Development and Evolution

Michinori Kobayashi

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Michinori Kobayashi
(Japanese Philosopher)

The evolutionary epistemology sees knowledge in light of action and generation. The so-called "problem of knowledge" is a problem that has long been debated from ancient times in philosophy. This paper attempts to explore a new approach to epistemology by focusing on how animals perceive things in the world, whilst considering problems associated with development and evolution, tools and technologies, in terms of behavior.

1 Development and Learning

Development

Piaget perceived the functioning of human knowledge from the genetic perspective and captured the dynamics of human development by considering human cognitive structure as a self-organizing system organized from repetitive activities. According to Piaget, development is a process of a subject moving from a certain cognitive structure to an yet higher cognitive structure. For a subject to live in a given environment, he must recognize the relations he bears with his environment. In, the subject often has a certain set of schemata, and recognizes objects according to the appropriate scheme. "Assimilation" refers to the act of recognizing an object in accordance with the scheme. However, disequilibrium constantly arises between the subject and the environment; if a state of disequilibrium arises, the subject makes an adjustment to recover the state of equilibrium. Adjustment here refers to the modification of a scheme in order for the subject to be able to recognize an object. Successful adjustment allows the subject to move to a novel state of equilibrium, enabling him to restructure his cognitive structure. Development refers to this process of restructuring via assimilation and adjustment. Further, as Piaget observes, this development takes place discontinuously through several stages. The process of development is a process of self-organization.

In the course of development, amongst others, performing activities or actions is of critical importance. As a matter of fact, activities are about the only thing neonates can do. Likewise, infants cannot recognize objects except through activities. Neonates and infants recognize things and develop intelligence by moving their hands and feet and touching things with their fingers. Action and movement comes first. The development of perception and cognition arises from these activities. It is not because of the development that the cognition grows and behavior becomes complicated; behavior facilitates cognition and development. Development must be conceived of within interactions between the subject and the environment. In the course of interacting with their environment, behavior facilitates cognition, and cognition provides a way of living for the subject. That is how development takes place.

Infant's reaching behavior to grasp an object marks the beginning of spatial search using hands. This, however, should also not be interpreted as an intelligent action performed with a certain intent or goal. Infant's reaching behavior consists of unique movements for each child and starts in an individualistic manner. During the movements, the child learns to discover the trajectory of his hand reaching an object for himself. The task that the child is about to solve is not a problem of trajectory calculation, rather a problem of dynamics unique to his bodily movement. When it is accomplished, a great cognitive stride is made and cognitive development seen. Development does not cause behavior; rather behavior causes development.

The development of object or spatial cognition requires coordination of hand movements with eye movements. In case of infants, however, they display awkward eye movements in their earlier stage of development, and their eye movements are not necessarily directed accurately to the direction of stimuli. However, as they repeat these movements, infants gradually learn to move their eyes and heads particularly to the direction of a moving object to commence with tracking movements and to turn their eyes on it. Obviously, turning one's gaze is not sufficient to recognize the shape of an object; it requires coordination of one's eyes with his hand reaching or grasping behaviors. However, grasping behavior of an early infant is just as awkward as his reaching behavior and eye movements, and it does not necessarily lead him to the tactual knowledge of the shape of an object. It is only until he learns to move his left and right hands simultaneously at a later stage that he can know the shape of a thing.

Space perception is also acquired only through such movements of eyes and hands, as well as leg movements if the infant learns to walk, and he does not have the concept of space from the beginning. Abstract thoughts such as "material objects exist in space" emerge only after the child learns to acquire spatial perception through his physical behavior. This underlies the child development.

Similarly, the development of physical movement itself takes place in a circle of movement and perception, where an original movement occurs first, which facilitates the development of perception, and this in turn allows the further development of movement. It is a self-organizing cycle. Movements do not consist of muscles moving according to a motor program in the brain. Movements precede everything else. Likewise, object perception does not arise from perception itself; it arises only from an action towards an object. This also accounts for the recovery of motor capability through rehabilitation.

Learning is, therefore, essential for the development of cognition. Learning is a discovery of connections between oneself and the world, and it is only acquired through his behavior and experience. Both human beings and animals accumulate knowledge through experience. Knowledge is information on how one should act on things in order to achieve a certain goal. However, it is not generated only within the brain. Knowledge is experience through and through and can be attained through behavior. Learning then is the very act of attaining knowledge through experience. To attain knowledge, it is necessary first to act on things. Knowledge attainment is an act, a practice and an active cognitive process. Knowledge cannot be detached from the environment including knower's body.

Learning

Animals including humans gain experience by adjusting their own behaviors to ensure their survival in an unceasingly changing environment. Learning is this attainment of empirical knowledge. Animals extract meaning and value of objects in their surrounding environments by learning and acquire a high discriminatory capacity. Animals learn meaning and value that should be extracted from their environments in order to adapt to them in an easiest and surest manner. This allows them to gradually refine their activities in their environment. Animals are exposed to unpredictable events, which they cannot control solely in terms of innate behavior. Learning is required in order to adapt to an unpredictable environment. Substantial portions of animal behaviors are acquired through learning.

Indeed, learning is largely involved in animal behaviors that are thought to be innate. Young spiders, for instance, appear to catch their food skillfully since their birth, according to genetically equipped innate programs. However, on close examination, young spiders repeat the trial a number of times to perform learning. Chicks' pecking behavior and birds' nest-building are also instances of behavior that is improved by experience. Earthworms and frogs perform behavior in a rather flexible manner according to variously different environments, than simple reflex or trial-and-error. Innate behaviors that appear to follow their instinct involve plasticity and diversity. Learning is necessary for animal behavior.

Similarly, perceptual consistency of the shape and size of an object involves experience and learning. Human neonates and infants learn perceptual consistency of the shape and size of an object, by stretch their hand toward it, grasp it, or check it while walking around it. Humans also learn perception of color consistency through experience during their neonatal and infantile periods. Color perception is formed by receiving a variety of color stimuli under incandescent light and learning their contrast. Color perception is not innately given. It is often said that humans and monkeys have color perception because they are genetically equipped with three types of cells responsive to differing ranges of lights that correspond to three primary colors. However, the truth is rather the other way around.

The cognitive map attained by animals is also a result of experience and learning. Honeybees attain a cognitive map of food locations and their hives through learning. Rats in a maze learn to build a cognitive map of the maze through exploring it. Homing pigeons learn to correctly return to their nests from their parents or older pigeons.

Both Pavlov's study on learning by classical conditioning in terms of conditioned reflex and Skinner's study on learning by operant conditioning tend to understand too mechanistically learned behaviors of animals. Nonetheless, even these behaviors are not innate and are results of learning. Animals have their own ways of interpreting the meaning and value of objects in a highly sophisticated manner in an environment in which they are involved. Even error-and-trial learning is not performed haphazardly. Error-and-trial learning involves sophisticated learning processes in which animals seek to solve problems, by gaining experience based on memory, investigating the validity of hypotheses and modifying them as necessary. More sophisticated animals develop the more sophisticated forms of learning such as imitative learning, learning by practice and habituation, and learning by insight. Regardless of the types of learning they adopt, animals recognize things while performing behavior, and behave while recognizing things, in an effort to solve their issues.

This behavior-based cognition comprises learning.

Innate Behavior and Innate Concepts

Certainly, large portions of animal behavior are also genetically controlled. Genetically inherited memory of behavioral patterns often allows animals to perform perfect behaviors from the beginning without learning from their parents. Instinctive behaviors performed by animals without learning are innate.

For example, releasing behavior induced involuntarily by a key stimulus such as color, sound, and smell is typical innate behavior of animals. Animals respond to a certain stimulus in a specified fashion, without the aid of reflex function, to the advantage of self-preservation and conservation of species, as seen in their behaviors for foraging, reproduction and self-defense. As a matter of fact, the three-spine stickleback (*Gasterosteus aculeatus*) involuntarily releases fighting behavior triggered by red belly and upright posture of its enemy. Wild turkey poults quickly flee into their dwelling as soon as they see figures of flying raptors without someone notifying it. Animals must properly and quickly process information of external world for their self-preservation and conservation of their species. Thus, the releasing mechanism of animal behaviors serves as a mechanism for appropriately utilizing genetically-embedded behavioral patterns as occasion demands.

It implies then that animals, since their birth, do not seek to solve their problems from a "black slate", by repeating trial and error and accumulating experience. This provides justification for the nativism about animal behavior, according to which, animal behavior is determined by programs embedded in their genes, and the form of behavior they exhibit, it claims, is a consequence of involuntarily following the instructions of the programs.

Aside from ethology, philosophical theory of knowledge has long presupposed innate ideas as seen in figures like Plato and Kant. Plato thought that "ideas" are forms or essence of things that we are endowed with before birth. Similarly, Kant thought that forms of intuition such as time and space and the category of causality, etc. are *a priori*, that is, they are given to us prior to experience, and they bring order to our sensible experience. This transcendentalism in the philosophical theory of knowledge suggests the possibility that animals and humans have *a priori* concepts prior to learning.

However, such nativism in the philosophical theory of knowledge at least seems to have lost its credibility. For example, spatial concepts like distance, depth, shape of an object are only made available to subjects through eye movements and limb movements, and are therefore not innately given to us. In short, spatial concepts are acquired.

Certainly, if we look at research findings in the field of ethology, we must acknowledge that innate behaviors account for a larger proportion of animal behaviors. In fact, insects can involuntarily engage in nest-building activities without learning, and snakes remember the types of prey they feed on and hunting techniques without learning them from their parents. Even higher vertebrates exhibit countless innate behaviors without experience. For instance, a freshly hatched cuckoo chick in a nest of host birds ejects host's eggs out of the nest. Meanwhile, a kitten that encounters a dog for the first time adopts a frightened and threat posture, stretching up and growling with its hair standing straight up. Kittens know instinctively that dogs are dangerous enemies.

It is certainly not true to infer from the fact that animal behaviors involve innate behaviors to the fact that learning by experience does not play any role in their behaviors. Nativism, among other things, cannot fully explain the development of animal movements. Even when focusing on the releasing mechanism of animals, animals should not be regarded as simple machines manipulated by external stimuli through their releasing mechanisms. On closer examination, even releasing behaviors of insects do not always follow the same regular patterns, hence, are not entirely determined by their instinct. As regards humans, even neonates observe the circumstance in which they are placed with astonishing carefulness.

While the idea that all animal behaviors are based on learning is extravagant, the idea that genes determine all animal behaviors is equally wrong-headed. In fact, innate capacity and learning, nature and nurture work together as a unity.

The nativism-empiricism controversy that has been hotly debated since seventeenth century in the field of philosophy must be overcome from a different point of view. Since Descartes, the rationalist tradition has endorsed nativism, claiming that our reason is endowed with innate concepts and schemata. In contrast, empiricists including Locke thought that human mind is *tabula rasa* at birth, on which sensuous experiences are to be inscribed after birth, and knowledge is the manner of making an association of ideas through inference from sense experiences. However, both rationalism and empiricism are flawed in viewing knowledge in a static manner. Knowledge must be understood from the evolutionary and genetic standpoint.

Evolutionary learning

Both animal innate behaviors and human innate concepts must be understood as a consequence of evolutionary learning. When observing animal behaviors in a static manner, we find quite a few seemingly innate behaviors which, when viewed in a dynamic, developmental standpoint, has been learned through a long, phylogenetic process. Learning includes phylogenetic learning as well as ontogenetic learning. Innate behaviors of animals must have been developed as a consequence of accumulated experiences entertained in the phylogenetic process. In this sense, animal innate behaviors are a kind of acquired traits.

Moreover, behavior is again essential for these evolutionary experiences and learnings. Animals gain experience through their behavior, know their environments through their own experience and inscribe behavioral patterns on their genes. That accounts for innate behaviors of animals. It is wrong to see animals simply as following their mechanistic releasing mechanism or reflex mechanism or stimulus-response system. It is a consequence of evolutionary accumulation of experiences, a result of preserved learning.

It is true that instinctive behaviors of animals do not depend on learning processes. However, they are based on experiences that have been transmitted from generation to generation and accumulated for four billion years since creation of life. Just as we remember what we have learned individually, in the course of evolution, species remember their ancestors' experiences. Innate characteristics seen in individuals are a consequence of phylogenetic learning and have been preserved as phylogenetic memory.

Individuals recall events that have been experienced by their ancestors. Our cognitive ability can be rephrased as an ability to recollect experiences that have been accumulated throughout the phylogenetic history of human species. It is in this sense that Haeckel's law expressed in his phrase "ontogeny recapitulates phylogeny" acquires legitimacy. A past experience often suddenly comes to our mind on a specific occasion. Likewise, in the long course of evolution of life, experiences have continuously been recollected. Plato understood our discovery of truth and knowledge of things to be recollection of truth and ideas that had been given to us before our birth.[2] Although this idea may lead to nativism, and cannot be accepted at face value, when reinterpreted from an evolutionary perspective, it has a deeper connotation.

As has been claimed by evolutionary epistemologists, *a priori* knowledge of whatever kind is a consequence of evolutionary learning. To be sure, innate mechanisms of animals and humans are independent of their individual experiences, hence are *a priori*. However, it is not independent from experience of life evolution, hence are *a posteriori* in a phylogenetic sense. *A priori* innate concepts and forms of intuitions that Kant claims humans have are equally not independent from evolutionary experiences. Kant's epistemology must be overcome. Meanwhile, empiricist idea that human mind is a *tabula rasa* (a blank slate) by birth is equally not correct in light of evolutionary history of life. When viewed from the standpoint of evolutionary epistemology, a life form cannot come into being from individual ancestors; rather, it takes over and stores the memory of a long chain of phylogenetic experiences.

Even when viewed from the standpoint of modern molecular biology, animals' innate behavioral patterns can be thought of as patterns whose information has been acquired and encoded in genes through a long chain of evolutionary processes. Animal species store survival skills in their genes, which have been developed from repeated experiences in the distant past, and bring stability to these methods as programs for innate behaviors. Afterwards, animals let them express themselves in each individual, and then transmit them to their future descendants.

In this regard, the idea of genetic epistemology developed by Piaget is adequate. Piaget thought of animals' innate behaviors as epigenetic processes assimilated into the genome through phenocopy. The genome learns under a given environment and accumulates experiences. This process can be understood as one that evolves both dynamically and interactively from genotype to phenotype and vice versa within an entire system. Moreover, genes are involved in the dynamism. ○[3]

Piaget's notion of genetic epistemology encompasses the idea of systematics, according to which, genes are not fixed deterministically as the blueprint for life; rather, they occupy a place in an ecological system of earthly environment that itself undergo changes over a long period of time. Then, a set of genes and a genetic network accumulate information of behavioral patterns acquired through interaction with environments within themselves. The genetic network incorporates behavior patterns and hypotheses generated in the course of overcoming the environment and organizing itself and proceeds to the next stage. Innate behaviors and innate concepts emerge in individual animals during this process. Evolution is a self-organizing process through interactions between the subject and the environment. Species-typical behavioral patterns of an animal species are traces of behaviors developed through interactions between the subject and the environment. Nativism-empiricism conflict can be overcome if one adopts interactionist epistemology and ecological epistemology.

Evolution of life is a learning process as well as a cognitive process. Life forms themselves learn about their environments through their behavior, enhance knowledge, store and transmit it to the next generation. Evolution of life is a process of enhancement and complication of cognitive abilities. Memory of behavior patterns must be captured in the flow of life that continues to form itself. Like everything else, behavior is in the flux of things.

2 Evolutionary Epistemology

Evolution via behavior

Animals act on their environments by engaging in such activities as navigation, migration, feeding, aggression, defense, reproduction, become aware of them and seek to expand their habitats. Animal exploration marks its beginning. Animals acquire their prey by exploring their environments, thereby polishing their survival skills. An effort is made in overcoming conflicts and felt tensions when animals have not acquired a target that they'd like to acquire. This effort brings about development and evolution. Behavior produces a quantum leap in life.

In the beginning is behavior. Behavior is not a consequence of evolution but its cause. Behavior also exerts a considerable impact on morphogenesis of animals. In the phylogenetic process, behavior would trigger animals' morphogenesis. For example, animals like sea urchins and jellyfishes leave to chance the possibility of encountering their prey, thus, do not have to orient themselves to the direction of the prey. For this reason, they normally take the radially symmetric physical posture. In contrast, animals like fish and terrestrial animals who move about in search of food have an elongated body, differentiated anterior and posterior portions, i.e., distinctive head side and caudal side, which enable them to take the bilateral posture. Furthermore, as demonstrated in animal forelimbs that had changed into fins, legs, arms, wings, etc., there are cases where a shift in behavior under a novel environment facilitates changes in the physical structure. These are generally called homologous organs. The evolution of homologous organs should also be considered rather as a behavioral consequence of animals that had positively acted on their environments, than as a simple outcome of selective pressures from their environments. Roles of behavior in the course of evolution of life must be appreciated.

Animal behavior has the further function of adjusting innate traits and abilities by adapting to a novel external environment. This adjustment simultaneously facilitates the development of animal behavior and triggers evolution. As an illustration, the mole ancestor is considered to have been a small, insectivorous mammal like today's shrew mouse. They are considered to have made their living by actively moving around earth's surface and hunting invertebrates such as insects and centipedes hidden between litter layers or between decaying logs. They had repeated the behavior of scooping the soil away to the side with their forelimbs wide open in their effort to catch their prey on the surface. In the course of time, this habitual behavior had gradually altered the morphology of their forelimbs in a way that is adaptive to their underground life. I believe this is how moles have established themselves as underground-dwelling animals. Behavioral adaptation and adjustment to the environment triggers evolution.

Animal behaviors are not necessarily fixed by their innate releasing mechanism, as there are a variety of flexible behaviors. For example, common ravens in North African disserts are scavengers like vultures feeding on the remains of dead animals, and those in islands in the North Sea feed on eggs and chicks of other birds as do the south polar skuas, whereas those in Central Europe forage for small animals in their return to the dietary habit of crows. This demonstrates that a wide variation arises from the same species, giving rise to divergence. Evolution involves divergence. Animal behavior is exposed to their environments, and the environment is not necessarily the sole author of their trait selection.

Furthermore, animals have the ability to acquire new movements. These behaviors often exceed capabilities required for their living. For example, rich novelties are found in the behaviors of dolphins, as they can create completely new movements such as somersaults, skidding alongside the bottom of the tank, water sliding using tail flukes, etc. all on their own. These creations and leaps give rise to evolution. A finch species that drinks the blood of boobies came to evolve only because a novel behavior created by their ancestral species has become their second nature. Behavior triggers evolution.

Life forms have the active faculty of transforming themselves in accordance with their environments for their survival. Moreover, they actively adapt to their given environments and even modify them. The life is composed of an active system that seeks to thrive. The life is not a passive entity formed entirely by the environment. Not only is life selected by the environment, but it selects its environment. Both the fauna and the flora change their habitats, adapt to a new environment and transform their morphology and physical structure. This is how evolution proceeds. The faculty of spontaneity and activity on the part of life forms, that is, their selective abilities cannot be dismissed.

In this regard, Neo-Darwinism has its own limits as they sought the primary driving forces of evolution only in natural selection and mutation. Neo-Darwinism held that evolution is a matter of the fittest being selected by their environments upon accidental variations, and that acquired traits would never be inherited. Needless to say, they never thought that voluntary action of animals plays any active role in evolution. However, a simple combination of mere accidents for life forms, such as mutations and environmental changes, could not have created precise, purposeful organs like our eyes. To understand it, we must consider the trends of evolution that move purposively to a certain direction, and this cannot be accounted for if we dismiss the roles played by animals' voluntary, adjustment ability and their ability to create new behaviors.

Seen from this perspective, Lamarck must be reevaluated as he understood the importance of the role of behavior in the evolution of morphology. Lamarck thought that a new behavior of animals becomes a new habit, and the shift in their habit generates an evolutionary mutation. Lamarck's idea of inheritance of acquired characteristics has a deeper connotation than on the surface.

Animals are living subjects that gain experience, learn and grow. Behavioral patterns that have been repeatedly exhibited by animal subjects gradually turn into a habit, and the information of the patterns is encoded in the genes to be inherited. Such phylogenetically acquired and preserved information induces evolution. Animals overcome difficulties in their environments through their activities, and the experience thus gained affects their morphogenesis. The role of active adaptation and adjustment of animal subjects, that is, the role of behavior is quite significant. Life forms are not puppets manipulated by their environments. Adaptive capacities of life forms to their environments are their subjective dispositions, and such dispositions inherent to life forms induce evolution.

Animal behaviors and morphology are not necessarily programmed in the genes from the beginning. Instead, we must think that genes themselves "accumulate experiences" as it were, flexibly transform themselves and acquire new characteristics. In other words, a phenotypic variation of learned behavior is, as Piaget suggests, mimicked by the corresponding genotype, which then is transmitted to the next generation. The flow of biological information is not unidirectional, from genotype to phenotype, rather it is bidirectional, accommodating the reversed flow from phenotype to genotype too, and the genomic change proceeds in a spiral manner. That is how evolution takes place.

Animal behavior mediates the interactions between the subject and the environment, leading to the self-organization of a gene network. Evolution involves such internal, self-organizing processes. Behavioral sophistication accelerates the pace of an evolution. We would not be able to understand the occurrence of orthogenesis in biology, if we do not presuppose such evolutionary systematics. In macroevolution of bio-species, gene mutation occurs rather in a successive, systematic manner towards the same direction than in a random way. Simple natural selection cannot account for such a systematic change. Rather, animals' creative selection of their initial behavior propels their self-reinforcement with a certain kind of necessity, leading to emergent self-organization of their morphology. Orthogenesis must be understood along this line of thought.

Role of Cognition

If behavioral evolution leads to evolution in morphology, the role of cognition must be significant as it mediates between behavior and morphology. Cognition bridges the gap between behavioral evolution and evolution in morphology. A leap in behavior leads to a leap in cognition, and a leap in cognition leads to a leap in morphology.

For example, shrews had repeated the behavior of actively scraping out dirt using their forepaws as they had dug soil to forage for insects. In the course of time, they developed an understanding or knowledge of underground circumstances via their forelimbs. As they had repeated this behavior pattern for generations over millions of years, forepaws of shrews had increasingly taken on the form of robust shovels. In this way, shrews had become moles.

Animals develop cognition through behavior and evolve through knowledge. The development of animal behavior accelerates the development of their cognitive capacity, and the development of their cognitive capacity accelerates the development of their morphology. Each animal species slices a unique world off of the World according to the manner distinctive to each species. Developing a unique worldview in this manner is the functioning of object-knowing, and of cognition. Moreover, animals are able to develop a new worldview, as evolution in their behavior assists in obtaining new information and broadening their worldview. To cognize is to acquire information. Information acquisition facilitates their ability to extract novel regularities in the external world, thereby creating novel behavioral patterns according to them. Life forms can store and load them in their genetic network. This is how evolution of life emerges.

Evolutionary epistemology facilitates the development of a new research field that may be coined as informational evolution. Information acquisition is indeed essential to any life form. Plants' ability to discriminate whether an external substance can be absorbed or not, as well as animals' ability to discriminate whether their prey is edible or not, is of great significance for their survival. Life forms cannot survive without cognition. Cognition enables life forms to determine whether a given environment is suitable for their survival and to adapt to their environments. Moreover, it even allows them to modify their environments. Life and cognition are deeply intertwined. To know well is to live well.

Hierarchical leap of cognition

In case of animals, life's disposition to thrive had been expressed as better behavior, better understanding and better morphology, providing more or less refinements in the long history of evolution. In addition, the evolution had proceeded in a hierarchical fashion with the upper layer incorporating and superseding the lower layer. In each of behavior, cognition and morphology cases, animals overcome their previous stage by interiorizing it and develop into a new life form. There, a leap in life or self-transcendence manifests itself. Life in the leap is a self-organizing system or a complex system.

In fact, even amongst prokaryotes or bacteria, organisms that are neither animals nor plants, some are equipped with the ability to move to the direction of food source, while others increase the chance of adopting an avoidance behavior against a harmful substance following exposure to it. For this reason, some bacteria have flagella. Even bacteria recognize an object through their behavior and have a simple physical structure for it.

This becomes clearer in case of protozoa like amoebae and paramecia. Behavior of paramecia, for instance, consists of two simple, conflicting behaviors—approach and escape behaviors, and they are not equipped with the ability to orient their body properly to the direction of a target to approach it. Nonetheless, their behavior is not a simple mechanical reaction to a stimulus from their environment. On the contrary, it is composed of voluntary movements with a certain degree of latitude and flexibility, such as halting, forward movement and backward movement, as they rhythmically move and contract flagella. Paramecia repeat the approach and escape behaviors to identify and judge whether an object they happen to encounter is their prey or an obstacle. Although their judgment is nothing more than a binary knowledge of whether the object is their prey or an obstacle, we must think that primitive emotions such as likes or dislikes and pleasure or displeasure are at work in making this judgment. Even paramecia display a fear response to an obstacle through their escape behavior. On this occasion, paramecia are assessing an obstacle as an object that does not allow them to keep moving further to the direction that they have hitherto been moving to, by moving backward, and when they encounter such an object, they understand it reasonable to avoid it. Animals know things outside them through behavior. Paramecia too promote information acquisition by enhancing their locomotion ability. Paramecia have flagella, excellent locomotor organelles that also serve as sensory organelles, precisely to meet this demand. Using this locomotor organelle, Paramecia perceive the external world and make a rational judgment in regulating their behavior.

Hidra, a Cnidarian species, display more complex behavioral patterns and have an enhanced cognitive ability. When feeding, *Hydra* are oriented toward the direction of the prey, and their feeding behavior in terms of their mouth and tentacles is, albeit reflexive, finely tuned. Through these activities, *Hydra* recognize in minute detail conditions of their prey and water conditions. To meet this demand, *Hydra* have a mouth and about six tentacles in the upper end, and a basal disk in the lower end of their cylindrically elongated body, allowing them to move to another place. The nervous system of *Hydra* is composed of a diffuse nerve net, which is designed to transmit information across the body, enabling their systematic behavior.

In contrast, jellyfishes, another Cnidarian species, can swim freely in seawater by contracting the ventral surface of their bell-shaped body, and rhythmically pushing water out of their umbrella. Their behavior is freer compared to the sedentary *Hydra*. Because jellyfishes have high, free-moving capability, they can actively assess the seawater conditions around them, and have an enhanced ability to recognize their location in the seawater. This accounts for the increased centralization of their nervous system, a nerve ring based central nervous system, as well as the emergence of ocelli and statocysts.

In case of cephalopod molluscs like squids and octopuses have a particularly well-developed perception and behavior regulating capability. Octopuses, for example, exhibit complex postural control capacity, aggression behavior, courtship, nest-building, territorial behavior and homing behavior. Accordingly, octopuses have an excellent cognitive ability to discriminate the shape of a target and identify it, as well as a learning ability to solve maze problems or detour problems after conditionalization. Even snails, a gastropod mollusc, or earthworm, an annelid, can solve simple T-shaped maze problems. If so, this demonstrates that an animal at this stage of cognitive development can process stimuli as signals that have a certain meaning and value. Their highly sophisticated learning ability implies their ability to recognize an object that they are about to encounter, and their readiness to respond to it in advance. In case of octopuses, this accounts for their surprisingly well-developed brain and eyes, seen in light of their morphology, organ and tissue.

Of invertebrates, insects, a class within the Phylum Arthropoda, have the best behavior-regulating capability and environment manipulating ability. In particular, honey bees live a highly-developed social life and display excellent abilities in every respect in terms of navigation, territory protection, homing, learning and communication. In general, highly intelligent insects tend to have a better cognitive map, excel in their learning ability in terms of conditioned reflex, and have the ability to engage in sophisticated behavior associated with communication, which can be described as intelligent behaviors. This accounts for their well-developed brain, sense organs, mouth and legs. In particular, they have excellent sense organs, with acute sense of vision, olfactory sense and tactile sense. Vision alone allows them to perceive a polarized light using their compound eyes, as well as to discriminate colors and shapes.

Vertebrates even in the development stage of fish can find their prey at a distance, chase, approach, attack and capture it. If what they find is an enemy instead of prey, they easily engage in a series of complex behaviors. This accounts for vertebrates' ability to properly orient themselves to the direction of the target, and move close to it or run away from it. Here, the emotions of "joy", "fear" and "anger" emerge each in the foraging, escape and aggression behaviors. Furthermore, animals can take various forms of behavior in relation to a single object. Thus, at this stage of development, the meaning of an object for an animal must be thought to have been expanded from two-valued to many-valued. To this end, vertebrates at the development stage of fish have excellent organs, visual, auditory and olfactory, as well as a well-developed neurological mechanism.

When fish evolves into terrestrial amphibians or reptiles, they are to be exposed to a wider variety of external stimuli with an increased frequency compared to fish, hence, it becomes obligatory for them to accurately identify environmental clues in determining their behavior. Because of this, amphibians and reptiles take a right defensive or a hunting posture and actively engage in exploratory behavior. Here, the predatory behavior may be temporarily suspended, which suggests that the animals now possess an idea of an object. Frogs and snakes must have an image of their opponents in their minds. Amphibians and reptiles have a highly developed locomotor organ and sense organs compared to fish out of necessity for terrestrial living. When animals achieved a leap from life in water to terrestrial life, their forms of behavior were greatly modified, as well as their perception of the world. Radical modifications of their physical structures including the respiratory organ, auditory organ and locomotor organ coincide with these modifications of their behavior and perception.

Mammals, intelligent vertebrates, are especially good at maneuvering their forelimbs and display active exploratory behavior out of their curiosity. As demonstrated in their forelimb maneuver to temporarily hold and play around with the prey using their forelimbs, they develop the ability to possess prey as an idea as if they have captured it in their mouth. Mammals are excellent in learning new tasks, and in designing solutions to issues they encounter primarily because of availability of their forelimbs for many different purposes and the progress in their exploratory behavior. By using their posterior limbs for locomotion and their anterior limbs for touch, animals develop cognitive abilities including the abilities to analyze, modify, recognize and integrate an object.

Apes and humans, intelligent mammals, display an excellent ability especially in the use and manufacture of tools. As for their cognitive ability, they are able to use concepts and a symbolic language, which in turn enhances their insight and reflective capacity. This fact coincides with their ability of holding an object using freed hands.

The evolution of behavior leads to the evolution of cognition, and the evolution of cognition leads to the evolution of morphology, and the evolution of morphology leads to the evolution of behavior. Through a circle of evolution involving behavior, cognition and morphology, animals have sought to thrive in a creative manner. Animals' effort to thrive leads to their effort to know, which in turn leads to the development and evolution of their physical structure.

Merleau-Ponty divided the structure of animal behavior into three levels—"syncretic form of behavior", "amovable form of behavior" and "symbolic form of behavior", and performed an in-depth analysis on their development processes and structures in *The Structure of Behavior*. In the "syncretic form of behavior", behavior is still imprisoned in the framework of natural conditions and so firmly entrenched in what the nature can offer that it cannot be modified. On the other hand, in the "amovable form of behavior", signals emerge in behavior, which are not determined by instinct, and this makes learning possible. Here, animals are released from a fixed, univocal world, which is entrenched in conditions of natural environments presented to them, and their behavior becomes more mobile and equivocal. In the "symbolic form of behavior", the object of behavior functions as a symbol, allowing animals to use tools and language. Of course, three types of behavior do not correspond to specific animal groups, as there are quite a few cases where some behaviors seen in one animal group can fall under one classification, while other behaviors seen in the same group fall under a different classification. 。[4]

If the term evolution is used to denote the spiral emergence of behavior, cognition and morphology, Merleau-Ponty's three types of behavior must be situated in this course of evolution. In this sense, Merleau-Ponty's three types of behavior must be understood dynamically rather than as mere ideal types. In fact, Merleau-Ponty understood his three types of behavior as a series of processes in which the later stage incorporates, unifies and overcomes the previous stage. Evolution of behavior must be understood as a process of yet another self-organizing system or complex system.

What is knowledge?

Evolution of life is a process of gaining knowledge. Take the evolution of animal eyes for an example. It is not the case that animals have developed as sophisticated eyes as they have without reason. To survive in an environment they themselves selected, animals explored the world that surrounded them, while "slicing" sunlight poured over the earth to use it for external information. This accounts for the possibility of evolution of animal eyes as a sense organ. It is not because animals had great sense organs that they were able to develop great cognition and behavior for their survival. It is because they tried to behave and know better for their survival that they were able to develop better sense organs.

The visual function must be understood from the circle of survival, behavior, cognition and morphology. There is latitude which is not necessarily be determined by the environment. In fact, there is a considerable variation in the range of electromagnetic waves sliced by the visual organ of animals, depending on animal species. The range of light sliced by human beings is called visible rays, which occupy only a small portion of the entire electromagnetic spectrum. Some animals can sense, besides visible rays, infrared rays, ultraviolet rays, and even X-rays or γ-rays. In short, animals know the world by extracting amounts of information necessary for the enhancement of their survival and behavior from electromagnetic waves poured over the earthly environments.

Similarly, a wide variation exists in the morphology of animal visual organs. The morphology of animal visual organs ranges from dermal photoreceptors to neural photoreceptors, eyespots, lens eyes and compound eyes. There are also eyes with a convex surface or a concave surface. Some animal eyes are laterally positioned while others' are positioned frontally or above their frontal face. Some animal eyes are mobile, while others' are immobile. Some animal eyes are capable of focusing on a particular object, while others' are not. Eyes of each animal have a form of their own that has arisen out of necessity for their survival at their stage of development.

For example, animals like jellyfishes only have primitive eyespots, yet they can discriminate the direction of the sun and the direction of the sea bed, that is, tops and bottoms, as their eyespots on the upward position receive stronger light than those on the downward position. This is due to the need these animals had of keeping their body position balanced in order to swim well in seawater. Meanwhile, honey bees, with their compound eyes, learned to analyze many rays reflected from flowers, out of necessity to discriminate colorful flowers of angiosperms to collect more nectar. This accounts for honeybees' ability to perceive ultraviolet rays. The structure of the organisms' eyes was developed out of necessity for their behavior and cognition.

Evolution of a precise organ such as animal eyes cannot be accounted for by simple selection pressures by the environment. Instead, the evolution of vision must be understood from animals' willingness to survive in their environments. Vision must be understood from their mode of living, as they engage in behavior in their environment in an effort to know the external world. The evolution of eyes arises from behavior that aims to know.

Evolution is an effort of animals to improve themselves. Evolution takes place through a correspondence between the intrinsic power of animal subjects and their environments. Both behavior and cognition exist amidst interactions between the subjects and their environments, and evolution is impossible without their behavior and cognition. Life forms discriminate their environments in their effort to act on them. The ability to discriminate their environments is their cognitive ability, and this ability brings about the evolution of their morphology.

Cognitive ability is also an ability for information extraction. Life forms select information necessary for them from their environments. To understand for life forms is to select information by virtue of their behavior and to elicit meaning and value necessary for them. Understanding is not a process of receiving information passively from the environment; rather, it is an active process of acting upon the environment and eliciting information from it. Understanding the environment requires the working of active faculties on the part of life forms. Life forms are active systems that seek for a better world for their survival. Their efforts to thrive, behave well and understand the world better also facilitate their evolution. Evolution is not simply a passive, adaptive process.

In the course of interactions between the subjects and the environments, subjects' behavior, cognition and morphology interact in a spiral, circular manner, leading to evolution. Life forms as the active subjects are not passive entities that are subjected to stimuli from their external environment. On the contrary, they actively act upon their environment and even modify it. Life forms in this way change their relationships with their environments. Life and environment have coevolved through mutual interactions. Emergence of cognition in life must be understood in the context of self-organizing evolution.

3 Tools and Cognition

Tool Use and Manufacture

In the course of interactions with their environments, life subjects exhibit their capacity to actively select and modify their environments. Life forms do not just respond reactively to their environments. Rather, they respond actively to the environment and even modify it. Animals do not simply live in an entrenched manner; rather, they explore their environments in virtue of their behavior. Life subjects are voluntary agents who behave in their environments and create a new environment. Herbivores living in the grassland modify the grassland itself. World is in the midst of flux, and that is because of the subjects working towards changing the world.

Too use and manufacture is also an important activity of animal subjects, which links them to their environments.

Animals exploit natural objects either as an intermediary or as a fabricated tool to indirectly act upon their environments. Tools refer to objects outside the user's body, which are used as a means to a certain end. Located amidst the subject and the environment, tools are put to good use by the environment, while, as an extension of the user's body, they play an intermediary role for animal subjects to actively act on their environments. Animals exploit their natural environments as materials and act on their environments for the purpose of obtaining food, caring their bodies, courtship and building a burrow.

If use of tools is understood to encompass use of these intermediaries, the idea that humans are the only animals that use and manufacture tools must be plain false. Not only humans but also animals have a remarkable capacity to use and manufacture tools. A deep gap should not be presupposed between animals and humans.

In fact, even some species of amoebae, protozoans, protect themselves by taking on a shape of a small croquette by covering themselves with sand grains. In this case, sand is a natural object used as a means of protection, is, therefore, a certain kind of tools.

Many insects, arthropods, use natural objects as intermediaries. For example, antlion larvae trap ants by digging a simple pit using sand and if they fail to catch prey ants in their first trial as these ants actively creep across the pit, they throw sand against the prey. In another instance, a certain ant species gathers leaves, pieces of woods and dirt, and uses them as a sponge, by immersing them into liquid food like fruit flesh or body fluid of the prey and letting them absorb liquid with an appropriate amount, and then brings them back to their colony. In cases like these, sand, dirt, leaves and pieces of woods used underwent change in their meaning from simple natural objects to foraging tools.

Birds also use such natural objects as twigs, bark, pebbles and rocks as tools for predation, nest-building and protection. As an instance, a certain group of woodpecker finch picks up a cactus spine or twig using their beak to dig out larvae of an insect or termites, while the blue jay tears a piece from newspaper into an appropriate size and shape, and uses it to rake in food pellets on the ledge near the cage. The egyptian vulture drops a large pebble over an ostrich egg to break and eat it, while the European herring gull carry a clam or sea snail to a rocky area, drops it several meters above the ground, then breaks and eats it. The great spotted woodpecker uses crevices in tree trunk or branch as an anvil to hold acorns and pine nuts when eating them. The striated heron, a species of heron, drops a twig, leaf, small fruit or feather that appears as food for small fish, and quickly pick them when they approach them. Male bowerbirds build an arbor furnished with remarkable decorations by gathering twigs and bark to seduce female bowerbirds. Furthermore, the New Caledonian crow, a New Caledonian native bird species, tears off the edge of a saw-like leave of Pandanus and fabricates and manufactures a sophisticated tool in order to fish and eat insect larvae. Once birds have reached this stage of development, they are capable not only of using tools but also of manufacturing them.

Mammals also use pebbles, twigs and dirt, as tools for predation, nest-building and protection. Gophers dig a hole with a hard material like a pebble holding between their forelimbs, while ground squirrels throw sand grains at a snake. Sea otters swim on their backs at the water's surface and break and eat a clam or abalone with a pebble as a hammer on their chests. Beavers make sophisticated use of tree branches and dirt to build a lodge, burrow, water channels and a dam. Moreover, when the water levels rise, beavers punch holes in the dam to lower the water levels. Elephants grasp twigs using their nose to scratch every part of their body, and when they notice other animals making noise from an adjacent zone, they pick their feces or straw with their nose and throw at them.

Primates have increased insight which allows even more sophisticated tool use and manufacture. For example, chimpanzees break off a branch, clean off twigs and leaves associated with it, insert it into a burrow of termites and retract it, and eat termites that come along with it. Furthermore, they use a variety of different pebbles and anvil stones to crash and open nuts of different types. In other words, they use a variety of different tools to improve tool functionality. Moreover, among groups of chimpanzees living in Senegal, West Africa, there is a group that has the habit of hunting small-sized primates living in a hollow of a tree trunk or branch using a spear they manufactured themselves. Further, in a laboratory experiment, chimpanzees demonstrated their ability to combine two tubes to extend a stick or to use it as a ladder, or to borrow or lend it to rake in distant bananas. They also demonstrate excellent tool-manufacturing techniques. In fact, when they need tools, chimpanzees do as much as tearing off a wire, or ripping out pieces from a crate or wooden boards, or straightening a portion of coiled wires.

Human beings have created tools out of natural objects, cultivated and modified the nature so as to facilitate the ease of obtaining food, of getting warm by the fire, of monitoring their surrounding environments even during the night. These activities must be seen as an extension of activities displayed in animals in general. Animals from insects, birds to mammals, prepare, use and even manufacture tools. Here, acute insight and sophisticated learning ability are at work, which assists in considering means to an end and solving new problems. Animals' abilities for tool use and manufacture are expressions of their power of activity as life subjects that aim to act on and modify their existing environment and create a new one. Behavior delivers a leap in life. Both tool use and manufacture are creative functions of life that open up their future.

Tools and Knowledge of the World

A fair number of animals exploit natural objects that intervene between their body and their environments as tools to engage in active behaviors such as predation, aggression and protection. Tools are an extension of their bodies and are a means of expanding functions of their bodies. Although tools are originally external objects that belong to the environment, if they are incorporated into the body scheme of animal subjects, they become a part of their body. For example, chimpanzees use a twig in their hand as an extension of their arm or hand, and as they become used to using it, they measure distance between themselves with their targets, and "feel" the targets as if their hand has extended to the tip of the twig. Tools are intermediaries between the subjects and their environments as are their bodies. They are also expressions of their power of activity over their environments. Tools as intermediaries extend their physical boundary and broaden their environmental world, thereby exposing them to a broader environment.

On top of that, tool use even changes the meaning of the world. Tool invention originally involves transforming the meaning of the existing environment. Concurrently, it gives rise to a new meaning in the environment. For example, when humans first started using a pebble as a tool for attacking animals, it was only done by transforming the meaning of pebble to that of weapon. Meanwhile, this invention of weapon changed animals that had been stronger and impossible to attack previously into attackable targets. Tool use broadens not only the perspective of humans but also that of animals, and transforms the meaning of objects in their environments. Knowledge of one's environment is awareness of the possibility for action, and tool invention can significantly broaden it. Our behavior exposes us to the world. As agents, humans and animal act on their environments through tool use, and generates new information.

To know is to know by means of one's body and tools. In fact, terrestrial invasion of aquatic animals brought about a great revolution not only in their physical organs but also in their worldviews. Furthermore, when evolution enabled monkeys to use their hands to grasp an object, the world became an object of apprehension for the first time in the history of life. When humans acquired full-blown upright bipedalism, the meanings of up and down, front and back greatly shifted for them. Likewise, invention of tools as an extension of their body greatly shifted the appearance of the world for them, and this demonstrates animal evolution and evolutionary leaps. Both animals and humans invented tools to slice newly discovered meanings from their environments and to transform their knowledge of the world.

Tool invention greatly shifted the meaning or value of objects in animals' surrounding environments. This implies that the entities that exist objectively in the environment do not exhaust the meaning and value of objects in the environment, and some of them are created actively by the subjects. Animal behavior propels active shift in the meaning of objects in their environments, which suggests that the subjects and their environments are inextricably linked.

If we pay particular attention to apes and humans, the fact that hands were freed from the traditional means of locomotion and developed into an organ for tool usage and manufacture is of great significance to them. Their hands acquired the functions of grasping and fabricating objects, which enabled them to develop a new form of understanding of objects. In particular, when humans acquired full-blown habitual bipedalism and completely freed their hands for tool use and manufacture, their relation to the world became freer than ever. Thus, humans began to see their environments as an object of their manipulation as they invented stone tools, arrowheads, digging sticks. Tool manufacture brought about a great revolution in the worldview of humans.

When humans acquired the ability to apprehend an object, they became aware of themselves. The development of self-consciousness requires a viewpoint that is dissociated from and transcends the given environment, and this viewpoint is deeply related to tool manufacture. "The I think" (cogito) presupposes "tool or item manufacture". The development of cogito must presuppose poiesis (manufacture). Mere thinking or contemplation does not constitute Cartesian cogito. "Manufacturing" must be at work under the backdrop of "thinking". The ability to manually manufacture things is the origin of self-awareness. When a person becomes aware of himself, he is rather dissociated from his egocentrism and is decentered. He can detach himself from his physicocentric orientation imposed by the world and learns to see himself and objects in the world from another perspective. There is a profound association between this decentralization and tool manufacture. Similarly, mere Cartesian thinking would not account for the subject-object division.

Technology and Science

Technology is the application of the ability to fabricate and alter the environment, by actively exploiting it via tools and machines. There, the power is at work of going beyond a given environment to seek for the place of one's self. There is a profound connection between the drastic development of human skills and their worldly awareness. When humans first discovered the use of fire, their worldview must have undergone a radical change. Objects take on a new appearance for humans through technology. As seen in birds' nest-building, humans have created a new world to live in through technology.

Technological advancement has largely contributed to the advance of scientific worldview attained by humans. The advance of geometry would be impossible without the advance of surveying techniques, and the transition from geocentrism to heliocentrism would be impossible without invention and improvement of telescope. Prevalence of clocks gave rise to the mechanistic worldview, and invention and improvement of steam engines encouraged the development of thermodynamics. The science of the day receives its paradigm from the technology of the day. Human knowledge is often limited by the level of technological development of the day. Knowledge produces technology and technology produces knowledge.

Modern science was driven by the experimental spirit. Use of experiments in modern science was an attempt to collect the substance of technological findings of the day, to project their own activities onto the nature, and to elicit a response from the nature.

Here too, the subject of action and the environment as a respondent were not separated. Even modern natural sciences were not entirely driven by the spirit of Cartesian dualism between human and nature, subject and object. On the contrary, scientific effort was pursued based on the spirit of non-separation between the subject and the environment. It is not hard to find examples in which phenomena observed in experiment led to a new scientific theory, as seen in chemistry, electromagnetism and thermodynamics. Moreover, technology usually played a significant role in these experiments.

The method employed by modern science was to obtain experimental data through observation of nature and build a theory based on them. The level of technological advancement in observation instruments and measuring instruments greatly affected how the theory was formed. Scientific knowledge is determined by the availability of observation methods of the day. To put it another way, technological progress in the observation instrument from optical microscope to electron microscope, and optical telescope to rockets for space observation has greatly changed our worldview as well. The progress of space rocket technology has increasingly expanded our image of the universe, transforming our image of its appearance. We cannot predict how this will lead to new theories in the future. Relativity theory which lays the foundation of the contemporary cosmology and the worldview provided by quantum mechanics may not reign permanently.

Schemes and hypotheses employed by humans or animals are subject to change with the discovery and manufacture of tools, which in turn shifts the meaning of objects in their worlds. Both humans and animals observe the external world by exercising their body, tools or intermediaries to know the external world and modify their scheme and hypotheses accordingly. In particular, the more intelligent animals become, the easier it becomes for them to modify their schemes and hypotheses, and the freer it becomes for them to change the meaning of objects in the world. Freedom lies in the revisability of the schemes and hypotheses.

In this sense, human knowledge as well as animal knowledge is not perfect. Even in the course of human scientific endeavor, if scientific hypotheses do not coincide with the experimental or observational results, then they may be largely transformed. This is another way of causing a paradigm shift in natural science. In this case, advancement in tools and technology play a pivotal role.

History of scientific endeavor is a history of human exploratory behavior. Just as animals know their worlds through exploration of their surroundings, humans try to find new meaning of objects in the world by observation and experiment. Moreover, deriving new meaning of objects in the world invokes another novel observation or experiment, which in turn generates new awareness in humans. Sciences must be understood as disciplines created and developed through the behavior-cognition circle. Both humans and animals know the world through behavior and perform behavior through their knowledge of the world. Evolution takes place in the behavior-cognition circle.

Interactions between subject and environment

Knowledge arises within the interactions between the subject and the environment. The subject and the environment limit each other and are interlinked. Cognition is a relation between the knowing subject and the environment known. Since both the subject and the environment move from one place to another, thereby shifting their relations, we must think that the correspondence between the moving subject and the moving environment underlies knowledge.

Cognition is neither a simple reception of stimuli nor mere products of subjectivity. The environment does not determine subject's knowledge, and the subject does not construct knowledge of the environment. The subject is not an entity detached from the environment, rather it is within the environment and is part of the environment. The subject is a living subject that gain experience and grow in the environment. The subject comes to know the environment by engaging in activities in the environment. The subject and the environment do not exist independently. Cognition emerges in the knowing subject in the midst of interactions between him and the world to be known.

Cognition is a form of activity. The function of cognition is for the subject to act on the environment through his behavior, to slice pieces from the environment, and to attribute a new meaning to them. Cognition is an act of the subject in the environment. The knowing subject behaves in the world and knows the world. Behavior and cognition are inseparable. Both behavior and cognition emerge only because the subject lives in his environment. The subject and the environment form a unity through mediation by behavioral cognition. The knowing subject is not an entity independent from the world, and the world is not an entity independent from the knowing subject.

The subject and the environment are themselves the processes of interactions. The subject acts on the environment and the environment acts on the subject, leading to spiral shifts in both the subject and the environment. Here, a circle is operative of the subject acting upon the environment and then being acted upon by the environment. Behavior and cognition are involved in the circular process between the subject and the environment and they themselves run in a circle. Sensation, perception, memory and thought must also be understood within this circle. Both the development and the evolution take place in the circular, developmental process between the subject and the environment. Life subjects know the world through behavior and develop themselves through knowledge. Moreover, this development and evolution exposes the life subjects to a new world, and both their behavior and understanding achieve a leap to a new stage. This is how life subjects create their environments. Environments create subjects, and subjects create environments. Environments build subjects, and subjects build environments. Such interactions facilitate self-organization of both the subjects and the environments. Sensation, perception, memory, thought, development and evolution must be understood from a new light as self-organizing systems or complex systems.

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