HETEROGENISTICS AND MORPHOGENETICS:

Toward a New Concept of the Scientific

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Until recently, questions regarding intra-group heterogeneity in sociology and physiology, intra-cultural heterogeneity in anthropology, and intra-specific heterogeneity in animal behavior were *mainly* confined to one or several of the following conceptual formulations: (1) statistical distribution around the mean; (2) variations which have no particular interactional advantage; (3) division of labor serving the whole; (4) dominance relations, pecking order, hierarchical stratification; (5) reciprocal interactions between heterogeneous individuals who *maintain* equilibrium or periodical cycles. From the epistemological point of view, the first was based on a *homogenistic* epistemology, the second on an *independent-event* epistemology, the third and the fourth on a *hierarchical* epistemology, and the fifth on a *homeostatic* epistemology.

Recent advances in several fields of science indicate that the basic principle of biological and social, and even some physical processes, is *increase* of heterogeniz*ation*, symbiotiz*ation* and pattern-*generating* due to differentiation-*amplifying reciprocal* causal *loops*. This has led to the emergence of a new type of epistemology: a *morphogenetic* epistemology. This epistemology makes us ask new types of questions regarding heterogeneity: (1) the process of non-hierarchical symbiotization among heterogeneous elements; (2) interaction network as contributing to further heterogenization and symbiotization rather than maintaining the status quo; (3) generating of new needs and goals rather than regarding the existing culture, society, its components, structure and function as inherently satisfactory. The purpose of this article is to discuss the genesis and the application of this new epistemology.

Heterogeneity can no longer be regarded as accidents, errors, deviations from the average, or necessary evil. Heterogeniz*ation* is basic to development, organizational sophistication and evolution. At the same time, evolution can no

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longer be regarded as having a fixed goal. Several systems with the same initial conditions and the same network connections tend to develop in *different* directions because very small kicks within the system can be amplified by the network.

Recent developments in "hard" science, particularly non-equilibrium thermodynamics in physics and differentiation-amplifying reciprocal causal models in mathematics and engineering, have produced a cosmology in which reciprocal causal interactions create new patterns, generate heterogeneity and structures, and increase the amount of information. Such processes were impossible or inexplicable under the theory of equilibrium thermodynamics and Shannon's information theory. More than a theoretical innovation, this change is an epistemological restructuring. Considering that the Aristotelian logic, in prohibiting "circular arguments," prevented conceptualization of reciprocal causal models in scientific research for over two thousand years, the recent development of several types of reciprocal causal models must be appreciated as the first major epistemological restructuring since the time of Aristotle.

From the several epistemologies in today's science, I have chosen four for the purpose of contrast: one type of homogenistic epistemology and three types of heterogenistic epistemologies:

a. homogenistic epistemology (hierarchical, classificational)
b. independent-event epistemology (heterogenistic, non-interactive)
c. homeostatic epistemology (heterogenistic, interactive, equilibrating)
d. morphogenetic epistemology (heterogenistic, interactive, pattern-generating)

These four are neither mutually exclusive nor exhaustive. They often overlap, and there are many other epistemologies. Furthermore, the categories used in the following tabulations are for the benefit of those who think in terms of categories. They are unnecessary and useless in non-classificational epistemologies. In a way the tabulations serve as an epistemological Rorschach test: you can identify your own epistemology by the way you *react* to them. Those in the homogenistic and classificational epistemology will ask whether the categories used are universally valid, exhaustive and mutually exclusive, and finding faults in the tabulations on these criteria, will attempt to construct universally valid categories. Those in the independent-event epistemology are relatively uninterested in the tabulations. Those in the homeostatic epistemology and morphogenetic epistemology are contextual and polyocular. They assume that the construction and the interpretation of these tabulations depend on situations and therefore vary from situation to situation. For them the criteria of universality, exhaustiveness and mutual exclusiveness are irrelevant. My own epistemology is morphogenetic. I do not use categories in my head. If I make categories for the convenience of those who need categories, my categorization comes out different each time.

With this in mind, let us look at the somewhat oversimplified tabulations. A more complex analysis can be found elsewhere.[1] The first half of the tabulations deals with conceptual characteristics of the four epistemologies as manifested in philosophy, causality, logic, perception, knowledge, information, cosmology, ethics, religion and research rationale. The second half relates to material culture, particularly to architecture and other design principles.

Recent History of the Four Epistemologies

(1) *Hierarchical and nonreciprocal causal epistemology.* This epistemology continues to be fashionable in the philosophy of science and in sociology, even though the physical and biological sciences are moving away from it. According to this epistemology there is a nonreciprocal flow of influence from the "cause" to the "effect". The influence occurs with some probability rather than with certainty. "Effect" can be predicted from the "cause" with some probability, and the "cause" can be inferred from the "effect" with some probability. Complete information can never be obtained because the information-collecting instrument interferes with the observed phenomena and the act of information-collecting disturbs the phenomena. The "scientific method" consists in discovering the probability distribution in the "effect" when the cause is hypothetically specified (neither cause nor effect can be completely accurately measured), and in establishing the limits of accuracy of observation. Multivariate statistical analysis such as factor analysis, correlation analysis, regression analysis, etc. can be attempted in the study of phenomena which are not completely amenable to laboratory experiments, such as weather, tropospheric scattering of electromagnetic waves and social revolution. If statistical relations between two variables are found, this may be due to one of the following nonreciprocal causal relations: a) one causes the other with some probability either directly or through other intermediate variables, or b) both are influenced by some common cause with some probability. The causal direction cannot be known from statistics alone, and must be determined by logical considerations.

(2) *Independent-event and random process epistemology.* A clear understanding of the basics of this epistemology is crucial for the appreciation of the differences between this and the remaining two epistemologies. Therefore

	HOMOGENISTIC	HETEROGENISTIC		
	Hierarchical	**Isolationistic**	**Reciprocally Causal**	
	Classificational	**Independent-event**	**Homeostatic**	**Morphogenetic**
Philosophy	*Universalism:* Abstraction has higher reality than concrete things *Organismic:* The parts are subordinated to the whole.	*Nominalism:* Only the individual elements are real. Society is merely an aggregate of individuals.	*Equilibrium or cycle:* Elements interact in such a way as to maintain equilibrium or go in cycles.	*Heterogenization, Symbiotization and Evolution:* Symbiosis thanks to diversity. Generate new diversity and patterns of symbiosis
Causality	Two things cannot cause each other. Cause-effect relations may be deterministic or probabilistic.	Independent events are most natural, each having its own probability. Non-random patterns and structures are improbable, and tend to decay.	Reciprocal: Counteracts deviation (negative feedback loops), both probabilistic and deterministic.	Reciprocal: Amplifies differentiation (positive feedback loops), both probabilistic and deterministic.
Logic	Deductive, axiomatic. Mutually exclusive categories. Permanence of substance and identity.	Inductive, Statistical.	Complementarity.	Heterogenization, symbiotization, non-permanence. Irrepeatable and irreversible processes.
Perception	Rank-ordering, classifying and categorizing into neat scheme. Find regularity.	Isolating. Each is unique and unrelated to others.	Contextual: Look for meaning in context. Look for mutual balance, seek stability.	Contextual: Look for new interactions and new patterns. Things change and relations change. Therefore meanings change and new meanings arise.
Knowledge	Belief in existence of one truth. If people are informed, they will agree. There is the "best" way for all persons. Objectivity exists independent of perceiver. Quantitative measurement is basic to knowledge.	Why bother to learn beyond my own interest?	Poly-ocular: binocular vision enables us to see three-dimensionally, because the *differential* between two images enables the brain to compute the invisible dimension. Cross-subjective analysis enables us to compute invisible dimensions. Diversity in perception enriches our understanding.	

	Homogenistic	Independent-event	Homeostatic	Morphogenetic
Information	The more specified, the more information. Past and future inferrable from present probabilistically or deterministically.	Information decays and gets lost. Blueprint must contain more information than finished product. Embryo must contain more information than adult.	Loss of information can be counteracted by means of redundancy or by means of feedback devices.	Complex patterns can be generated by means of simple rules of interaction. The amount of information needed to describe the generated pattern may be greater than the amount of information to describe the rules of interaction. Thus amount of information can increase.
Cosmology	Causal chains. Hierarchy of categories, supercategories and subcategories. "One-ness" with the universe. Processes are repeatable if conditions are the same.	The most probable state is random distribution of events with independent probability. Structures decay.	Equilibrium by means of mutual corrections, or cycles due to mutual balancing. Structures maintain.	Generate new patterns by means of mutual interaction. Structures grow. Heterogeneity, differentiation, symbiotization and further heterogenization increase.
Ethics	*Competition.* Zero-sum. If not homogeneous, then conflict. Let the "strongest" dominate homogenistically. Majority rule (domination by quantity).	Isolationism. Zero-sum or negative sum. Virtue of *self-sufficiency*. If poor, own fault. Do your own thing. Grow your own potatoes.	*Symbiosis: static harmony*. Avoid disturbance. Restore previous harmony. Positive sum.	*Symbiotization: evolving harmony.* Positive sum. Look for mutually beneficial relations with new elements and aliens. Regard differences as beneficial. Incorporate new endogenous and exogenous elements.
Religion	Monotheism: Creator and prime mover, omniscient, omnipotent, perfect god. Missionary work to convert others (belief in superiority of own religion).	Individual beliefs.	Static polytheism. Maintain established harmony of diverse elements.	Dynamic polytheism. Evolving harmony of diverse elements. Look forward to new harmony when new elements are added or new events occur.

	Homogenistic	Independent-event	Homeostatic	Morphogenetic
Research Rationale	Dissimilar results must have been caused by dissimilar conditions. Differences must be traced to corresponding differences in conditions which produced them.	Find our probability distribution and conditional probability.	Dissimilar conditions may lead to similar results due to asymptotic convergence to an equilibrium or cyclic oscillation. Find range of initial conditions which lead to same states. (*Note:* Equilibrium does not mean homogeneity. It means *maintenance* of heterogeneity.)	Similar conditions may produce dissimilar results due to differentiation-amplification. Find the amplifying network instead of looking for different initial conditions. (*Note:* Same amplifying network may produce different results: the difference is due to a disproportionally small initial kick which may be accidental. The amplifying network is more crucial than the initial kick itself.)
Esthetic Principles	Units by similarity, repetition and symmetry. Dominant theme is reflected in subdominant themes. Examples: Gothic. Islamic. French garden. Japanese Yamato culture.	Random, capricious, haphazard, self-sufficient and unrelated to others.	Static harmony of diverse elements. Balance. Completed equilibrium which cannot be disturbed. Design may be asymmetrical. Avoid repetion of similar elements. Perfectionist. Example: Japanese Yayoi culture.	Changing harmony of diverse elements. Avoid repetition and symmetry. Designed for simultaneously multiple as well as changing interpretations. Deliberate incompleteness to enable addition of new elements and changes. Example: Japanese Jomon culture.
	Some Japanese architecture shows hierarchical principles originating from Korea, homogenistic principles originating from China, and more recently from Europe and USA.		The Japanese garden design and flower arrangement incorporate both homeostatic and morphogenetic principles in varying proportions, depending on whether the Yayoi principle or the Jomon principle is emphasized.	
Space	Defined as between masses, between points, along shafts.	Unrelated units.	Miniature universe. Self-contained internal interaction of heterogeneous elements.	Locality with its characteristics (spirits or feelings) connected to other localities. Often thought of as around something (rock, grove) which is considered to be condensation of spirits permeating the locality.

	Homogenistic	Independent-event	Homeostatic	Morphogenetic
Objects	As volume and mass opposing empty space. Often mass represents human; space represents nature.	Each is its own expression.	Represents elements of universe in static harmony.	Represents growing process, vitality, vicissitude. Often the object is a condensation of spirits which permeate locality, and it therefore represents space, not mass.
Time	Building is designed to persist in time. Permanence. Building is also considered to embody eternal principles.	Permanence is unimportant.	The form persists while the building materials may be renewed. (Example: re-building of ISE Shrine every twenty years).	Increasing heterogeneity and symbiotization. Design permits addition of new elements, change in patterns, etc. (Example: Katsura Villa).
Conceptual Movement between Objects	Tension. Straight shaft extending beyond object. Straight line spanned between points. Lines radiating from a point or converging to a point. Curves created by physical contour of buildings.	Caprice. Random.	Balance. Triangles of unequal sides. Circular loops or oscillation keep returning to the same points. (Example: some Japanese gardens).	Flow. Spiral or curve suggested by relative positions of objects, but not by objects themselves. Curves extend and do not return. If returned, some change has occurred such as height. (Example: some flower arrangements).
Perceiver's Movement	Sequential. The perceiver maintains his identity as a point which moves in space.	Random.	Perceiver permeates simultaneously in all parts, and feels invisible parts and behind objects. The entire design is perceived simultaneously, not sequentially.	Spiraling in the sense that at each return to the same point, the perceiver has been enriched and changed by intervening experience.
House	Separate the inside from the outside.	Separate one household from another.	Continuation of outside into inside. Removable outer shells. Garden continues into house. River flows under floor. Floor extends to outdoors. Passive appreciation of nature and environment.	A base for activity and interaction with environment, such as Japanese farm house. Or can be a base for interaction with other households.

	Homogenistic	Independent-event	Homeostatic	Morphogenetic
Room	Specialized rooms (bedroom, dining) occupied by specialized furniture (beds etc.)	Specialized to individual user's needs rather than to generally categorized functions such as dining room.	Convertible. Furniture removable. Walls and partitions removable.	Convertible. Furniture removable. Walls and partitions removable.
Sociability	Socialize within homogeneous group. Hierarchy of groups, subgroups and supergroups.	Self-containment. Freedom from social obligations and freedom for individual caprice.	Mutual dependency. Concern over not disturbing equilibrium. Perpetuation of familiar relations.	Make new contacts, new networks, change patterns of interaction. Go beyond own group.
Privacy	Own group's privacy against other groups. Group solidarity. Concern with patent, copyright and other legal rights.	Individual insulation.	Maximum sharing of intimate concerns.	Less concern with privacy or property right, because interaction is seen as positive sum.
Activity	Hierarchically and homogenistically organized.	Up to the individual.	Nonhierarchical mutualistic activities to *maintain* harmony.	Generate new activities and new purposes through new contacts and new networks. Seek new symbiotic combinations and dissolve no-longer-symbiotic combinations.
Clarity	Neat categories, clear without context.	Individual meaning is what counts.	Contextually interpreted, interdependent meaning.	Ambiguity is basic to further development and change.
Design Choice	There is "the best design" for all persons.	Individualized design.	Traditional designs are considered to be results of most satisfactory equilibrium.	Generate new designs by interaction in new contexts.
Planning	By "experts".	Everybody makes own plan.	Plans are generated by members of the community and pooled together.	
Decision Process	Majority rule, consensus or "informing" the public in such a way that they will understand the "best" design.	Do your own thing. Let others alone.	Elimination of hardship on any single individual regardless of which way the decision is taken.	

let me explain this epistemology at some length. During this discussion, it will be useful to keep in mind the contrast:

a. Independent-event and random process epistemology is of a *decaying* and homogenizing universe;
b. Homeostatic and morphostatic epistemology is of a *stable* universe;
c. Morphogenetic epistemology is of a *growing* and heterogenizing universe.

The independent-event and random process epistemology developed with the theory of equilibrium thermodynamics in the nineteenth century. It is based on a logic similar to that of tossing coins. In the coin-tossing situation, each toss is considered to be *independent* from other tosses. The outcome of the first toss should not influence the outcome of the second toss. The third toss should not have influence from the outcome of the two previous tosses, etc. This assumption is considered true even if the coin itself may be "unfair," i.e. heavy on one side. For example, if the coin is unfair and is heavy on one side, and has the probability of 30–70 for the head on each toss, the second toss should have the same probability of 30–70 regardless of whether it was a head or a tail at the first toss.

Suppose you have 1,000 coins, each of which is similarly unfair, having the head-tail probability of 30–70. Suppose you paint the head side of all coins blue, and the tail side of all coins yellow. Suppose you put them in a box, shake the box well, and pour the coins onto a tray. You will see coins spread over the tray, mostly yellow but some blue. If you put the tray on the table in your garden, go to the airport, rent a helicopter and hover over your garden, you will see the tray without being able to distinguish individual coins. The tray will look yellowish-green.

If the probability of each coin is 30–70, the chances of getting two heads out of two coins are $0.3 \times 0.3 = 0.09$ or nine percent. The chances of getting two tails out of two coins is $0.7 \times 0.7 = 0.49$, or forty-nine percent. The chances of getting 1,00 heads out of 1,000 coins are very small, even though such a possibility exists. Therefore the chances of getting a completely blue-looking tray is very small. So are the chances of getting a completely yellow-looking tray. Most of the time you get a green-looking tray, more to the yellow side than to the blue side. How about the chances of one-half of the tray looking completely blue and the other half looking completely yellow? Again, such a possibility exists, but very small. Most of the time both sides of the tray have about the same hue.

Similar reasoning can be applied to the distribution of temperature in equilibrium thermodynamics. Heat is caused by movements of molecules. If left alone for a long time without interference to or from the outside, the most probable distribution of temperature in a non-living isolated object is an homogeneous distribution. If an isolated "system" is found in a state in which the temperature distribution is not even, it is thermodynamically in an improbable state. The more uneven the distribution of the temperature, the more improbable its state. The heat tends to move from warmer zones to colder zones either by direct transmission through solid body, by being carried by the flow of liquid or gas, or by radiation. The system *tends* to change from a low-probability state to a higher-probability state, even though there is a small probability that the change might occur in the other direction, just as once in a while the coin-tossing might produce a very improbable distribution of hues.

This tendency is called the "law of increase of thermodynamic entropy." "Entropy" is *defined* in such a way that the higher the degree of homogeneity of the distribution of temperature, the higher the entropy. The change from a low-entropy state to a higher-entropy state occurs gradually, not by a sudden jump, because it takes time for the heat to move. There is some degree of continuity in the sense that the state of the system at a given time is related to the state of the system at a previous time. Therefore this change is not "independent" in the sense of coin-tossing. In fact, the state at a later time is related to the state at an earlier time with a certain probability distribution, and this type of change is called "stochastic process."

Shannon's theory of information[2] is based on the same epistemology. Working in the Bell Telephone Laboratories, Shannon had to deal with the problem of loss of transmitted information in telephone circuits due to overloading or noise. He also had to develop ways to pack information in compact coded forms in order to make maximum use of transmission circuits. In telephone circuits the human voice is converted into patterns of electric oscillation. At the listener's end, these electric oscillations are reconverted into a vibration of air which corresponds to the original voice of the talker. In the transmission lines and in the amplifiers inserted along the transmission lines there are random movements of electrons caused either by amplifiers themselves or by external electro-magnetic phenomena such as lightning. These random movements of electrons interfere with the transmitted patterns of electronic oscillations, and decrease the amount of information. It was therefore natural for Shannon to define the amount of information as the degree of non-randomness of the patterns. It is not surprising that the mathematical formula for the amount of information thus conceptualized turned out to be exactly the same as the mathematical formula for thermodynamic entropy.[3] The only difference is that while thermodynamic entropy was *defined* in such a way that it is greater when the degree of randomness is higher, the amount of information was *defined* in such a way that is greater when the degree of randomness is lower. Thus, mathematically, the formula for the amount of information has a negative sign as compared to the formula for thermodynamic entropy.

The fact that the thermodynamic entropy and the amount of information have opposite signs is *purely coincidental.* Thermodynamic entropy could have been defined in such a way as to decrease with increased randomness. In that case, thermodynamic entropy and the amount of information would have had the same sign. It must also be stressed that *neither* thermodynamic entropy *nor* amount of information is a quantity which persists like energy or matter, and that there is *no* physical conversion between thermodynamic entropy and amount of information (while energy is convertible to and from matter), *nor* is entropy or information convertible to and from energy or matter.

The first law of thermodynamics is the law of conservation of energy. The second law is the law of increase of entropy, in other words law of homogenization. They are two *logically independent* and *physically independent* laws. Furthermore, there is *no* law of conservation of entropy. If entropy increases somewhere, it *does not have to* decrease somewhere else. In fact, one form of the second law of thermodynamics says that in an isolated system, entropy tends to increase with a great probability. It is important to note that: (1) entropy increases inside the system without decreasing entropy elsewhere, but also (2) there is no energy input nor output during the process of this increase of entropy, and (3) the total energy remains constant inside the system even though entropy changes. Entropy and energy can change *independently*. Therefore it is *not logically contradictory* to find that entropy can decrease within an isolated system if there are reciprocal causal processes going on in that *isolated* system without any energy input from outside.

The amount of information corresponds to the degree of improbability of the given pattern on the basis of the assumption of random independent events. For example, a series of footprints on a sand beach is improbable on the basis of the assumption of the sand being blown randomly by the wind, and conveys the "message" that something other than wind was present. When the footprints are left to the winds or waves, they decay. The more details of the footprints remain, the more "information" they have as to what kind of animal was there. Just as in thermodynamic process in which the distribution of temperature in an isolated system became more and more homogeneous, in the information theory as formulated by Shannon the amount of information gradually decays if left to random influences. Shannon's information theory was partly aimed at combating this decay and restoring the lost information. It was not intended to, and cannot, generate new information. The other part of Shannon's information theory was aimed at coding and packing information in a compact form in order to maximize the total amount of information transmitted in a given channel. For example, suppose you want to transmit a black-and-white image on a television screen. An uneconomical way is to transmit the brightness of all the points on the image. A more economical way is to indicate only the places where the brightness changes in the scan. In this way you can pack the information more efficiently. There are still other ways of packing the same information more efficiently.

The procedure of indicating only the places where the brightness changes is a procedure which ignores the homogeneous parts and pays attention only to heterogeneous parts. In this sense, homogeneous parts have less "information" than heterogeneous parts. For the same reason, repetition of identical elements has less "information" than combinations of different elements. If the same element is repeated several times, it suffices to transmit information on one element and indicate how many times it is repeated, instead of transmitting the same information several times. It is worth remembering that the amount of Shannonian information is greater when the degree of heterogeneity is greater, as we will reconsider this point in the discussion of the reciprocal causal epistemology.

The purpose of science based on Shannonian information theory is to identify the amount of information, the type of coding and decoding, and the mode of transmission in living organisms and in man-made control and communication devices. Since noise and overloading of channels result in loss of information, and since information can never be increased, the primary concern of this type of science was the *economy* and the *efficiency* in the coding and decoding as well as the *maximum* use of channel capacity without creating overloading. Examples of fields of specialization which flourished under this epistemology are: the study of so-called "genetic codes," neurophysiology, coded data transmission in space technology, data bank and information retrieval.

(3) *Homeostatic and morphostatic epistemology;* (4) *Morphogenetic epistemology.* These epistemologies attained a sophisticated mathematical formulation in Western science during the Second World War, although they existed in the philosophies of many non-Western cultures for a few thousand years. The development of these epistemologies in Western science occured in two

phases: a) The phase of the deviation-counteracting and equilibrating reciprocal causal epistemology. This phase occured in the period extending from 1940's to 1950's; b) The phase of the differentiation-amplifying and heterogeneity-increasing reciprocal causal epistemology extending from the early 1960's to present.[4] There may yet be a third phase, characterized by mathematical elaboration of the diversity-symbiotizing reciprocal causal epistemology.

Even though intuitive formulations of reciprocal causality in Western science can be traced back to Darwin, Adam Smith and several others in different fields of specialization,[5] the notion of reciprocal causality had not become a "respectable" scientific epistemology until it was formulated with some mathematical sophistication in the mid-20th Century. The mathematical formulation which marked the beginning of the first phase of the reciprocal causal epistemology occured during the Second World War, when anti-aircraft artillery became equipped with a corrective feedback loop consisting of a radar and a computer.[6] The initial mathematical formulation for the second phase occurred in 1960 when mathematician Stanislaw Ulam developed a theory that complex patterns can be generated by means of simple rules of interaction.[7] The mathematical formulation for the third phase is yet to be made. The history of the development of the conceptualization of the reciprocal causal epistemologies both before and after the Second World War is discussed elsewhere.[8]

Deviation-counteracting equilibrating reciprocal loops can be found in many self-regulating processes in biology, ecology and man-made devices; for example, the self-regulation of body temperature, and the auto-pilot mechanism. In such a causal loop the effect of any changes in one element comes back to itself through other elements in the loop in such a way that the change is counteracted and cancelled out.

Differentiation-amplifying heterogenizing reciprocal causal loops can be found in many biological and social processes which increase complexity, diversity and structure. For example, in the interaction between a species of moth and a species of bird which feeds on it, camouflaged mutants of the moth will survive better, as will the mutants of the bird who are clever at discovering the camouflaged moths. As a result, the moth gets more and more camouflaged generation after generation, and the bird gets more and more skillful in discovering the camouflaged moth. Another example is the growth of a city on a homogeneous plain. Suppose that there is a plain which is homogeneous before the arrival of human pioneers. One day someone arrives and settles down on a certain spot. The choice of the spot may be accidental, due to the man's being too tired to go any further, the horse becoming ill, etc. But once he is settled, someone else may come and join him, and gradually a village may grow. This increases the attractiveness of the spot to other pioneers, and more people will come. Gradually industries develop, and a city grows. The plain is no longer homogeneous. Within the city many types of differentiation and heterogenization take place, business sections and residential sections become differentiated, several different kinds of vocational schools are built, etc.

Ulam's formulation has profound implications in these processes. He discovered that when a complex pattern is generated by interaction, it often takes more "amount of Shannonian information" to describe the finished pattern than to describe the interaction rules which generated the pattern. In other words, the "amount of Shannonian information" *grows* in such processes. We remember that in Shannon's formulation based on the random process epistemology, the amount of information can never increase. In the random process epistemology, structures decay and information decreases. On the other hand, the deviation-counteracting equilibrating reciprocal causal processes can *maintain* structures and information against decay, and the differentiation-amplifying heterogenizing reciprocal causal process can *generate* and *increase* structures and information.

This solves one of the puzzles of science. Thermodynamics based on the independent-event and random process epistemology could not explain how living organisms decreased entropy (increased temperature differentiation). It simply begged the question by saying that living organisms are not isolated systems. But this question-begging was as unsatisfactory as the attempt to explain how a computer works by saying that it works because it is plugged into a power source. A more satisfactory explanation lies in the recognition that the biological processes are reciprocal causal processes, not random processes.

Let us recall for a moment the example of the footprints on a sand beach. As late as 1953 Hans Reichenbach, one of the leading philosophers of science of that period, denied the possibility of reciprocal causal processes and advanced the following argument.[9] There are several types of time-asymmetrical processes. If you take a movie film of a time-asymmetrical process and run the film backward, you can tell it is run backward because the process does not obey the laws of physics. As an example of one of the types of time-asymmetrical processes, Reichenbach discussed the process of a footprint on a sand beach being blown by winds. He said that the actual event runs in the direction of gradual decay of the footprint. If you take a movie film of this event and run it backwards, you can recognize that the film is being run backward. His argument was that it is highly improbable, though not completely impossible, that random influences consistently accumulate in such a way as to gradually produce a structure. Faced with the question of how structures came about in the first place, Reichenbach tended to think that structures can be created by sudden events such as an explosion, but not by a gradual, slow process. His nonreciprocal causal epistemology could not explain gradual growth of structure such as we have seen in the case of the growth of a city on a homogeneous plain. He had to introduce the notion of "finality," i.e. the future determining the present, in order to account for the processes which he could not explain with his nonreciprocal causal epistemology.

Some readers may have noticed the affinity of Reichenbach's explosion theory to LeMaitre's "Big Bang Theory" in astronomy. There are two theories in astronomy regarding how the universe began. The "Big Bang Theory" maintains that the universe began with a big explosion, while the "condensation theory" holds that the universe initially consisted of homogeneously distributed gas matters which gradually condensed into astronomic bodies due to mutual gravity. The condensation theory is in the morphogenetic epistemology. The theory poses an interesting question: if we regard the entire universe as an isolated system, then the entropy decreases in this isolated system provided the condensation theory is correct. This is a very interesting epistemological consideration.

At the end of the 19th Century, Boltzmann proposed the following possibility.[10] He proposed that there may be other universes in which the direction of time runs opposite to ours. We cannot receive any information from such a universe, because any information *leaving* it according to its time direction would be seen by us as *going* to that universe. But if it were possible to observe such a universe, the decays in it would look like growth, and growth would look like decay. It would not be easy to talk about decay and growth in such a case.

One of the characteristics of deviation-counteracting equilibrating reciprocal causal processes is that dissimilar conditions are counteracted and the result converges to similar conditions. On the other hand, the differentiation-amplifying heterogenizing reciprocal causal processes have a characteristic that similar initial conditions may produce very dissimilar results. These properties have very profound theoretical consequences. First, neither the past nor the future can be inferred from the present, nor can the present be inferred from the past or from the future. This is not because of the "indeterminism" and "probabilism," but because of the deviation-counteracting and differentiation-amplifying reciprocal causal loops. Secondly, in the research method, the existence of a "difference in the initial condition" cannot be assumed on the basis of a difference in the result. One would be looking for a non-existing straw man if one looked for a difference in the initial condition. One must look for the amplification network. For example, the difference in the national character between Denmark and Holland may not come from the difference in climate, geography, racial origin, and such "conditions." Instead, it may be more worthwhile to look into how the various aspects amplified one another within each culture.

The research method regarding "information" also changes considerably in the reciprocal causal epistemologies. In the random process epistemology of Shannon's information theory, the amount of information can never grow. Therefore, all existing information must have come from somewhere. For example, the genes must contain the amount of information necessary to describe the adult body. For each part of the adult body, there must be a corresponding unit of information that can be located in the genes. The research therefore aims at locating these units. On the other hand, in the morphogenetic epistemology the amount of information as defined by Shannon may grow by interaction. Therefore it may be more profitable to discover the rules of cellular interaction than to try to locate in the genes the information units corresponding to each part of the adult body. Experiments in embryonic grafting or embryonic interference may be performed instead of the analysis of genes per se.

Probabilistic reciprocal causal processes. As we have seen, even *without* the introduction of probabilistic indeterminism the reciprocal causal processes do not conform to the notion that "similar conditions produce similar results." In the *deterministic* reciprocal causal processes, dissimilar conditions may end up with similar results due to deviation-counteracting, or similar conditions may produce dissimilar results due to differentiation-amplifying. But when we combine the indeterminism with the reciprocal causal processes we obtain the following: a) The *same* conditions may produce different results. b) Different conditions may produce the *same* results. This is because a very small initial difference, which is within the range of high probability, may be amplified to the degree which would be very improbable in the probabilistic nonreciprocal causal processes. In the deterministic deviation-counteracting process, the equilibrium is usually reached asymptotically, but not necessarily completely. The process *approaches* the ideal equilibrium but does not completely attain it. On the other hand, if small probabilistic fluctuations are allowed, it is possible that the process jumps into the ideal equilibrium state once in a while, even though it may jump out of it as well.

Let us return to the discussion of the reciprocal causal epistemologies and discuss the third phase. The third phase, which is not yet mathematically formulated, must deal with the question of symbiotization of diversities at a more sophisticated level than is now practiced. There is already a great deal of data from ecology and biology regarding symbiosis and heterogeneity. But in ecology and biology we have been studying so far the symbiotic relations *which are already established* between diverse species. We do not concern ourselves with the possibility of *creating new symbiotic relations* between the species or heterogeneous individuals within a species which are not yet interacting. Yet this is the kind of concern we need to develop in dealing with the social and cultural change taking place in our world, not only in order to avoid possible catastrophes but also in order to explore positive alternatives.

Heterogeneity has survival value for at least three reasons: (a) symbiosis, (b) resource utilization, (c) catastrophe contingencies. The traditional European-American ideology of unity by similarity considered differences as sources of conflicts. This amounted to the ideology of homogenization, standardization, religious and technological universalism, missionarism and ethnocentrism. But the new scientific epistemology is "symbosis *thanks to* diversity." For example, animals convert oxygen into carbon dioxide and the plants do the opposite, and by so doing they help each other. Another example of the survival value of heterogeneity is seen in a coral reef or in a tropical rain forest. The heterogeneity of species enables maximum utilization of solar energy and diversification of food requirements. If all species ate the same food, there would be a food shortage, and if not all species were eaten, there would be food waste. Diversity allows for a higher probability of survival in case of catastrophes such as radical change of environment.

Traditionally the Europeans and white Americans had to choose between two sides of the same coin, occasionally with various degrees of mixture: the homogenistic epistemology and the independent-event epistemology. Examples of such limited choices are: the medieval controversy between universalism and nominalism, with an intermediate position taken by conceptualism; the 19th and 20th centuries' contrast between idealists such as Kant and Hegel on the one hand, and existentialists such as Kierkegaard, Heidegger and Sartre on the other. The same limitation is found in many of the conflicts in today's social sciences. In sociology, the quantitative school reflects the homogenistic epistemology, and the phenomenological school represents the independent-event epistemology, even though some symbolic interactionists have moved toward the morphogenetic epistemology. In anthropology, the universalists belong to the homogenistic epistemology, while most of the arguments of the relativists are still confined in the independent-event epistemology, or even in the quantitative and therefore homogenistic epistemology. It must be pointed out that both phenomenologists and relativists *can* base their thinking on the morphogenetic epistemology, and that some of those in the quantitative school are already using morphogenetic models.

It is incorrect to identify the homogenistic epistemology and the independent-even epistemology as "Western" epistemologies; they predominate in many of the non-Western cultures also. The Islamic religion is more hierarchical and categorical than the Christian religion. Hindu philosophy is also hierarchical and homogenistic. On the other hand, the Mandenka who live on and near the border between Guinea and Senegal in West Africa are morphogenetic.[11] The Chinese philosophy is homeostatic.

It is interesting to note that Japanese philosophy has at least three underlying currents: the Jomon current which originated more than 9000 years ago is morphogenetic; the Yayoi current which began about 300 BC is homeostatic; and the Yamato current which came later via Korea is hierarchical. The Jomon current accounts for the Japanese view that nothing remains the same, and hence their readiness to change. This contrasts with the traditional Chinese philosophy of oscillation in which the process returns to the same states. On the other hand, the Yayoi current is responsible for the Japanese's apparent rigidity, formality and perfectionism, and the Yamato current is seen in the hierarchy-consciousness of the Japanese. To add to the heterogeneity within the Japanese culture, the three currents have been distributed differently in different social classes. Until and including the feudal period the ruling class, which was small, was hierarchical and homeostatic, while the grass-roots culture of the farmers was egalitarian and reciprocally interactive. After the Meiji reform. the Yayoi and Yamato epistemologies spread into the growing middle-class, even though the Jomon current is still very basic in all social classes. Each person in Japanese culture incorporates all three currents. The interaction between the Jomon and Yayoi currents are also expressed in various forms of traditional and modern Japanese architecture.[12]

Furthermore, the Japanese and Mandenka philosophies are heterogenistic, while Chinese philosophy is dualistic. In this respect Chinese philosophy resembles Greek logic, and it is this superficial resemblance which made the Europeans interpret Chinese philosophy as having a "logical" structure, even though this interpretation contains some distortions. Similarly, Europeans recognized the Islamic and Hindu philosophies as "great philosophical systems" because these are hierarchical and homogenistic. One difference between Christian philosophy and Islamic philosophy is that the former has the dualistic structure of good and evil, while the latter is more unitary. In summary, Islamic, Hindu and Chinese philosophies, which the Westerners consider as "typically Eastern," have affinities to Greek philosophy. On the other hand Jomon philosophy, Mandenka philosophy, and to some extent Navajo philosophy and Eskimo philosophy, form a different cluster and have not yet been recognized as "philosophical systems" by Western philosophers. But using the framework of the morphogenetic epistemology, the members of this cluster can be formulated as philosophical systems. The details are discussed elsewhere.[13] For example, the Mandenka's notion that "If you force individuals to be similar, the only way left to them to be different is to get on top of one another. This creates conflicts" is based on the epistemology in which it is held that homogeneity, rather than heterogeneity, creates conflicts.

Morphogenetic epistemology is increasingly being used in several fields of biological and social sciences. At present, however, most of the efforts are focused on the study of the process of heterogenization, while the process of symbiotization has hardly begun to be studied.

Our social thinking proceeds with two assumptions: a) that each culture, each social group or each individual has its own goal, and there are *several alternative ways* to attain this goal; b) that the current international relations, intercultural relations, intergroup relations, inter-individual combinations, etc. are by no means satisfactory. We must find more satisfactory ways to rearrange these relations and structures. We have not yet produced a mathematical formulation for this kind of thinking. The existing "mathematical models" of society have many short-comings: a) they are culture-bound and paradigm-bound and cannot be applied to different cultures; b) they are homogenistic, and cannot even deal with the heterogeneity in our own culture; c) consequently they do not even conceive the problem of finding possible symbiotic combinations among heterogeneous elements; d) not many of them include the consideration of existence of alternatives.

The formulation of the third phase of the reciprocal causal epistemology can begin with considerations such as the following. Suppose there are three individuals, A, B, and C. A has his goal which we call Ga, B has his goal which we call Gb, and C has his goal which we call Gc. Suppose A has five different ways to accomplish his goal Ga, B has two different ways to accomplish his goal Gb, and C has three different ways to accomplish his goal Gc. Then there are 5 times 2 times 3 = 30 different combinations of these alternative ways in which all three individuals can attain their different goals. Some of these 30 combinations may produce symbiosis among the three individuals, while other combinations may not. Our problem is to find these combinations of alternatives which produce symbiosis. We need not only a mathematically sophisticated but also a practically implementable formulation to deal with symbiotization of not-yet-interacting intra-specific heterogeneous elements. Individuals in a culture, or cultures in the world, among which symbiotic combinations can be found, can be hooked up in a network. For example, old people who like to be with children can be housed near families who need babysitters. On the other hand, those among whom no symbiotic combinations can be found need to try different networks. Such studies may be called *Morphogenetics*, or in order to avoid confusion with the biological study of morphogenesis, simply *Heterogenistics*.

Heterogeneity of Epistemologies

We have been discussing the *epistemologies of heterogeneity*. Before concluding this paper, however, I would like to say a few words on the *heterogeneity of epistemologies*.

The individual in the Mandenka tribe goes through different phases of tasks and functions in the society: adolescents are assigned certain specific tasks, those between 30 and 35 are assigned administrative and care-taker functions of the tribe, those who are older are given less demanding tasks, etc. By going through these different phases, the individual learns to see the same situation from different points of view, and to understand individuals in different situations. The individual becomes heterogeneous in himself, and becomes capable of poly-ocular vision. They are skeptical of Westernization mainly because the system of specialization brought by the Westerners will lock each individual in one task, and he will become incapable of seeing other persons' points of view.

The Japanese also think in poly-ocular vision. Americans, who believe in the existence of one truth, will inevitably ask: if you have different views, which one is right? But consider the following: in the binocular vision it is irrelevant to raise the question as to which eye is correct and which is wrong. Binocular vision works, *not* because two eyes see different sides of the same object, but because the *differential* between the two images enables the brain to compute the *invisible* dimension. When there are different points of view, Americans tend to say: "Let's ignore the parts on which we differ, and work on the parts on which we agree." Well, if you reduce binocular vision to parts on which two eyes agree, what is left is much less than the monocular vision. For the same reason, insistence on the "objective" parts on which everybody agrees is a tremendous impoverishment of our vision, even though many people would consider this as "scientific" thinking. We can say that the "objective" parts are the most insignificant parts of our thinking. The Japanese do not even bother to determine "objectivity," because they can go much further with cross-subjectivity. Similarly, heterogeneity of epistemologies provides us with a poly-epistemological vision.

Conclusion

The epistemological restructuring goes much beyond the controversy between the relativists and the universalists. It makes us realize that the basic principle of biological, social and some physical processes is increase of heterogeneity and symbiotization. It requires us to see heterogeneity not as deviation from the average but as indispensable components in the system; not as source of conflict but as source of symbiosis and mutual benefit. Furthermore, it goes beyond the concept of division of labor and considers heterogeneity as interactive network which contributes to further heterogenization, symbiotization and cultural change instead of maintenance of the status quo. It sees heterogeneity not as an instrument of evolution which is assumed to have a universal direction, but as a producer of *un*predetermined directions of evolution. It sees culture or elements of culture as generating new needs and goals rather than regarding them as internally satisfactory. And it prompts us to develop a science of finding symbiotic combinations among alternative ways the heterogeneous elements can select, rather than watching unsymbiotic combinations defeat themselves.

NOTES

1. Magoroh Maruyama, "Paradigmatology and Its Application to Cross-Disciplinary, Cross-Professional and Cross-Cultural Communication," *Cybernetica* 17 (1974), pp. 136–156, 237–281.
2. Claude Shannon, *et.al., Mathematical Theory of Communication* (Urbana, 1949).
3. The conditions for the determination of the formula are given by Shannon, *ibid.*
4. In this paper, the deviation-counteracting and equilibrating reciprocal causal epistemology is abbreviated to "Homeostatic and morphostatic epistemology" and the "differentiation-amplifying heterogeneity-increasing reciprocal causal epistemology" is abbreviated to "morphogenetic epistemology."
5. Magoroh Maruyama, "The Second Cybernetics: Deviation-Amplifying Mutual Causal Processes," *American Scientist* 51 (1963), pp. 164–179, 250–256; John Milsum, *Positive Feedback* (Elmsford, New York, 1968).
6. Norbert Weiner, *Extrapolation, Interpolation and Smoothing of Stationary Time Series with Engineering Applications* (Cambridge, Mass., 1949).
7. Stanislaw Ulam, Lecture at Stanford University, 1960; Magoroh Maruyama, "Generating Complex Patterns by Means of Simple Rules of Interaction," *Methodos* 14 (1963), pp. 17–26.
8. Maruyama, "Second Cybernetics," *op.cit.;* Milsum, *Positive Feedback, op.cit.;* Walter Buckley, *Modern Systems Research for the Behavioral Scientist* (Chicago, 1968).
9. Hans Reichenbach, *Direction of Time* (Berkeley, 1956), p. 39.

10. Ludwig Boltzmann, *Vorlesungen über Gastheorie* (Leipzig, 1898).
11. Sory Camara, "The Concept of Heterogeneity and Change among the Mandenka," *Technological Forecasting and Social Change* 7 (1975), pp. 273–284.
12. Kenzo Tange and Noboru Kawazoe, *Ise* (Cambridge, Mass., 1965); Kenzo Tange, *Katsura* (New Haven, 1972).
13. Camara, "The Concept of Heterogeneity and Change among the Mandenka," *op.cit.*