Simultaneous cognitive origin of life and information

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Abstract: Shannon's information quantity, *I(E) = log (1/P(E))*, is defined under the assumption of the existence of "cog nitive subjective entity" capable of judging yes/no or occurred/non-occurred of an event E (which occurs with a probability *P(E)*). Final acceptor/user of information is a living individual, although first and/or intermediate sender(s) and/or acceptor(s) of information may be either living individual(s) or non-living element(s) or man-made machine(s). Thus we can conclude that information is a most essential character of living individuals, and that information and life must have had simultaneously emerged as "minimum cognitive system (MCS)". Since then, living individuals/lives must have evolved as "self-improving learning neural network machine" capable of "active evolution". How MCS could have emerged was discussed. Not only cognitive origin and evolution of life, but also active evolution of cognitive organisms were concluded as basic, general evolutionary principles.
Keywords: origin of information, semiogenesis, minimum cognitive system, active evolution

I. INTRODUCTION

Biotic systems are full of "information" [1][2], but the question, "what is information ?" is not fully answer -ed in biology as well as in other areas of information sciences. In this paper, the origin and evolution of information systems and semiotic systems were analyzed from evolutionary and cognitive viewpoints. The results strongly suggest that information-accepting ability is an essential character of life, and information and life seem to have simultaneously occurred by the emergence of earliest cognitive life. Semiogenesis would have generated efficient biomachines which are bio-individuals.

II. ORIGIN OF INFORMATION

Shannon's "amount of information", *I(E) = log (1/P(E))*, is defined under the assumption of the existence of "cognitive subjective entity" capable of judging yes/no or occurred/non-occurred (= 1/0) of an event E (which occurs with a probability *P(E)*). Final receiver/user of information is a living individual, although first and/or intermediate sender(s) (=outputter (s)) and receiver(s) of information may be either living individual(s) or non-living element(s), or man-made/ organism-made machine(s).

Let us consider some examples of information systems.

Example 1. Solar light energy (photon) $h\nu$ ($\nu = \nu_0$) is received as information for driving a bioenergy-aquiring proton-pump by bacterioro-dhopsin of an archean,*Halobacterium salinarun* [1]. In this case, initial sender of $h\nu_0$ information is the sun, a non-living entity, and the information is recognized by thelivin g archean with using its information-receiving molecular tool or machine (receptor), bacterio-rhodopsin. The sender of the information is a non-living thing (the sun), and the last receiver (acceptor) of the information is the living individual of an archae-bacterial uni-cellular organism which can use a protein -tool or protein-machine for receiving the $h\nu_0$ – information, which is further converted to bioenergy inside the uni-cell individual via proton-pum p. The $h\nu_0$ energy was not "information" before the emergence of bacterio-rhodopsin-possessing archaea, and the end-user of this information is the living uni-cell organic individual. Therefore the origin of the $h\nu_0$-information occurred when archaea first possessed or made the $h\nu_0$-utilizing bacterio-rhodopsin.

Example 2: A unicellular individual of a eubacteria, *E. coli*, receives DNA codon-information from its intra-cellular DNA derived from the previous generation, by using intracellular information-processing molecular machines called mRN A s . The sender of codon-information is the DNA derived (via cell division) from the uni-cell individual of the previous generation, and the final user/receiver of the DNA-information is the living uni-cell organism capable of using mRNA and other RNA-machines and protein-enzymemachines.

Example 3: A multicellular human individual utilizes solar $h\nu_{00}$ light-energy($\nu = \nu_{00}$) by using green-sensitive rhodopsin molecules embedded in the membrane of green-sensitive optic cells in human's optic organ. The final user of the $h\nu_{00}$-energy information is the living multicellular human individual. Note that optic cells as well as green-sensitive rhodopsi n s a r e not living individuals, and do not actively use the $h\nu_{00}$-photon information.

Example 4. In vocal conversation between two persons, both of the first sender of vocal information and the last receiver/user of the vocal information are living human individuals, who can actively use the finally

received information.

Example 5. In radio-broadcasting of various sounds, the first sender(= outputter) of the sound-information is either non-living entity/element or a living organismic individual, and inter-mediate information-receivers and intermediate information-senders are also either non-living entity or living organic individuals, as well as man-made information-processing machines which are biotic (or human) cultural products. The last information receivers/acceptors being end-users of the sound-information are living human individuals possessing acoustic organ, "ears".

From all of these Examples 1-5, end-users of information are unexceptionally living organic individuals, every of which is the unit of Darwinian natural selection. Thus, "information" is a kind of value for the living individual in increasing Darwinian fitness. Before the emergence of life, any end-user of information did not exist, and therefore, any "information" cannot be reasonably defined for pre-biotic world. Information-using is an actively cognizing behavioral process of living organic individuals.

In conclusion, "information" first emerged simultaneously with the origin of life (= the origin of living individuals capable of evolving via Darwinian natural selection). This means that "information" is a most essential feature of life itself, and that life and information have had emerged simultaneously. A most important problem for finding the origin of life is, therefore, how to know the earliest "minimum cognitive system" which possesses information-using faculty. How "minimum cognitive machine" could have emerged is an important problem remaining to be solved.

II. ORIGIN AND HIERARCHICAL EVOLUTION OF INDIVIDUALITY

Biotic individuals such as unicell bacteria and multicellular animals are actively behaving entities which are units capable of evolving via natural selection. Throughout evolution different levels of individualities have had evolved, and every behaving individual is well-made biomachine having cognitive information-processing systems [3][4].

In modern living organic individuals, unicell bacteria and haploid uni-cell organisms are lowest levels of individuality, confirming that unicell organsmic individuals having one set of DNA genes are earliest living-organisms immediately after the emergence of DNA-type genetic machinery. Any of living organic individuals before the emergence of DNA has not yet been known to date. Emergence of unicell diploid individuals is the first hierarchical evolution of individuality, as has been discussed by Maynard Smith [5] and Dan-Sohkawa [6]. Multicellularization of unicell diploid and/or haploid individuals is the next step of hierarchical evolution. The so-called super-organism of bee or other hymenopterran eusociety is the most highly evolved

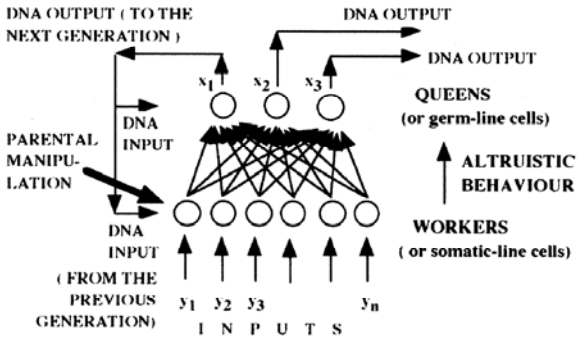

Fig. 1. Hierarchical neural network-type biomachinogenesis generating upper-leveled individuals via Altruistic sociogenesis (Modified from [3]). Bee-superorganisms and multicellular individuals are compared. DNA-flows make a hierarchical neural network machine possessing feedback DNA flows. "Parental manipulation" such as *Polytes* maternal manipulation and *Drosophia* bicoid-mRNA seems tofunction as "teacher information" in man-made learnin g neural network machines.

level of hierarchical individuality [3].

Paralell hierarchical evolution of individuality has occurred in generating bee-super-organismic individuals and multi-cellular animal individuals, as illustrated in Fig.1. Queen-worker-type hierarchical (eu-)society such as bee society is known to have evol -ved by kin selection [7]. Since relatedness (r) between workers and queens(=worker's younger sisters) is 3/4 of DNA (r=3/4), such altruistic behavior is considered to be equivalent to DNA-information flow from workers to queens, as shown in Fig. 1. DNAs outputted by gametes of queens are further inputted to the workers and queens of the next generation via fertilization, which makes feedback DNA-flows from the queens of present generation to the workers and queens in the next generation.

Similar DNA-flows can be found in multicellular animals in which each animal is originally an altruistic queen-worker-type hierarchical society of uni-cell animals consisting of queen-type germ-line cells (=queen-cells) and worker-type somatic cells (= worker-cells). Hamilton considered multicellular animals have had evolved via altruistic behaviors of worker-cells (= originally, uni-cell animals) to queen -cells [7].

In animals, multicellular individuals are considerd to have evolved via an early super-organismic kin society of uni-cell animals. However, the evolutionary results show that upper-leveled (multi-cellular) individuals really live and behave as active evolving organisms, and that germ-line cells and somatic cells are elements or parts of upper-leveled living individuals. This is very similar to bee-superorganisms, which strongly suggests that "worker-bees and queen-bees are not living individuals, and are elements or parts of super-organisms. The living individuals are bee-superorganisms.

Parallelisms between bee-superorganisms and multicellular animal individuals are much more striking, as shown in Fig.2, where the well-known bee-dance system for collecting pollens and honey is compared with the *Aplasia* simple neural system. Worker-bees coming back to hive and making dance (=sensory bees) well correspond to sensory neurons (= worker-cells) in *Aplasia* siphon system, and bees receiving dance-language correspond to *Aplasia* motor-neurons (worker-cells). The dance language being a semiotic signal corresponds to synaptic molecular signals evolved as semiotic signals. Thus, dancing bees and dance-recognizing bees are "sensory bees" and "motor-bees", respectively. Semiogenesis generating bee-dance and *Aplasia* synaptic molecular signals must have had important roles for the genesis of biomachine consisting of queens(or queen-cells) and workers(or worker-cells). Neurons are not living individuals, and quite similaely, bees are not living animal individuals. Bee-superorganisms are "genuine living bee-individuals".

In Fig. 2, Aplasia neural system is evidently a "cognitive system" for accepting water-flow information and making adaptive muscle-moving. Very similarly, bee-dance system is also a "cognitive system" of bee-superorganism for accepting pollen-information and making adaptive pollen-collecting movements of motor-bees. The parallelism between these two cognitive systems tells us "how biotic cognitive systems could have had evolved." Semiogenesis is very essential for making efficient biomachinogenesis.

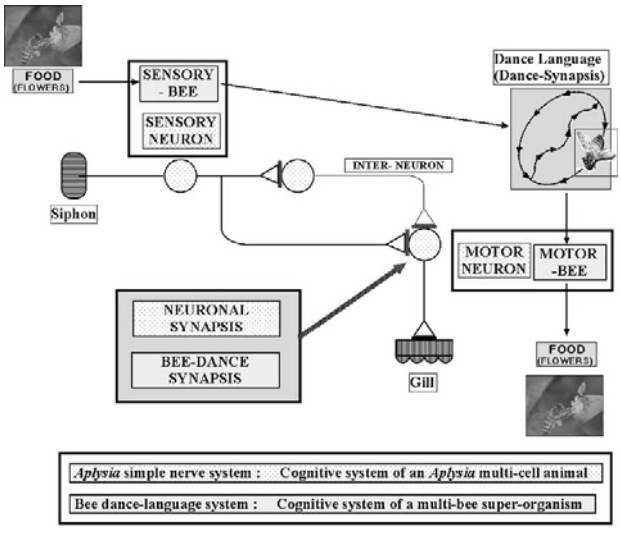

Fig.2. Close similarities between the *Aplasia* nerve system and the bee dance-language system.

II. BIOTIC INDIVIDUALS AS THINKING MACHINES

Returning to Fig.1, we can find that the DNA-information flows in the hierarchical superorganismic biomachine suggest that biotic individuals would be a cognitive machine similar to a hierarchical neural network machine. In the case of the eusociety of *Polystes* (hymenopteran), maternal manipulation to daughter wasps makes daugtters be worker-wasps. Similarly, earliest determination of embryonic cells in Drosophia depends on the gradient of the concentration of maternal mRNAs (such as *bicoid*-mRNA). These maternal effects are very similar to the so-called "teacher-information depending on feed-back information" in learning neural network machines, as shown in Fig. 1. Thus the scheme in Fig 1 suggests that these superorganismic biomachines would have evolved as "hierarchical learning neuiral network biomachines". Such biomachines can input enviomental and intra-body information, and output DNA information as schematized in Fig.1. Accordingly, repeating of generation is a "thinking process" of the individual, which is a cognitive neural network machines. Thus "thinking" of the well-made cognitive bio-machines must have improved biomachines in generating the present-day well-made bioorganisms. Repeting of generations of such learning biomachines is thinking processes of organisms. Now we have reached to a clear answer to the important question,"Who made the well-made biomachines ?", proposed by Dawkins [8]. The answer is that "Biotic individuals have had "actively" made and improved the well-made biomachines by "thinking" via repeating generations.

The essential difference between autopoietic/active bio-machines (= biotic individuals) and man-made learning neural network machines (NNwMs) are the difference of teacher-information (TI). TI is given from outside by man-made program in man-made learning NNwMs. However, as shown in Fig.1, IT is included in the biotic system, and therefore, bio-individuals can actively self-improve their own individuals (=bio-machines) by repeating generations. Thus, bio-individuals are cognitive self-improving leaning NNwMs. The NNwM in Fig.1 is not a simple 2-layered NNwM capable of performing "linearly separable" cognitions, but a multi-layered complex NNwM capable of performing "non-linearly separable" cognitions, because every element of the both layers (= queen-layer and worker-layer) in Fig.1 is originally a cognitive (uni-cell or multi-cellular) living individual possessing intra-individual neural networks of information-flows. Hierarchical sociogenesis is thus considered to make an efficient multi-layered neural-network bio-machine via semiotic function.

Uni-cell organisms also have intracellular complex information networks capable of inputting environmental and intracellular information, and adaptively outputting various kinds of information. Thus unicell organisms are also considered to be cognitive machines which are complex thinking NNwMs. Accordingly we have reached a conclution that

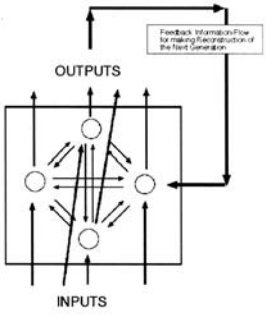

Fig. 3. Generalized model of biotic individual possessing intra-individual cognitive complex neural networks of info rmation flows and feedback information-flows.

living individuals are cognitive NNw bio-machines which can actively think/consider and self-improving. Accordingly, evolution is "active thinking process" of living organisms, resulting in "active evolution".

A most generalized bio-individual consisting of complex NNwM possessing feed-back information flow from present to the next generation is schematically shown in Fig. 3.

Furthermore, diploid "species" can be considered as a "hierarchical super-neural network machine shown in Fig. 4, where multi-cellular male and female diploid individuals are input layer, and haploid gametes (ova/sperms) are output layer elements which make feedback DNA-flows to the next generation. The "species really exists as a probabilistic neural network machine, which is also a cognitive biosystem capable of thinking and improving to make more adaptive bio-systems and eco-systems.

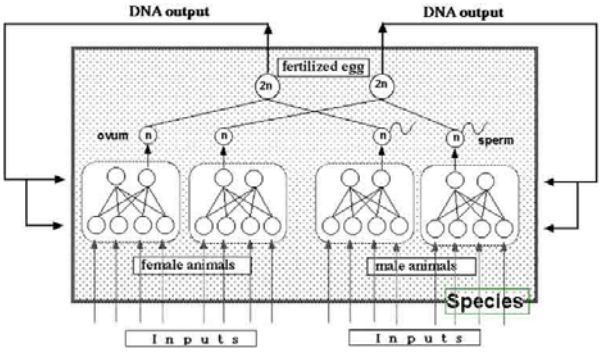

Fig.4. Hierarchical probabilistic neural network machine model of diploid species.

III. EMERGENCE OF "MINIMUM COGNITIVE SYSTEM" AS A FIRST LIFE

The question, "What is first life ?", needs to be re-considered from the aspect of above-mentioned cognitive life. "Information" emerged simultaneously with the emergence of cognitive individuals as the last receiver(or acceptor)/user of information. For efficient bio-individuals to evolve as thinking bio-machines, semiogenesis must have been important throughout evolution.

Early evolution having generated "minimum cognitive system(MCS)" needs to be analyzed from various aspects. An interesting approach is to analyze the emergence of MCS from simple harmonic oscillator, $F^2x = -\omega^2 x$, where $x = (x_1, x_2)^T$, $F = (a_{ij})_{2,2}$, in which $a_{22} = -a_{11}$, $a_{21} = -(a_{11}^2 + \omega^2) / a_{11}^2$, and where x_i and a_{ij} $(i,j = 1,2)$ are real numbers or real functions. This model gives a MCS-like oscilla -tor, as shown in Fig.5, as has been recently discussed. See legend of Fig.5 and ref. [8] for details.

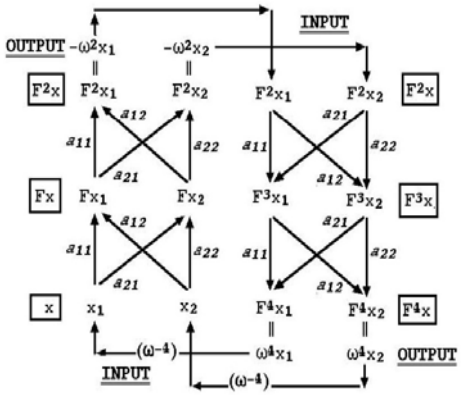

Fig. 5. Three-layerd neural network-like structure of generalized harmonic oscillator system, where $F = {}^t((a_{11}, a_{12}), (a_{21}, a_{22}))$, where $a_{22} = -a_{11}$, $a_{21} = -(a_{11}^2 + \omega^2)/a_{12}$. By letting $Q_s = F^4$, and $w = \omega^4$, we find that Q_s and w satisfy a self-replication equation, $Q_s\, x = w\, x$. If $\omega^2 = 1$, then F^2 is a complete self-replication operator. $x = F^0x = (F^0x_1, F^0x_2)^T = (x_1, x_2)^T$; $Fx = F^1x = (F^1x_1, F^1x_2)^T = (a_{11}x_1 + a_{12}x_2, a_{21}x_1 + a_{22}x_2)^T$; $F^kx = (F^kx_1, F^kx_2)^T$, where $F^kx_1 = a_{11} F^{k-1}x_1 + a_{12,}$ and $F^kx_2 = a_{21} F^{k-1}x_1 + a_{22} F^{k-1}x_2$.

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