
THE ORIGIN OF NATURAL SELECTION ON THE SPOT

KOICHIRO MATSUNO

ABSTRACT. Darwinian natural selection is an incontestable principle of evolutionary processes, as epitomized in the form of differential reproduction of heritable traits. Still, it remains open as to how each of the reproduction and heritable traits could emerge on a material and empirical ground. Addressing the issue of the origin of natural selection focuses upon some physical and chemical processes underlying biology, without smuggling those components and structures already established in the discipline. One candidate for such enterprise is the evolutionary occurrence of a cycle of chemical reactions functioning as a heat engine, a harbinger organization exclusively within physical and material origins. Heat engines of natural origin are functional both in maintaining the internal tendency for feeding upon energetic resources and in utilizing for itself the resources taken. Inevitable limitedness of available energetic resources puts the faster heat engines in resource in-take and more efficient in its utilization on a more evolutionarily advantageous cutting edge. Heat engines of a natural kind that are already selective in their operation can serve as evolutionary precursors of biological organizations subject to natural selection.

KEY WORDS. Natural selection, reaction cycle, heat engine, resource take-in, efficiency, thermodynamics, recursive time, flow equilibrium, association-dissociation.

INTRODUCTION

The significance of Darwinian natural selection cannot be overemphasized. One witness underpinning such significance in the comment raised by Richard Dawkins on the remark made by Fred Hoyle:

A junkyard contains all the bits and pieces of a Boeing 747, dismembered and in disarray. A whirlwind happens to blow through the yard. What is the chance that after its passage a fully assembled 747, ready to fly, will be found standing there? So small as to be negligible, even if a tornado were to blow through enough junkyards to fill the whole Universe (Hoyle 1983).

In response, Dawkins made this comment:

Fred Hoyle was a brilliant physicist and cosmologist, but his Boeing 747 misunderstanding, and other mistakes in biology ... suggest that he needed to

Nagaoka University of Technology, Nagaoka 940-2188, Japan. / CXQ02365@nifty.com

have his consciousness raised by some good exposure to the world of natural selection. At an intellectual level, I suppose he understood natural selection. But perhaps you need to be steeped in natural selection, immersed in it, swim about in it, before you can truly appreciate its power (Dawkins 2006).

A key agenda at this point is how we can conceive natural selection. If one picks up a fossil record over the geological time span, no doubt we could see the occurrence of natural selection in the products, as Dawkins emphasized. Evolutionary products are certainly selective. However, if one focuses upon what is occurring right in the process of natural selection on the spot, as Hoyle eloquently called our attention to such a situation, it cannot be subsumed under natural selection in the products. Natural selection in the making is going to act there. It is just more than what natural selection in the products would imply, since natural selection in the making does not dismiss from the outset the case, such that the process itself, in addition to the products, could be selective. We would need to be steeped in natural selection in the making if so is required to respond to Hoyle's concern more seriously.

In particular, any biological organism processes an organized assembly of gene products. Even the most primitive unicellular organism called *Methanococcus* possesses about 1 700 gene products of roughly 1.7 million base-pairs length, perhaps close to the minimum necessary for supporting living organisms in an independent manner (Patterson 1999). At issue is the selective nature latent in the organized assembly of the gene products. Both the genes and the gene products are products of the assembly process. Addressing the assembly products is certainly in accordance with the differential reproduction of heritable traits, rather than the inheritance of acquired traits, due to the built-in stipulation of the gene products following the gene instructions. Nonetheless, the assembly process could maintain some room for exercising a variable selectivity as it goes through precipitating both the gene products and the genes themselves by means of a DNA replication, whose fidelity may not strictly be a hundred per cent perfect.

A likelihood of the selective capacity latent in the assembly process is much broader than what biology may imply, since an organization processing a material assembly is also conceivable in the realm of physics, even without invoking biological processes. A case in point is a material organization called a heat engine entertained in the framework of thermodynamics.

HEAT ENGINE

A heat engine conceived within thermodynamics is a material organization feeding upon energetic resources and accordingly transforming them

into useful work circumventing its direct transference into heat dissipation. Of course, although the original conception of a heat engine owing to Sadi Carnot in 1824 was an engineering artifact, its naturalization could be straightforward as demonstrated, for example, in the build-up of a tornado in the tropical zone, feeding upon the high-intensity sun radiation available there.

What is unique in a heat engine of natural origin is its self-perpetuating tendency as a material organization, even prior to the advent of biological organizations (Matsuno 2006). Since available energetic resources are always limited, as seen in the energy flow density of the sun light per unit surface area on the Earth, a likely heat engine would be one that could be faster in the resource in-take while beating the slower contenders at the same time. There would be neither resources' leftovers nor chance of self-perpetuation for the slower contenders. Moreover, self-perpetuation may further be enhanced for those heat engines that could be more efficient in utilizing the acquired resources for their own self-perpetuation, for example, through multiplication of heat engines of the similar kind. There is no chance for those heat engines that are less efficient in utilizing the acquired resources for their self-perpetuation when competing with the one that is more efficient.

A heat engine of a natural kind is marked by its selective capacity favoring the faster resource in-take and its more efficient utilization, even without invoking evolutionary processes specific to biology. This perspective may provide us with an opportunity to develop a heat engine of physical nature in order to better understand biology in general or natural selection in particular.

CYCLE OF CHEMICAL REACTIONS

One possible vehicle for testing the likelihood of the selective capacity latent in a heat engine of a natural kind to be exemplified through material assembly is to appeal to experiments in the laboratory. One candidate for the stated objective could be the elongation of an oligomer synthesized from component monomers, such as an oligopeptide from amino acid molecules in prebiotic environments. A plausible site for a prebiotic synthetic reactions that proceeds prior to the onset of photosynthesis must be near the hydrothermal vents in the primitive ocean, where the energy needed for forming chemical bonds could be available in the form of heat.

These considerations will make us set up in the laboratory a flow reactor simulating a hydrothermal circulation of seawater from a hot vent to a cold surrounding environment, and back to the vent repeatedly (Matsuno 1997). One central point of the present experimental protocol is recruiting the energy necessary for realizing the material assembly in the form of

chemical bonds when the reactants are positioned in the vicinity of a hot vent. The resulting products may be stabilized once they are transferred into a cold environment due to a rapid quenching proceeding. As a consequence, the repeated presence into the hot and the cold regions in succession may enhance the likelihood of the elongation of oligomers when the starting reactants are monomers of some kind.

When we choose amino acid glycine as the initial reactant and circulated it across the temperature gradient set between 230°C and 0°C in a repeated manner, oligopeptides made of glycine up to its hexamer were identified in the products in the presence of divalent copper ions serving as metallic catalysts (Imai, et al. 1999). Oligopeptides in the elongation process inevitably undergo a partial decomposition into shorter oligomers through hydrolysis, while the partial decomposition can eventually be compensated by letting the shorter ones further bind to the component monomers available from their surroundings. One can thus observe the elongation in the process as an instance of exchanging the component monomers in that the decomposed shorter oligomers recruit the new component monomers from the neighborhood when they are further elongated.

Elongation is anabolic even on the physicochemical level. It is anabolic in associating the component monomers into the oligomers to be elongated. The present anabolism reveals that the elongation in the process constitutes a cycle of chemical reactions as it lets the preceding reaction products to be the succeeding reactants in a cyclical manner. Accordingly, such a reaction cycle can be viewed as a form of heat engine transforming the thermal energy latent in the reactants into the binding energy upholding the resultant products.

Once a heat engine embodied in oligomeric elongation is set in motion, the more likely-elongation could be the faster one in the resource in-take, competing with the possible contenders. An evidence of experimental nature is available from a simulated hydrothermal circulation of reactants, including both glycine and alanine as the starting ones (Ogata, et al. 2000). The predominant initial dipeptides were glycylalanine; however, once the resources for synthesizing glycylalanine were depleted and alanyl-glycine appear in the reaction solution by whatever means, it started dissecting and feeding upon the pre-existing glycylalanine for its own growth. Although alanyl-glycine cannot compete with glycylalanine for feeding upon monomeric glycine and alanine, it can regard glycylalanine as a resource to be fed upon for its own growth, once the monomeric resources are depleted. Underlying the vicissitudes of heat engines is the domination of the faster resource in-take.

Needless to say, the faster resource in-take, that is anabolic, is one major aspect of the material assembly in the physical domain, which may function as a precursor for a material assembly of biological nature. Moreover,

one major aspect in utilizing the elongated products is for enhancing the assembly process more efficiently. Utilization of the elongated products through their disassembly is catabolic. While the anabolic process puts the normal environment on the lower temperature side of a heat engine involved in the resource in-take, the catabolic process in turn puts the normal environment on the higher temperature side of the heat engine utilizing the resources taken in. At this point, those less efficient in utilizing the energy stored in the elongated products for the succeeding assembly cannot compete with those more efficient. This selective characteristic touches upon another theme of the operation of a heat engine, that is, its operational efficiency.

TOWARD HIGHER EFFICIENCY

The efficiency in extracting useful work from a heat engine operating between two heat reservoirs at different temperatures is limited by the ratio of the temperature difference between the two to the temperature of the higher side. Since the elongated products are found in the normal environment at ambient temperatures, the likely heat engine acting upon the products may be required to decrease the temperature of the lower side as much as possible to increase the operational efficiency. A possible scheme for decreasing the temperature of the lower side may be conceivable from consulting contemporary biochemical processes.

Biochemical processes are full of enzymatic reactions using ATP molecules as their effectors. For instance, consider the synthesis of carbohydrates from carbon dioxide and water in dark process of photosynthesis utilizing ATP molecules synthesized in light process. At issue is the transformation of the energy stored in the phosphate bonds of the ATP to the energy stored in the covalent bonds of the synthesized carbohydrates. One possible way to enhance such transformation efficiency is to make the energy release from ATP as slow as possible. Since the slower energy release implies to let the amount of each energy quantum carrying the transformed energy from ATP to be smaller, the effective temperature of those low energy quanta, when randomized and read out by a radiation thermometer, would also be reduced.

When the actin-activated ATPase activity of a myosin molecule is focused upon as a typical example of enzymatic reactions hydrolyzing ATP molecules, the time required for releasing energy from one ATP molecule can be prolonged even to orders of 10 milliseconds. It would be equivalent to emitting a train of microwave photons of roughly 100 MHz continuously over 10 milliseconds (Matsuno 1999). When these microwave photons are randomized, the effective temperature would reduce down to roughly 1 milliKelvin. This, however, by no means implies that the

enzymatic reactions would proceed at such a low temperature; quite the contrary, the actual enzymatic reactions proceed at the normal ambient temperatures. At issue is that the enzymatic reactions can radiate and dissipate such low-frequency microwave photons toward the deep outer space from the thin surface of the Earth. Deep outer space is in fact almost transparent to the low-frequency microwave photons and can serve as a heat bath absorbing them while maintained effectively at the temperatures as low as 1 milliKelvin.

Enzymatic reactions utilizing ATP can reach out to deep outer space for disposing the used and randomized microwave photons. A physical means for radiating the low-frequency microwave photons around 100 MHz is the rotational movements of the orientational dielectric polarization latent in enzymatic molecules incorporating into themselves polar amino acids such as arginine, glutamic acid and lysine.

Energy disposal in the form of microwave photons of frequencies around 100 MHz can thus furnish enzymatic reactions utilizing ATP as effectors with a heat engine operating between the normal ambient temperatures around 290 K and an extremely low temperature as 1 milliKelvin, letting its maximum operational efficiency to be greater than 99.9 per cent.

ASSOCIATION AND DISSOCIATION

Both facilitating the faster resource in-take and attaining the greater efficiency in resource utilization are the two principal characteristics of the evolutionary heat engine unique to reaction cycles. Implementation of these two characteristics is to proceed through generating variations. Instrumental to the precipitation to the selective characteristics is the generation of variations. At this point, reaction cycles are suggestive in incorporating into themselves a scheme of generating variations through molecular association and dissociation.

What characterizes a reaction cycle of natural origin is its affinity extended toward those molecular resources present in the vicinity of the cycle, while at the same time suffering from its constant partial dissociation. The identity of a reaction cycle is thus kept in those molecular relics, surviving inside the cycle passed over from the preceding stage; though those relics would have to eventually be alternated by new ones entering into the cycle at the later stages.

In particular, the functional competence of a reaction cycle is seen in the interplay between the associative or anabolic molecular flow and the countering dissociative or catabolic one. Robustness of a reaction cycle rests upon an equilibrium between the two opposing flows, otherwise it would either go into extinction or cease to be a cycle. Furthermore, since

there is no material scheme for securing the flow equilibrium between the associative and the dissociative molecular flow in a synchronous manner, molecular flow equilibration as a process is a norm (Matsuno 1989). Although it is constantly involved in eliminating the flow disequilibrium, molecular flow equilibration is generative in precipitating the further flow disequilibria to be eliminated subsequently.

A reaction cycle is thus passively agential in exercising this capacity of molecular flow equilibration, manipulating its own chemical affinity extended toward the molecular resources to feed upon, while constantly revising the similar acts made at the preceding stages. As a consequence, the role of time here is recursive, the past acting upon the present.

CONCLUDING REMARKS

The recursive nature of time makes the genesis of variations selective, in accordance with the material necessity of the molecular flow equilibration in any organism as an integrated whole of reaction cycles. This selective characteristic is certainly consistent with the differential reproduction of the heritable traits, rather than the inheritance of acquired ones. The identity of an organism as a form of reaction cycles is necessarily partial, due to the underlying material process of on-going molecular association through its constant partial dissociation.

Specific to the recursive nature of time from an evolutionary perspective is the built-in framework that makes possible natural selection in the products to be in conformity to natural selection in the making. Once the recursive time, which is dynamic and generative, is frozen and registered in the record, a linear progression of time can emerge. This reflection reveals one significant aspect of evolutionary processes pointing to the nature of time, namely whether time is recursive or not and, if recursive, how linear progression can emerge.

REFERENCES

- Dawkins, R. (2006), *The God Delusion*, London: Bantam Press.
- Hoyle, F. (1983), *The Intelligent Universe*, London: Michael Joseph.
- Imai, E., Honda, H., Hatori, K., Brack, A., and Matsuno, K. (1999), "Elongation of oligopeptides in a simulated submarine hydrothermal system," *Science* 283: 831-833.
- Matsuno, K. (1989), *Protobiology: Physical Basis of Biology*, Boca Raton FL: CRC Press.
- Matsuno, K. (1997), "A design principle of a flow reactor simulating prebiotic evolution," *Viva Origino* 25: 191-204.
- Matsuno, K. (1999), "Cell motility as an entangled quantum coherence," *BioSystems* 51: 15-19.
- Matsuno, K. (2006), "Forming and maintaining a heat engine for quantum biology," *BioSystems* 85: 23-29.
- Ogata, Y., Imai, E., Honda, H., Hatori, K., and Matsuno, K. (2000), "Hydrothermal circulation of seawater through hot vents and contribution of interface chemistry to prebiotic synthesis," *Origins Life Evol. Biospheres* 30: 527-537.
- Patterson, C. (1999), *Evolution: Second Edition*. Ithaca NY: Cornell University Press.