), should it be dismissed as an inexact use? Words have both conservative and progressive aspects by nature. A new use of words provides a possibility to renew the perception of the world through the transformation of paradigms. If it is possible that the word "entropy" contributes to the creation of a new concept of the world, it should be effectively used outside the natural sciences. It is not until the word is widely applied in various fields and a unifying concept is found that "unity of the sciences" may be accomplished.

In this article I should like to review briefly how the notion of entropy has been used so far in various fields, including my own contribution toward it. It will be understood that they are not irresponsible applications of the notions, but they have reasonable grounds. Then it will be possible to find underlying concepts valid

for them.

2. Information Entropy

As is well known, information entropy H introduced by Shannon in 1948 is given by the equation

$$H=-\sum_i p_i \log_2 p_i \qquad (1)$$

where Pi is the probability of the ith phenomenon. The more uncertain the phenomenon gets, the more the quantity grows. Therefore it is defined as a quantitative measure of uncertainty, unprobability, the degree of disorder and diversity. Why is such a general definition of entropy related with information? In this respect Watanabe's [1] argument is instructive. He called

$$\phi(p_i)=-\log_2 p_i$$

"surprise function" because the quantity increases more and more as phenomenon unlikely to occur actually occurs and besides it satisfies psychological independence against independent phenomena, namely the additional nature of surprise. The mean value of this surprise can be regarded as the degree of ignorance I of phenomena. The more we are ignorant of it, the greater the surprise is. Thus

$$I=\langle\phi(p_i)\rangle_{\text{average}}=-\sum_i p_i \log_2 p_i \qquad (2)$$

is given.

By the way, information can be regarded as a response to a situation where a particular phenomenon occurs through the process of trials. If, as a result of trials, we have come to know a certain fact (particular $p_j=1,\ p_{i\neq j}=0$) information defined in such a way is described in the following formula:

information= $$I-I(p_j=1,\ p_{i\neq j}=0)=-\sum_i p_i \log_2 p_i \qquad (3)$$

As the equations (1) and (3) are equal, entropy can be regarded as information. However as is clarified in the above-mentioned observation, all "free" information is not entropy. Information defined as entropy is defined as a result

of selection. When phenomena are equal in their probabilities, the quantity is equal to the number of alternatives in the process of arriving at selection.

3. Entropy in Thermodynamics

It was Clausius who first proposed the notion of entropy in 1865. He came up with this important notion in the research on the efficiency of thermal engines. Later Boltzmann laid the statistical foundation for the notion. Boltzmann's notion of entropy is in the same form as the equation (1) except for invariables. The difference lies in the fact that as to entropy in thermodynamics the number of phenomena is equivalent to the extremity, namely infinity. There emerges the law of the increase of entropy which is called the Second Law of Thermodynamics as a law of huge numbers. On the other hand as to information entropy, except for special cases, such as of detailed balance, - roughly speaking for instance, disorder of rooms - there is no principle of increase of entropy in this sense. However, whether in phenomena in information theory or in molecular motion in thermodynamics, entropy is a constant measure of uncertainty and disorder. In this sense it is quite natural to use the word "entropy" in both fields.

Entropy in thermodynamics here described as S, which means the degree of disorder of particles within material, is described by the following equation:

$$S=\frac{Q}{T} \qquad (4)$$

Here, Q stands for the amount of thermal energy going into and out of material and T, the temperature. It is quite natural that entropy stands in proportion to heat. When heat is given to material thermal motion within material gets stronger and, as a result, the degree of disorder increases. The reason why Q is divided by T is to normalize the influence of this heat. So internal energy in material is in proportion to temperature, the influence of heat can be considered in proportion to internal energy when Q is divided by T.

Suppose the temperature of a high-temperature object is described as T_1,

while that of a low-temperature object is T_2. Consider a case where the two objects make thermal contact. If the amount of heat Q is transformed from one object to the other, the change of entropy dS is described as follows:

$$dS = -\frac{Q}{T_1} + \frac{Q}{T_2} = \frac{T_1 - T_2}{T_1 T_2} Q > 0 \qquad (5)$$

It follows from this equation that the natural phenomenon of heat transfer from a high-temperature object to a low-temperature object is accompanied by increase of entropy. This is a typical example of the principle of increase of entropy. According to the Second Law of Thermodynamics, entropy within isolated systems never decreases. It always continues to increase, and it arrives at the state of thermal equilibrium. As the principle of increase of entropy is a natural phenomenon, it exists everywhere. Such phenomena as the transformation of dynamic energy into friction heat and diffusion of molecules into space are typical examples. In isolated systems, it is impossible to reverse this movement. What is possible is just to decrease entropy production to a minimum extent. For this purpose it is necessary to slacken the movement as much as possible so as to bring it close to the state of equilibrium.

4. Entropy in Open Systems

While entropy in isolated systems one-sidedly increases, in many instances in our environment entropy decreases along with the increase of the degree of order. One instance is a living creature and another is a process of industrial production. They are not inconsistent with the second law of thermodynamics at all. As they are phenomena in open systems, entropy can decrease. An open system is a system where a give-and-take action of both energy and material occurs between the system and the outside world. Systems where only energy is engaged in the give-and-take action are called closed systems. When entropy within open systems is indicated as So, it is expressed by the equation of adding entropy generated within it (here indicated by S) and entropy going in and out of the

outside world (here indicated as S_e): $S_o = S + S_e$ (6)

As S is equivalent to entropy within isolated systems, the amount of increase is described as $dS \geq 0$ according to the equation (5). As $dS < O$ is given so that entropy within open systems decreases, the equation should be

$$dS_e = dS_o - dS < 0 \quad (7)$$

It means that greater amount of entropy than the counterpart generated within systems should be released toward the outside world.

Living creatures, while maintaining order, grow by emitting a greater amount of entropy than the counterpart taken from food and generated within them. It is not necessary to think that living creatures take "negentropy" as Schrödinger did. They are emitting a large amount of positive entropy in such forms as excretion, perspiration and febrility. Factories are a typical example of open systems. They are emitting large amounts of waste and unnecessary heat in order to produce highly ordered products while taking such "food" as material, oil and water. Both in the case of living creatures and factories, water flow plays a very important role in discarding entropy. In societies before the Industrial Revolution, emitted entropy was sufficiently absorbed within the cycle of nature. However, in the modern society of industrialization, such a large amount of entropy has been accumulated due to the development of huge science and technology and the top priority given to efficiency, that it cannot be absorbed within the cycle of nature.

5. Economics and Entropy

5.1. Dissipative Structure of Industrialized Societies.

In non-equilibrium open systems, dissipative structures are typically seen in living creatures, in laser and structures of flows. Highly-developed industrialized societies can be regarded as possessing a kind of dissipative structure. After the formation of non-equilibrium state far from nature due to high production

technologies, products dissipate through consumption and obsolescence. On top of that, savings are fedback to production as investment. Thus the system continues to expand. The cycle of production, consumption and investment brings about an economic growth, but at the same time such problems as pollution and environmental distruction occur due to the emission of entropy. Keynesian policy is regarded as a policy to maintain and expand the dissipative structure by promoting investment and consumption. I would like to show in Appendix I my analysis of the economic process of industrialized societies from the viewpoint of dissipative structure.

5.2. Myth in Economics

Georgescu-Roegen[2] sharply pointed out a myth in established economy from the viewpoint of entropy. He pointed out that whether in modern economics or in Marxism economics, established economics is based on a presupposition that the process of production and consumption, which uses definite amount of natural resources, is eternal. Although the limit of growth was reported at the Club of Rome meeting, he claimed that growth itself is a "myth". Theories in economics are based on the principle of conservation and the principle of extreme values on the basis of models in dynamics. In these theories scarcity of natural resources is ignored, autonomous and circular flow of production and consumption is presupposed, and one-way directivity and irreversibility of time is not considered. Distribution of resources in the same generation or at most, several generations is considered. It is quite natural that resources are consumed more in previous generations only in the market mechanism. As growth is given the top priority, GNP is the only index which consist of a mere addition of heterogeneous things or values. Despite the fact that pollution is irrecoverable and no costs should be involved in it, industries which create pollution contribute to GNP. Soon an "entropy nation" where costs for gaining a definite amount of resources are equivalent to costs for consuming resources will emerge.

Georgescu Roegen, though pessimistic about the future of mankind, has made various proposals. One proposal is the gradual decrease of population so that man can live only by organic agriculture. Although there are instructive points in the proposal, is it possible for man to return to the primitive state? As long as there are natural resources and man's desire is inherent, it will be impossible to go back to the original state (because it is impossible that all men will become saints like Buddha).

5.3 Entropy and Analogy of Price

By making an analogy with entropy in thermodynamics, I would like to interpret Fisher's formula, one of the basic formulas in economics. By indicating the price as P, the amount of currency as M, the rate of rotation as V, and the amount of dealings as T, the formula will be described as follows: $P=\frac{MV}{T}$ (8)

The formula means that while the price is in proportion to the amount of the flow of currency, the actual value is determined by normalizing it by the amount of dealings.

At first glance, the formula is similar to equation (4). When we compare the flow of currency with the amount of heat and the amount of dealings with temperature (internal energy), price corresponds to entropy. In fact, it is possible in some case to regard price as briskness of economic activities, or the degree of disorder. However in economy, there is no general law like the principle of increase of entropy. In economic activities money (heat) doesn't always flow from areas abundant in dealings (high temperature source) to areas poor in dealings (low temperature source). Therefore the above-mentioned analogy is quite restricted. However, it is interesting that inflation in economy is analoguous to the Second Law of Thermodynamics.

6. Law of Entropy and Eastern Thought

Higher efficiency in industrialized societies and the idea that speed comes first has brought about the abuse of resources, natural destruction and pollution, and ultimately spiritual strains. The earth is moving toward greater entropy. Although it is very difficult to reverse this tendency, it is possible to somehow suppress this speed. The idea can be summarized in the following three points from the viewpoint of the law of entropy.

(1) to save resources and energy, namely to get eliminate waste

(2) to produce slowly, namely to avoid over-work

(3) to think things from a larger perspective; to avoid giving priority to local considerations: for instance, in designing production installations, as well as assessment, disposal and recycling of wastes should be considered in addition to improving the speed of production.

The above-mentioned idea is the same with the idea of Total Quality Control (TQC) which aims at removing overwork, waste and inconsistency. The idea of cutting down on entropy is, after all, rather common. From the argument on entropy in open systems, the following points are important.

(4) In order to activate systems, wastes are discarded into the outside world. (The importance of discarding wastes in water flow)

(5) The generation of entropy is restricted to a minimum degree by dividing systems into smaller units. For instance, living creatures grow by going through the process of cell division.

The above-mentioned five ideas for suppressing generation of entropy are completely contrary to the age of high economic growth, but are suitable to the age of low economic growth. They are also consistent with Eastern thought which, based on the idea of removing contradictions and classifications, depends on nature regarded as in the state of chaos.

In Buddhism there are many double-meaning expressions which unify two completely opposing ideas from a higher standpoint. The law of entropy is, however, most consistent with the philosophy of Lao-tze and Chuang-tze [3]. Their basic point lies in such ideas as "don't try to do things unnaturally, leave them as they are. It means "abide by tao", which constitutes the law of nature. The five points mentioned above are expressed in their thought. I would like to show typical words by Lao-tze.

(1) "Learn to be satisfied with things as they are". "Save as much as possible".

(2) "Don't try to do things unnaturally. Just let them be." "Those who stand on tiptoe will stumble. Those who stride cannot proceed."

(3) " The Heavenly net is huge. The mesh is loose but loses nothing." "Ruling a large country is not so different from simmering small fishes." (important is to have a holistic perspective)

(4) "The highest goodness is like water".

(5) "Small country and few people." (recommendation of decentralizing organizations into smaller units)

7. Culture and Entropy

In cultural anthropology and cultural semiology, the word "entropy" is frequently used. In most cases, it is used in the sense of "chaos", "disorder", "things which can't be expressed in symbols". It has nothing to do with the word employed in thermodynamics. However, this cannot be put away as haphazard usage, and it has a qualitative relation with information entropy. I would like to explain the grounds for this statement.

Why have cultures and civilizations come into being and developed? According to cultural semiology, human beings have become an "excessive" existence expelled out of nature, namely an existence driven by "desire", just because they have acquired language. For such human beings, nature is none other than chaos. Therefore it is necessary to symbolize nature which is a continuum in order to sectionalize it. Human beings, by inventing instruments as an extension of human organs, have brought about technology and civilization (Homo Faber). However the world expressed in symbols is not the whole world; parts which are not sectionalized or the excess are driven into "sacred territory" as "taboos". The diffusion into the world of symbols into the prohibited region is expressed as "entropy" in theories of culture. "The unusual" expressed as "entropy" pose a threat against "The usual". They are regarded as "chaos" or "disorder". As it is impossible to suppress it, "entropy" must be temporarily emitted in the form of rites of passage, festivals and carnivals.

The fact that culture is based on the presupposition that the "probability" of the parts removed by sectionalizing the originally continuous world into discontinuous parts should be zero, signifies that "information entropy" for phenomena in the world defined in the equation (1) is being artificially lowered. However, as excess parts do exist, parts that cannot be absorbed in festivals, etc. will be emitted in the form of violence or sexual activities. Man cannot breathe deeply within a solidly set framework. When information entropy in the world is artificially lowered, it is unavoidable that entropy forced out of the framework will be released somewhere. This is the fate of culture.

8. Cosmology of Bali Island

It is often said that Bali Island has a culture with cosmology. When we visit there, we get the impression that all aspects of human lives are united harmoniously. Nature, religion, festivals, art and agriculture are correlated with each other on the island. In this sense, culture on the island is coherent and low in entropy. I have analyzed the Bali culture from the viewpoint of information entropy . Professor Masao Yamaguchi who teaches cultural anthropology at Tokyo University of Foreign Studies has summarized my analysis with proper appendices [4] (see Appendix 2 of this article).

9. Conclusion

From the above-mentioned considerations, concepts of entropy can be largely classified into two. One concept derived from ideas in thermodynamics is based on two themes: (1) the principle of increase in entropy and the minimization of its generation and (2) establishing an order within open systems against the principle. Concepts of entropy which appear in thermodynamics, biology, economics, and Eastern thought belong to this. The other concept derived from information theory appears in cultural semiology and anthropology. To sum up, while a culture which works toward establishing an order tends to lower information entropy, anti-culture functions toward diffusing culture into chaos as a counterforce against order. Therefore it is necessary to emit entropy so produced periodically through festivals and the like for the maintenance and activation of culture.

However, the two concepts have something in common. Entropy in thermodynamics is based on information entropy in the sense that the former extends the number of phenomena in the latter to infinity and the former is gained by introducing the principle of detailed balance in the latter. Certainly the Second Law of Thermodynamics is a stochastic phenomenon of diffusion, and the formation of orders in living creatures is a result of the activity of genes, and self-organization by the emission of entropy in open systems. On the other hand,

the cause for increase of entropy in culture lies in a psychological factor such as man's death instinct. However the two concepts are common in the following three basic facts: (1) destruction of order proceeds toward a situation of equal probability, (2) establishment of one sided orders heightens the probabilities of specific phenomena, and (3) the existence of motion and the contact with a new degree of freedom cause irreversible increase in the entropy of the system.

Lastly, in extending the concept of entropy toward social and human sciences such as economics, Eastern thought, and cultural anthropology, it is inevitable to consider problems of values. The point is whether or not we should approve of a specific economics, thought and culture which may suppress the increase of entropy. It will be necessary to formulate a "Unified Science" which stands on a global perspective in order to objectify the judgement on the above-mentioned point.

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1) S. Watanabe: Knowing and Guessing, pp 8-10, Wiley, New York (1969)

2) N. Georgescu Roegen: Economics of Natural Resources-Myths and Facts, Toyokeizaishinpo-sha (1981)

3) M. Takatsuji: Lao-tze and Entropy Law (in Japanese), Goma Publishers (1983)

4) M. Yamaguchi: A View Point of Cultural Anthropology (in Japanese), pp 134-139, NHK Publishers (1985)

Appendix 1 Economic Process and Dissipative Structure (1) Economic Process

Economic process is a process of producing goods and service by using production elements such as resources, labor and technology, and of distributing produced goods and service, consuming a considerable part of them, and reproducing goods and service through investment. In the process, currency plays, as a mediator of distribution and exchange, a vital role for carrying out economic activities without any difficulty.

This does not mean that the economy is closed; there is the so-called "external economy", which means that economic activities such as production and consumption bring gains and losses to a third party's economic activities without going through the economic mechanism of markets on the whole. Usually, more losses are seen than gains. This particular case is called an "external bad economy". A typical example is pollution and natural destruction, but all kinds of mental discomfort caused in the process of economic activities are also included.

I would like to describe the above-mentioned economic process in Figure I by partly using terms in physics, and to re-explain it using these terms.

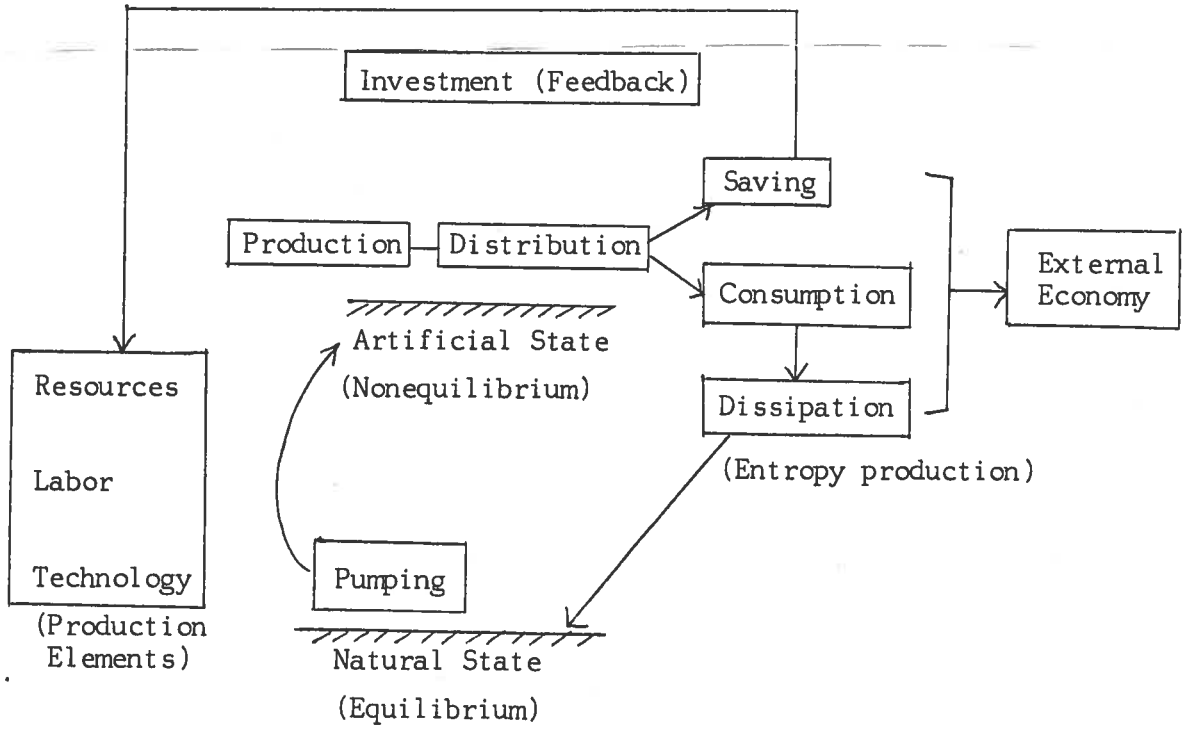

Figure 1. Thermodynamic description of the economic process

In the beginning production elements are acquired from nature, the natural state or world of equilibrium is transformed into an artificial world far from nature. In societies with only low-level technology, the artificial world was not so distant from nature and was near equilibrium. However, with the arrival of the age of technological innovation after the Industrial Revolution, the artificial world has been transformed into a nonequilibrium state remote from nature. Raising an equilibrium state into a nonequilibrium state is called pumping (input). As the nonequilibrium state is characterized by high energy unlike the equilibrium state, it is necessary to throw energy into the latter.

Products, after being produced by using production elements, are distributed (exchanged) and consumed. Consumption is equivalent to dissipation in physics, because products are exhausted, destroyed and diffused. Dissipation appears also in the process of production in the form of refining resources, processing parts and consuming labor. Dissipation, according to the Second Law of Thermodynamics, increases entropy. On the other hand, part of products are saved and fedback to input as investment. Reproduction is thus carried out, and the economy grows.

Economic systems are open. After material and energy are pumped in from an outside system, they are dissipated in different forms to the outside world. However, when economic systems grow too large, the outside world is internalized and problems such as scarcity of resources and pollution appear.

2) Dissipative Structure of Economy

In an open system a structure of flow may be formed. It is called "dissipative structure." Some conditions are necessary in both aspects of energy and entropy for such a structure to be formed.

As to the aspect of entropy, the emergency of this structure means that

some form of order (negentropy) appears. That is to say, entropy in the system must diminish in order for the structure to be formed. However, within an isolated system there is the principle of increase of entropy. Therefore, entropy greater than the amount decreased must be discarded to the outside world so that entropy within the system decreases. It goes without saying that emission of entropy is brought about along with the dissipation of energy and materials.

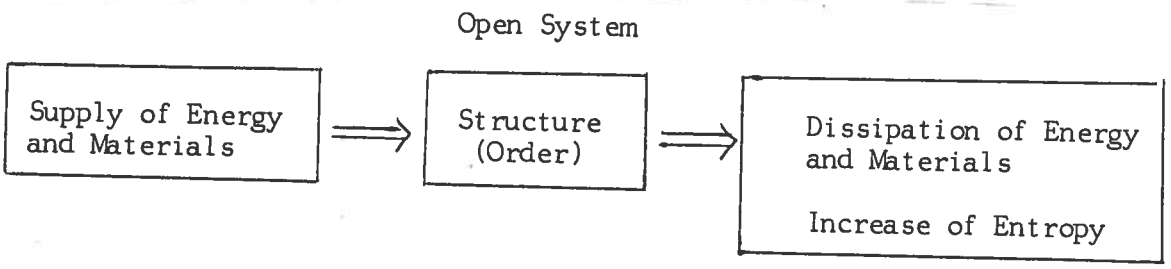

Figure 2. Formation of the structure of open systems

Secondly the amount of energy and material input should be greater than that of dissipated energy and material inherent in the system, because otherwise structure thus formed will gradually diminish due to lack of energy. In terms of economy, the amount of input energy and material should be greater than the total amount of dissipation caused in economic processes.

Concretely speaking, the amount of production should be larger than that of consumption and depreciation. The excess is saved and used for enlarging the structure in the process of producing capital goods (investment goods).

A dissipative structure is formed essentially in nonequilibrium open systems. It is not until the symmetry of the equilibrium state is destroyed that a dissipative structure is formed. But when the system is brought back to the equilibrium state, this structure disappears. The more remote it is from an equilibrium state, the more sonspicuous features a dissipative structure displays. If pumping is sufficient flows will be greater and more vigorous. A structure can take various shapes. It sometimes takes a periodical character both in time and

space.

When the pumping gets weaker, a structure will become unstable. It will be transformed into a different structure with weaker flow. In the process of structural transformation, a system is distorted and the flow is temporarily thrown into disorder. For example, the dissipative structure of highly industrialized society, as the result of weakened pumping due to the oil shock, reduced the system into a structure with smaller flow. At the same time in the process of transformation, the world economy was thrown into a big turmoil. "Dissipative structure" is a very suitable term to express the present reality. This is because dissipation itself determines the degree of activation or liveliness of the system. The more active a structure becomes, the more dissipative it gets. Even if the amount input increases, economic activity will remain stagnant when products merely accumulate. It is not until the increased portion is either consumed or invested to purchase capital goods that the economy begins to grow.

On the other hand, if dissipation does not decrease according to decrease of input, the system itself will be destroyed. When the input decreases while dissipation continues, a company will go bankrupt and a country will accumulate debt. Dissipation, as a rule, decreases up to the point where it balances with the input.

3) Mechanism of Economic Growth

The factor which brings about growth is increase of productivity, which of course is a result of investment. As is shown in Figure1, expanded re-production is carried out when savings are fed-back into investment. Investment is nothing other than the purchase of investment goods (capital goods). Since production means production of consumer goods and capital goods, it is understandable that

an amplifying mechanism of the positive feeback type is internalized in the economic system.

However growth is not actualized only by increasing the amount of production. If a considerable part of products is not dissipated in the process of consumption, the structure of flow will never grow. Therefore the important issue is to adjust production and consumption, namely total demand and total supply in a Procrustean way.

The market mechanism itself does not possess a capability to adjust production and consumption, or total demand and total supply to a given quantity. Even if Walrusian "balance" is secured, there is no capacity to determine the size of markets. When production is excessive, the economy will fall into a recession. When consumption is excessive, inflation occurs. The market mechanism is a cause of inflation and recession, but it never provides any cure; a macro-economic policy of finance is demanded to prevent them. Demand should be stimulated according to the increased amount of production so that the economy can grow. In fact, it was to the great depression of America that Keynesian policy was first applied. At that time, by the introduction of the Ford system of conveyors, productivity increased considerable, and after that the need for labor was reduced. If such a situation continues, more people will lose their jobs, while products remain unsold, because purchasing power is insufficient. Factories cease to operate and banks are forced to close.

Thus, the government adopted a policy of expanding total demand by increasing the national expenditure. As a result of increased employment and individual income, demand also grew, signifying that the economy had recovered from the recession.

Keynesian policy aims at balancing total demand and total supply. It can be utilized both as a policy of expanding or reducing total demand. However, in growing economies, only a policy of expanding total demand has been adopted.

During a growth period, we see a constant trend of technological innovation. As technological progress improves productivity, consumption should grow accordingly. When the cycle of production, consumption and investment functions in the form of positive feed-back, the economic system expands. A typical example was the high growth period of 1960's in Japan.

Keynesian policy may be called a "dissipation policy" in the sense that it promotes demand of products. Demand exists not only for consumer goods but also for investment goods. However, investment goods dissipate in the long run repayment, and investment promotes consumption.

Another way of promoting dissipation is advertisement and publicity. This is a microeconomic policy of controling demand, carried out by each enterprise. Each enterprise stops to grow when production becomes excessive. Management will fall into crisis, and therefore products should be sold by stimulating or newly creating consumers' desires. In this sense the advertisement industry may be called a "dissipation industry".

Both "dissipation policy" and "dissipation industry" function to absorb expanded production and foster the economic system, although they allow the production of large amounts of entropy at the same time.

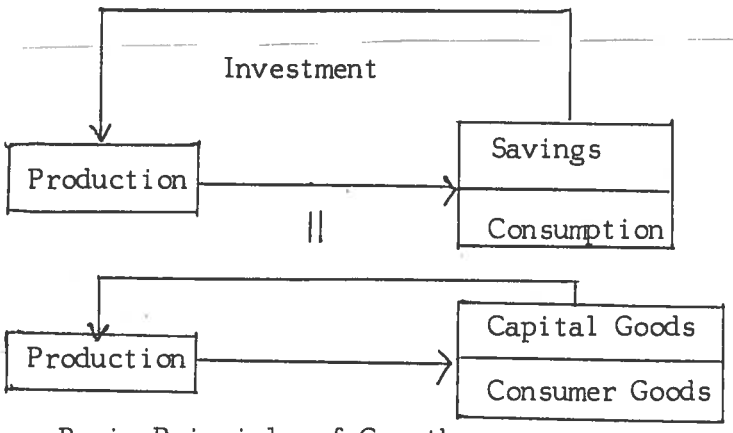

Figure 3. Basic Principle of Growth

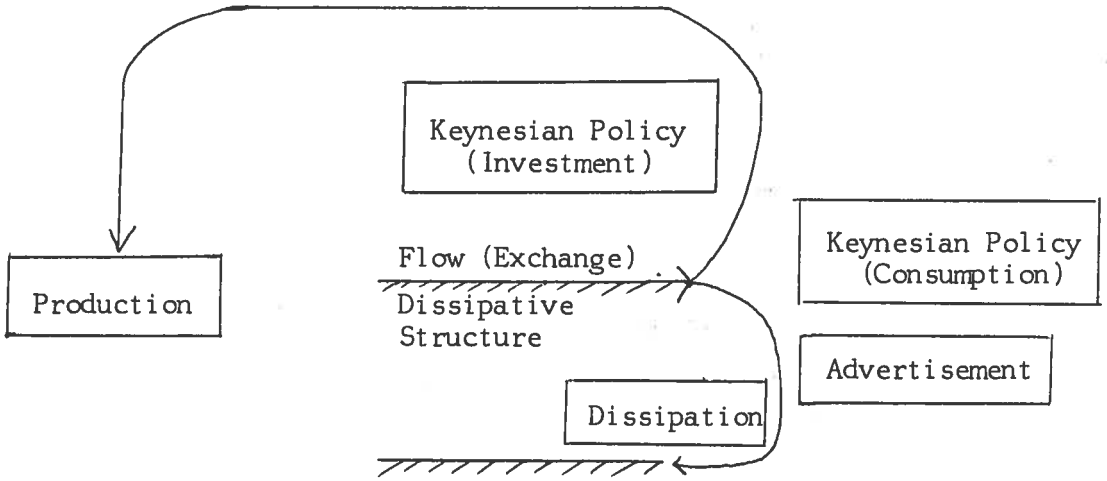

Figure 4. Dissipative structure of a growing society

Appendix 2. Social Structure of Bali Island and Its World View (4)

It is said that the inhabitants of Bali Island experience frustration the least in the world. This does not mean that they are wealthy nor that they never meet with unhappiness, nor that they lack the daily hardships of other peoples in the world.

The life style of the inhabitants has been the object of observation for scholars and researchers in various fields. One of the best known researches was made by Margaret Mead and Gregory Bateson concerning Balinese child raising. Particularly, Bateson, on the basis of this research and his preceding study on the Jatmul tribe of New Guinea, developed concepts such as the generation of schizoprenia and the double bind which have exerted a deep influence on today's post-modern ideas.

Another unique observation is a study made by M. Takatsuji (3) to the effect that the Bali Island is the last paradise, not from the view point of anthropology nor psychology but of thermodynamics.

Takatsuji says that everything concerning man's life on the island such as nature, religion, festivals and agriculture is harmoniously united and people are living a peaceful and fulfilling life even if they are poor. To put it differently, the island is characterized by a low-entropy (inactive negative energy) society. Entropy is a term derived from the Second Law of Thermodynamics. It is explained as an index of uncertainty, disorder and ambiguity. According to him, in the greater the state of disorder, the higher the entropy, while the higher the state of order, the lower the entropy. In other words, while entropy is low in a state of certainty, it increases in a state of uncertainty.

There is some opposition to apply a term derived from thermodynamics to man's spirit, because the term entropy, when applied to the human spirit, tends to be mistakenly interpreted simply as frustration. However, frustration is a result of

the phenomenon. Entropy can be regarded as synergism between the environment and the spirit. Although it can be expressed as something like negative energy, this can also be interpreted in various ways.

Takatsuji emphasizes in response the German mathematician Hermann Weil's idea that beauty cannot be perceived in phenomena which do not contain a kind of asymmetry, that symmetry is not the only factor which defines beauty. By applying this idea, he maintains that low entropy cannot exist where excluding all entropy has been removed. The question is where entropy should be allowed.

By applying the criterion of beauty, Takatsuji claims, "Imbalance (disorder) in parts generates beauty as a whole, to make it a first-class work of art. In other words, when creating an order for a whole, partial disorder is unavoidable." Such an idea is also valid in negentropy. This is the idea that entropy, when it moves in the positive direction by providing a context where it works positively, is transformed into negentropy (the positive as the negative of the negative).

A similar idea was advocated in the aesthetics of the Prague structuralism. According to this theory by J. Mukajovski, beauty, by including some things rejected as poor taste in the former age, is reinvigorated. What is called "shift" or "fluctuation" in the argument of today's post-structuralism is already included in the idea of negentropy.

Takatsuji contends that even if some aspects of phenomena are incovenient (namely, in the state of entropy), entropy as a whole is maintained in the low level on condition that man's spirit is united by the order of nature. For example, such customs as compromise and "nemawashi (or spade-work)" function to keep entropy low as a whole although one of the parties concerned may have some dissatisfaction. On the other hand, within the individualistic rational society of the western-type, partial confrontation among individuals is persued on and logically solved, entropy is partially low but on the contrary entropy is high as a whole.

On Bali Island, dogs are strolling around everywhere. It makes us feel a bit strange, but on the island, dogs are absorbed into the whole eco-system. According

to Takatsuji, even mentally disordered persons are not ilienated there. It sometimes happens that people go and see them to discuss problems that occur. Their answers may be nonsensical, and an this view, entropy might be high. But the custom functions as a means of keeping entropy low, because some expectations of the Balinese are satisfied through the process. Societies that anthropologists select as a subject of their researches are abundant in such elements. However, as anthropologists still tend to explain such societies from the perspective of Western logic, they still do not have a principle or a model for explaining such phenomena from a unified viewpoint.

In societies where ways of thinking based on western-type reason are dominant, only efficiency of material production is regarded as important. Therefore elements unsuitable for this purpose are excluded and left as they are in the midst of disorder. As a result, Takatsuji contends that entropy in the whole world including both the spiritual and the material is rather high.

In the world view of the Balinese there is no absolute evil. According to their idea, the world is purified by the interaction of the two forces of good and evil.

A drama entitled "Rangda" which is well known in Bali, is a story about a community ritual centering on witches. Barong, the good beast and Rangda, the queen of witches are two major figures that appear in the drama; Barong takes the shape of a masculine beast similar to the Japanese lion figure of New Year's Day in Japan, but its attitude is as gentle as a woman. On the other hand, Rangda appears as a widow but her character is as fierce as a beast. Each reflects in itself the other's character. In the Barong's dancing, Young people stand against Rangda in an abstracted state of mind with daggers called Kris in their hands. In these daggers it is said part of their soul resides. At this moment, they see in Rangda an image of their own mothers who are sometimes kind yet sometimes strict. The Youth, by standing up half-mad against Rangda, can externalize and

release dark pathos accumulated in themselves. As a consequence, what has begun as evil is ultimately turned into goodness.

Takatsuji emphasizes that the Balinese utilize negative elements by taking them in as part of the universe. He quotes the former mayor of the artist village Peliatan which is as popular as Ubud, who says that man is given power because of the existence of evil. It means that the Balinese know how to use entropy as a source of power by turning it into negentropy.

The dichotomy as a source of a world view is well known in Bali also. Taking Gunung Mountain as an axis, a contrast is pointed out between the mountain and the sea. The contrast has been expanded to express such concepts as "good fortune vs ill fortune" "day vs night" "male vs female" "birth vs death" "east vs west" "up vs down" "sacred vs evil".

However the dichotomy is relative, not absolute.

A dichotomy forces men into an irritating confrontation. Even the Balinese will accumulate frustration if they are confined in a single vertical system. But they have developed a technique to nullify chaos that appears in their spirit. In this sense, the word "sophisticated" can be applied to them.

There are many clubs with different purposes in Bali. One man belongs to more than one club instead of just one. Thus one is related to various different groups by dividing his identity. When one is travelling on a usual sight-seeing route, one sees people cooperating with each other to accomplish one task at a meeting place. There are organizations for cultivating a rice paddy, organizations to hold a festival, organizations for ceremonies, organizations of relatives, and organizations of castes. Relations between organizations and individuals overlap and interrelate to form a multiple-layer structure. Their ranks differ from one organization to another. Therefore it is possible that while a man is a leader in cultivating a rice paddy, the same man is the lowest in the rank of ceremonies. The Bali people advocate Hindu, and castes are the foundation of social structure.

However, it is not that only people in the higher class of castes are respected. Each man is respected in the various organizations depending for example on his ability to dance or to play the Gamelan.

This means that the Balinese can act out different selves in the respective organizations. Each does not restrict himself to one self. In contrast to Bali, Japan after the Meiji Restoration has succeeded in separating the individual career from the family status. However instead of family status, educational background became dominant as a single criterion of social strata and order according to which identity of individuals is determined. If a man stumbles within this order, his identity is destroyed. Thus it follows that the so-called "examination hell" and society of "careerism" function toward expanding entropy and are unsuitable to transforming entropy into negentropy. It seems much more clear that a large part of the suicides of the Japanese, unexpected crimes, school violence by lower-grade pupils, family violence and mental disorder have been caused by the single hierarchy of the Japanese society in comparison with the multiple layer society of Bali Island.