From "Function Designing" to "Bio-Environment Designing"

***Naohide TOMITA**, D.Eng.,D.Med.Sci., M.D.*

Kyoto University

Part 1 : Biological functions

It is difficult to design an artificial shape and a function for use in the body. Designed shapes and functions sometimes ruin the surrounding tissue, because they disorder the adaptive self-remodeling of living tissue. For example, if a fractured thigh bone was supported by a rigid fracture plate for a long time, then the strength of the supported bone reduced gradually because of disuse bone atrophy. This thought to be an example that the function of thigh bone was ruined by artificially designed function. Our theme is "Bio-Environment Designing" which is thought to be the key concept for successful tissue-engineering treatment and advocates that the object of designing is not the biological functions but the environments.

As living things show a proper shape and a function in proper environment, bio-environment setting has been commonly used in several fields such as agriculture and so on. On the other hand, function designing is a dominant concept of engineering where the function is analyzed and reconstructed in an optimized structure. Back-grounds for the bio-environment setting are rather teleological, but that for designing are mechanical. Fundamental methods for the "Bio-Environment Designing" are similar to that for the bio-environment setting, but do not based on only teleological arguments. So, before explaining concrete methodologies of the "Bio-Environment Designing" this part discuss what the biological function is, and what essential difference is between “interaction” and “function”.

Evolution of memory systems

There would be some adaptive interactions which could be seen in the relationship between continuous diversity and environmental change as shown in Fig. 1(a). This kind of adaptation or function-like shape can be seen in some crystal growth, Conway's Game of Life, and so on. Each diverse interaction is not a function itself, but shows adaptive action when certain shapes are selected in environmental changes. These inorganic or electronic interactions may appear functional, but I suppose that many readers hesitate to recognize them as functions.

One characteristic of the biological functions is having memory systems. If time-series cascade such as the bio feed back loop shown in Fig. 1(b) had been acquired and responded to the environmental changes then the system obviously may be called function. This adaptability to the environmental change has a short-term memory system. Some types of long-term memory systems such as the gene or the brain system may be acquired by the same token as shown in Fig. 1(c). They might be the highest functional mechanisms acquired in living thing which have complex structures including sensors and programs and show efficient and strong adaptation to the environmental change. The long-term memory systems also have some complex and prodigious functions.

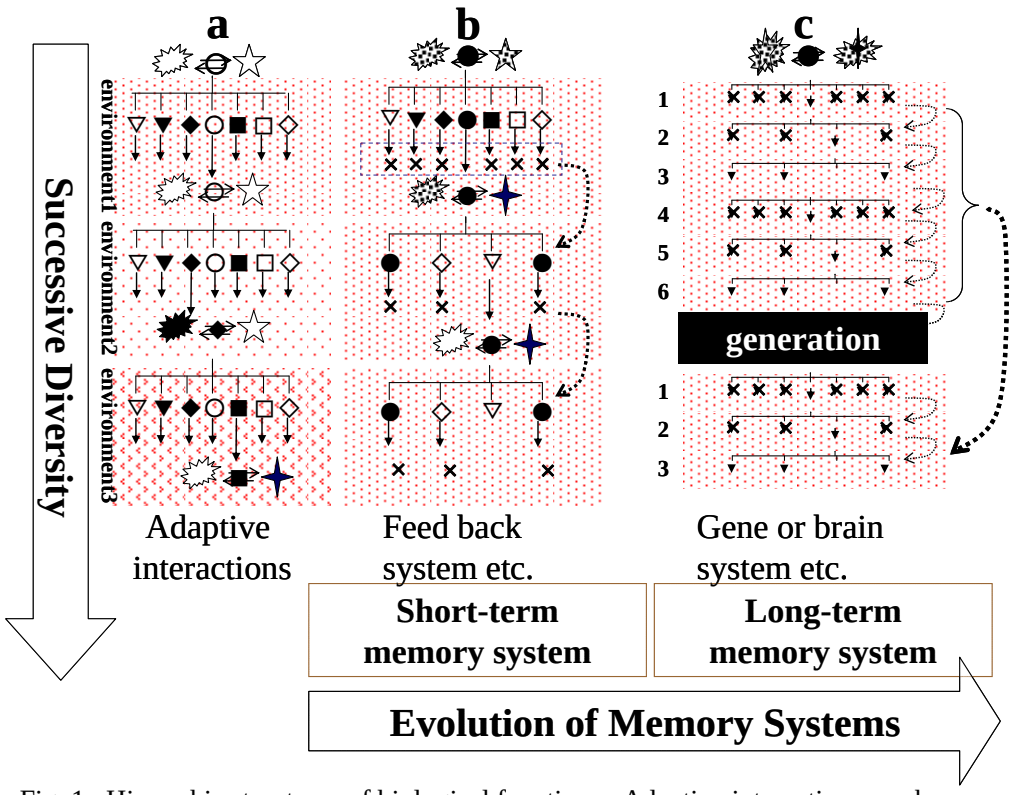

Fig. 1 Hierarchic structures of biological functions. Adaptive interactions can be seen between environmental change and diversity as shown in (a) process. Short–term memory systems such as feed-back system (b) would be acquired as a biological function which shows an adaptive function. Long–term memory systems such as gene or brain system(c) might be acquired by the same token. The long-term memory systems show some complex and prodigious functions.

If making an unnecessary additional comment on Fig. 1, it is not necessarily the case that the memory system is typical for all the living things. If all the noninvertible phenomena could be the physical memory system, the meaning of Fig.1 would lead us to a delusional idea that all the phenomenon including time itself is observed by interaction between non-serial information (such as coherent process) and serial information (such as noninvertible process). The diversity essentially is caused by coherent process. For example, if the interactions of cellular automaton are set one by one in the “Conway's Game of Life”, we cannot see the wonderful diverse shapes and movements. However, scientists should not think thus far, because it leads us to Zen riddles which cannot be expressed logically. I will go back to the logically-acceptable assumption that the memory system shown in Fig.1 is confined to a general “biological” category.

Essential difference between “interaction” and “function”

Then, what is the difference between “interaction” and “function”. Both depend on physical matters or phenomena, but teleological words are often used for explanation of biological

functions such as ”What purpose that this shape appears?”, or “What function does the protein serve?”. Some people think that “function” is an objective attribute. However, semiotic considerations teach us that the functions exist through interpretation. For example, speed itself is not a function if there is no interpretant. Speed is one physical attribute of interaction measured by distance and a certain time scale. However, if a person wanted to arrive somewhere by a car quickly, then the speed would be a function of the car interpreted by this person. Functions of a spoon depend on whether the interpretant is a baby or a magician. So the functions depend on the users criteria notwithstanding what function is intended by the designer.

Biological memory systems are not the objects of designing but milestones for nurturing function

The "functions” as they are known in the engineering field are imitations of the biological functions, and interpreted by human’s brain. For example, a function of the automatic pilot system for a helicopter is to control the flying route. So the function may be assessed by the accuracy of its flying route. But imagine the function of the swallow’s flight, which should be assessed by other criteria such as catching worms or escape from crows. The swallow’s function should not be interpreted by human criteria but by a swallow’s criteria. The swallow’s brain system would be an interpretants of these functions. However, considering that biological function (for example that of protein) has multiple meaning by tissue type, by time, and by the amount of each, the assumption that “the network of biological memory systems are the interpretants of function” would explain the ambiguity and complexity of the biological functions. And, this assumption lets the scientist to design the bio-environment easier. The "Bio-Environment Designing" is not mere “setting” based on teleological concept, nor some arrogant bio-function designing, but scientific methodologies designing the environment to nurture the biological functions in it. The memory structures such as gene expressions, feed back loops and so on, are not the objects of designing but milestones of the nurturing. If the biological functions have its interpreting standpoints on each memory system, we should not change the standpoint so easily using arbitrary translation to our brain-system’s meaning. Our knowledge on the memory systems have not reach to such a high level, but to just the alphabet level.

REFERENCES

Concepts

1. Tomita N., :From "Function Designing" to "Bio-Environment Designing"(Japanese) Maruzen Tokyo (2005). 富田直秀, 機能設計から生体環境設計へ. 丸善(2005)
2. Tomita N., :Bio-Environment Designing for Biomaterials. (Japanese), Zairyo 53(1) (2004), 91-94.
3. Tomita N., Basics of Bioengineering Ⅰ～Ⅲ, New Diamond, 21(3) (2005), 38-41. 21(4) (2005), 47-50. 22(1) (2006), 53-56.
4. Tomita N., Bio-absorbable materials and Bio-Environment Designing. (Japanese), 生物工学会誌, 83(5) (2005), 227-229.
5. Tomita N., Concept of Environment Designing and its application. (Japanese), 臨床リウマチ, 17(1) (2005)
6. Tomita N., Bio-Environment Designing (Autopoietic machine as methodology) . (Japanese), 骨・関節・靱帯, 17(3) (2004), 269-274.

Articles

7. Yamamoto K, Tomita N, Fukuda Y, Suzuki S, Igarashi N, Suguro T, Tamada Y., Time-dependent changes in adhesive force between chondrocytes and silk fibroin substrat. Biomaterials, accepted.
8. Chueh S, Tomita N, Yamamoto K, Harada Y, Nakajima M, Terao T, Tamada Y., Transplantation of Allogenic Chondrocytes Cultured in Fibroin Sponge and Stirring Chamber to Promote Cartilage Regeneration. Tissue Engineering, 13 (2007), in press.
9. Seto Y., Tomita N., Harada Y., Sakoda H. and Takakura Y., Regenerated Soft Tissue Survival Using Repulsive Force of Magnetized Devices: Preliminary Report. J. Orthop. Sci., 11 (2006), 58-63.
10. Harada Y., Tomita N., Nakajima M.,Ikeuchi K. and Wakitani S., Effect of Low Loading and Joint Immobilization For Spontaneous Repair of Osteochondral Defect in the Knees of Weightless (tail suspension) Rats. J. Orthop. Sci., 10 (2005), 508-514.
11. 山本浩司，門林義幸，中嶋正明，富田直秀, 生体環境設計のための状態還移モデルの作製. 日本臨床バイオメカニクス学会誌, 26 (2005), 291-296.
12. Wakitani S., Aoki H., Harada Y., Sonobe M., Morita Y., Mu Y., Tomita N., Nakamura Y., Takeda S., Takeshi K. Watanabe K., and Tanigami A., Embryonic Stem Cells Form Articular Cartilage, not Teratomas, in Osteochondral Defects of Rat Joints. Cell Transplantation, 13 (2004), 331-336.
13. Aoki H., Tomita N., Harada Y., Hattori K., Sonobe M. and Suguro T., The Report of the Cartilage Regeneration Using Total Joint Regeneration System (Internal-fixator type). Bio-Medical Materials and Engineering, 13(4) (2003), 411-417.
14. Harada Y., Tomita N., Wakitani S., Mii Y., Oka M. Tsutsumi S., Use of Controlled Mechanical Stimulation in Vivo to Induce Cartilage Layer Formation on the Surface of Osteotomized Bone, Tissue Engineering, 8(6)(2002),969-978