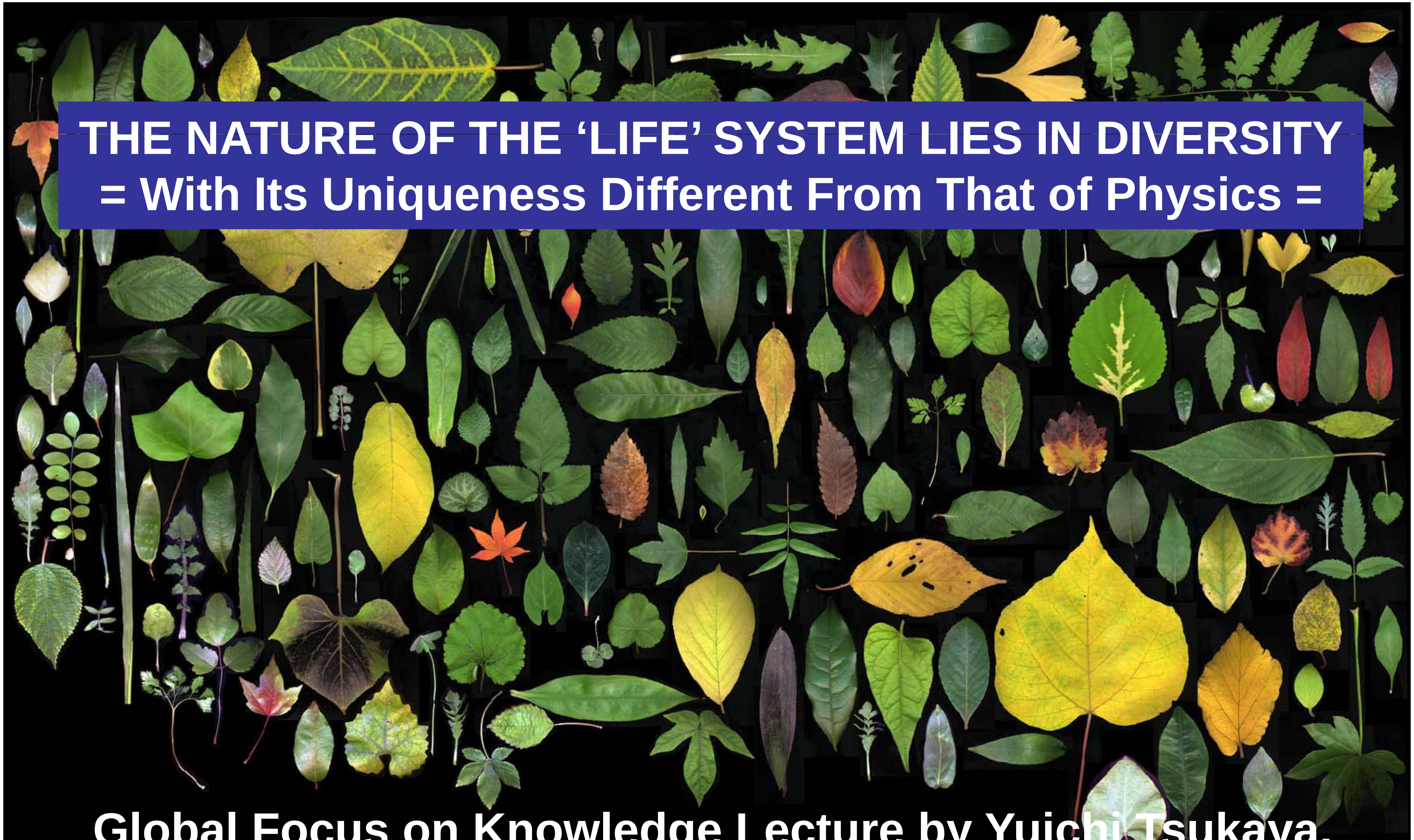
THE NATURE OF THE 'LIFE' SYSTEM LIES IN DIVERSITY
= With Its Uniqueness Different From That of Physics =



Global Focus on Knowledge Lecture by Yuichi Tsukaya,
Biological Scientist, School of Science,

The University of Tokyo, April 8, 2009

In ancient times, people resorted to theology and philosophy as their way of thinking.

In time, physics emerged and grew to be a model of the way of thinking in natural science.

In some disciplines of physics, it is assumed that absolute truth exists; i.e., thinking that everything in the universe is born by itself from this only one absolute truth.

On the other hand, biology, having no common principle that is the only one and absolute, tended to be treated with contempt for being a mere “enumerativism.”

The only “basic principle” admitted was “the principles of genetics.”

However, they were considered a lower-level concept, different from the so-called “principle” in nature as referred in physics and chemistry, for they were nothing but a nature naturally deduced from an assumption that the genes were discrete type factor.

Compared with physics and chemistry, biology was regarded as developing immature knowledge, lacking in universality and fundamentals.

However, at the end of the previous century, genetics unveiled genes to become molecular genetics, and in the process, it was found that **all** lives were controlled by a common mechanism, i.e., common codes on the DNA, as well as by “central dogma” of DNA-RNA-protein.

Physicists who assumed the existence of “common principle” there began to join biology.

There is no doubt about their contributions.

However, not a few physicists had misconceptions:

Misconceptions that living things have definite common principles from which everything is born.

Such misconceptions were noticed when they estimated the DNA structures, i.e., the genetic codes, as well as when they supposed any mechanism of such codes.

Some physicists thought:
“Propagation has characteristics that it is transmitted steadily over hundreds of years and it is the system which creates orders from orders against the increase in entropy.”

How should they be in order to be translated from DNA to protein? George Gamow, eminent physicist, made theoretical studies with other leading researchers, radical in the field of physics, these physicists including Delbrück and Feynman who, too, were well-known.

However, almost all of their abundant hypotheses missed the point. Deciphering the genetic codes was eventually done by biologists who carried out experiments with “living things.”

What was wrong then?
Are physics and biology so different from each other?

On the other hand, in biology, too, a new style became the mainstream, since the rise of molecular genetics, where biologists concentrated their studies on particular “model organisms,” contrary to conventional “enumerativism.”

Further, the studies that would look back to individual properties, as well as to diversities, prevailed, based on the research findings with model organisms, though in a way of follow-ups.

Then, what do individuality and diversity mean to biology? Is enumerative biology really immature as a science?

The above two points will now be introduced and discussed during this GFK lecture.

Firstly, why model organisms? What are model organisms?

→ Biology has been aiming to explore rules similar to those in chemistry and physics, denying natural history by itself.

("Unifying principles")

→ The result was <u>molecular genetics</u>.

(Discovery of the mechanism common to all living organisms: Genetic codes, → Central dogma: DNA→ RNA→ Protein)

"If it is true with Bacillus coli, it is true with an elephant."

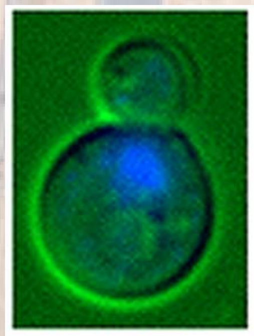
→ Studies conventionally made with discrete materials were now integrated into a model organism of Bacillus coli first.

Thus, research in “molecular genetics” made progress and the basic mechanisms of living organisms became clear more quickly than ever before.

However, as it was known more, living organisms proved to be quite rich in variety (e.g., prokaryotes vs. eukaryotes, mono-cellular organisms vs. multi-cellular organisms, etc.).

More and more cases began to show that the rules that were true with Bacillus coli were not true with an elephant. It was still even further from understanding humans.

So, as the second best approach, representative "models" were established for each group of organisms to find out unifying mechanisms common to each group.



eukaryote model

plant model

arthropod model

mammal model

For example, thale cress (Arabidopsis thaliana) as model plant…

Advantages of thale cress as model:

▸ The plant is small and easy to cultivate indoors homogeneously;

▸ Its genome size is the smallest among the known;

▸ It is easy to grow and can grow under indoor fluorescent lights;

▸ Short in life cycle (approx. a month and half);

▸ Being self-fertile, genetic analyses are easy.

Results:

▸ Deciphering the genome already completed. (130 million base pairs: the smallest among the known);

▸ International cooperation system established. (The stock center and the website maintained/ International conference held annually);

▸ Researchers' population increased rapidly, leading to development in research.

Thus, thale cress became the species with the most advanced knowledge among all plants.

- **For example: The research history of thale cress is so short in terms of the mechanism of floral bud formation and just over ten years ago, many people thought it was a very unfavorable material for study, compared with the morning glory which had long been used to observe floral bud formation.**

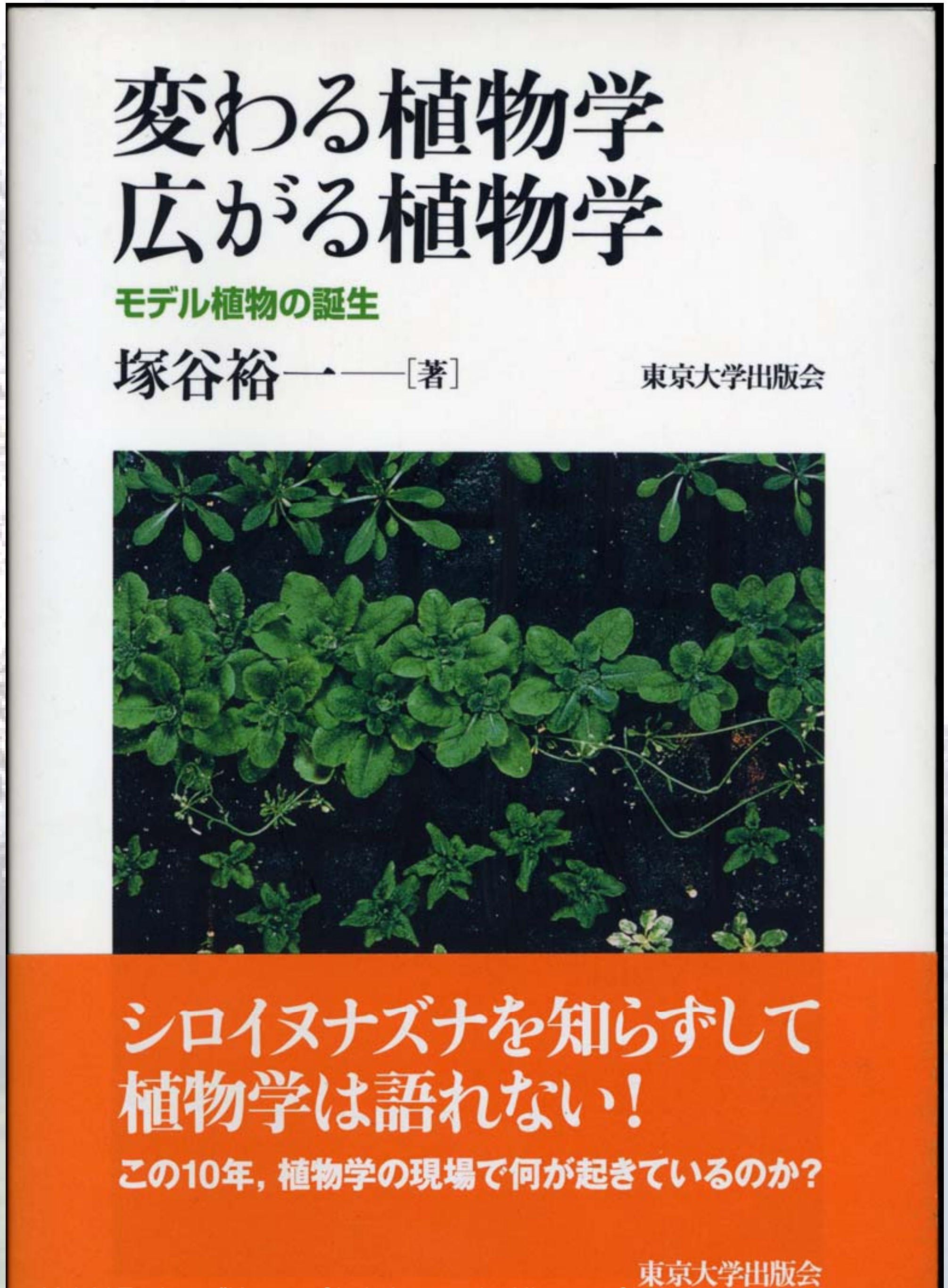
However, once they started to study…

The advantages of thale cress as model plant, on which the studies were concentrated, easily surpassed its short history. You may even say that, in terms of the mechanism of floral bud formation, almost nothing has been known about the morning glory, compared with the findings about thale cress.

However, thale cress is not all-purpose.

Refer to the textbook on the right for the history and advantages of thale cress as model organism, as well as its limitations (i.e., questions not cleared by thale cress or knowledge exclusively applicable to thale cress).

The point of this textbook is that knowing thale cress alone doesn't mean that one knows all plants.



‡Yuichi Tsukaya "Kawaru Shokubutsugaku Hirogaru Shokubutsugaku (Changing Botany, Expanding Botany)" University of Tokyo Press

The more the studies with model organisms showed the detailed mechanisms about each life phenomena, the more it was highlighted that organisms had their own inherent characteristics by taxon, or even by individual organism.

On the other hand, any "model species" proved to have a mannerism peculiar to that species or its close taxa, that is, no such living organisms exist that could be formed by the basic systems alone that would integrate all organisms.

Since diversity is the very nature of living things, as noted above, you should not make a quick judgment that the phenomena just seen are the basics of organisms, even when you have established any "model organism" convenient to your study.

After all, even such model species is a kind of eccentric in various points, when seen from the whole organisms, as it has the inherent nature peculiar to that species.

→ Thus, thale cress was downgraded from a plant model to a spermatophyte model, and then to an eudicots model.

Model plant species added →

Gramineous plant model = rice plant

Legume plant model = bird's foot trefoil

Bryopsida model = physcomitrella patens subsp. patens

Hepaticae model = marchantia polymorpha

…and so on.

As you see, various models were set one after another and genomic analyses began to be worked out with them all.

Illustration from *Honso Zufu*: Bird's foot trefoil:

Near future image of studies with model organisms:

Now that technology has developed to the point where the time required for complete sequencing for a certain organic species was shortened and its cost reduced, it has become possible to analyze genomes of all organisms.

…Revival of 〈enumelativism〉?

On the other hand, for preceding model species, abstraction and solution of genetic networks are under way, including the initiatives to build virtual organisms on the computer.

Science of diversity = ‘Resurgence’ of natural history

In the meantime, not a few physicists and philosophers believe in “theory of everything” that could be expressed in a simple mathematical form, the only and absolute one.

To such people, living things might be, after all, an existence to be described some day in their theory of everything. If so, such diversity in organisms means nothing.

For instance, in 1954, when Einstein was asked by a man how he would feel if he had found that the ultimate rule of nature was not simple, he replied that he would not be interested in such a rule.

But, does the theory of everything really exist?

“Physicists in the past who sought after the process to simplify and integrate worked it well. … However, there is no ‘reason’ that things have to become simpler. They might have become more and more chaotic, more and more tangled.”
Sheldon Glashow

In fact, Kobayashi-Masukawa Theory, which asserted there were six types of quark, was ignored at first, as it increased the number of elements too easily, but it proved to be correct, as you see it was nominated for the Nobel Prize last year (2008).

Is it at all necessary that the ultimate rule of nature should be simple?

Speaking of the universe, too many physical constants seemed favorable to make the existence of human beings possible. Therefore, even an “anthropic principle-like” thoughts used to get into circulation in physics that the world was made to make this possible.

However, in recent years, the idea has grown stronger that the universe is not only one but rich in variety and our space just happens to have such properties.

This kind of “diversity” or “contingency” is very natural way of thinking in biology, while there seems to be many physicists and philosophers who cannot fit in this idea.

Incidentally, when these ideas of “theory of everything” or “anthropic principle” work to the utmost, the world of science fictions like *Theories of Everything* (written by Greg Egan, translated by Makoto Yamagishi) will be created.

‡ Greg Egan（2004）”*Banbutsu butsur(Theory of Everything)*”Tokyosogensha

As you will realize after careful discussion, the only absolute “theory of everything” is at risk of being replaced by the absolute God with the slightest change in thought. It must be the reason why so many highly-intelligent people from physics got absorbed in questionable religions and cults.

Also, some physicists insists: “Western science has got bogged down. We need a new science now, adopting oriental philosophy.” (Incidentally, he is not a scholar! Instead, he is a real pro physicist who represents his discipline in Japan.)

However, seen from the biologists’ point of view, it is but a misunderstanding. It only means that the “science” the physicist worked on in the past was something like religion and the direction in which he will be aiming is the real science which biologists have long been seeking after.

Surprisingly enough, however, this point does not seem to be known to the public.

Recently, the Asahi Shimbun published an article as follows…:

From the book-review column, The Asahi Shimbun, morning edition, February 8, 2009

NTRODUCTION TO COSMOLOGY

Why the Universe Is What It Is

by Katsuhiko Sato

Article removed due to copyright restrictions

Incidentally, Mr. Katsuhiko Sato, professor emeritus, at The University of Tokyo, referred to in this book-review, once mentioned: “Science by biologists seems to differ from our science.” **(NIKKEI SCIENCE, April number, 2004)**

Sato: I’m not sure if it is to answer or not, but I have felt that the culture in science differs a great deal depending on the area of expertise.
Sena: When did you feel so?
Sato: When I was invited to a preparatory meeting for the establishment of a certain science museum, something like the concept of science came up as a topic of conversation. When I said at that time I was pursuing truth to solve cosmic questions, a biologist said there existed no truth and in fact they were only studying mechanisms or systems of nature. I was very surprised to hear him saying, as if it were a pseudo-scientist that would utter a word like “truth.”

Sato: However, we, physicists, quite simply believe in it, a belief that there is truth in this world, following which the world goes on. Of course, I don’t think we would know everything in the world, once we’ve learned the ultimate truth.

In cosmology, for instance, the laws of physics are something like warps and various mathematical phenomena are incorporated as woof, including quantum fluctuations and chaos. Indeed, this interesting world has emerged from fluctuations between necessity and contingency. But I still believe that there is truth in this world and this knowledge makes us realize the world. That’s a theoretical physicist.

Furthermore, there are some among philosophers who cannot fit in "contingency" or "evolution":

"Debate boiled up here again. To conclude, according to them, there happened to be circadian rhythm reactions, which were more favorable to biological bodies than other rhythms, so it was possible for them to survive. In any way, unless they answered so, they would have to assume that protein or cyanobacteria perceived earth rotation in some way or other. Of course, I can understand their situation well, but my brain is not satisfied somewhere and the signal '?' is still blinking.
The theory of 'evolution as results' is likely to stop thinking."
UT ODYSSEY, Yasuo Kobayashi, UP Magazine, September issue, 2008

Mr. Kobayashi is professor of formative culture, Interdisciplinary Cultural Studies, Graduate School of Arts and Science, The University of Tokyo.

Practice is better than precept. Now, realize diversity.

In the first place, the reason why complex life like that of human beings was born is because living organisms are on the system that creates diversity. Otherwise, living organisms should have remained primitive lives or stayed at the bacteria level. That’s evolution.

Indeed, complexity of genome, to be “outlined” first in this lecture of Global Focus on Knowledge, reflects “the evolution by contingency” itself behind such diversity.

The cell mediator system that follows, too, is not so logical nor simple as is led by a single “principle.”

And the “brain” to be discussed finally: Activities of the brain, as you see it here making excuses, are the product brought in as the results that living organisms gradually added to diversity in the course of contingent evolutions. If nature of the living organisms lies only in common principles or in necessity, such a special organ as the human brain will no longer be worth studying. The nature of life is in diversity, as well as in contingency that produced it.

Biology based on diversity is not only important in basic studies. It is also important, or even more important, in applied biology.

WHY?

Here, let us discuss about what basic knowledge is required to improve useful plant varieties, including crops. For instance, suppose that you have a plan to improve a rice variety. The knowledge required is, in fact, not the knowledge about unifying basic mechanisms, common to all living organisms, from amoebae to men, that recent molecular biology has been pursuing.

It is, of course, essential as basic knowledge, but what is actually necessary and useful is not such knowledge, but genetic-level understanding of characteristics and properties of that rice variety to be improved.

More specifically, suppose that you want to improve a rice variety at hand so that it can keep its leaves from hanging down.

What is necessary then? Is it an understanding of a mechanism common to all "from colon bacillus to an elephant," e.g., an understanding of the process that produces protein, from DNA to mRNA, as molecular biology has been aiming at?

Or an understanding of the control system for leaf forms that every plant species has?

What is required here is the genetic level understanding of the reason why that rice variety has long leaves, unlike those of morning glory, and why their tips hang down.

Even if such understanding is only applicable to rice plants, it is still an important understanding and there is no reason to criticize it as 'enumerativism.'

Here again, for example, suppose you've got a plan to make your rice plant have salt-resistant properties.

In this case, is it enough to just examine the rice plant, or thale cress alone about which studies are most advanced among other plants at the moment?

Of course, you can expect a certain progress from them, and in fact, you will see some progress, but the objects to be examined are the plant species that have developed to thrive even in an environment with a higher concentration of salt in the natural world.

In human medicine, too, analyses of the genetic background of "individual difference" have been made in large scale via SNP analysis based on gene sequencing.

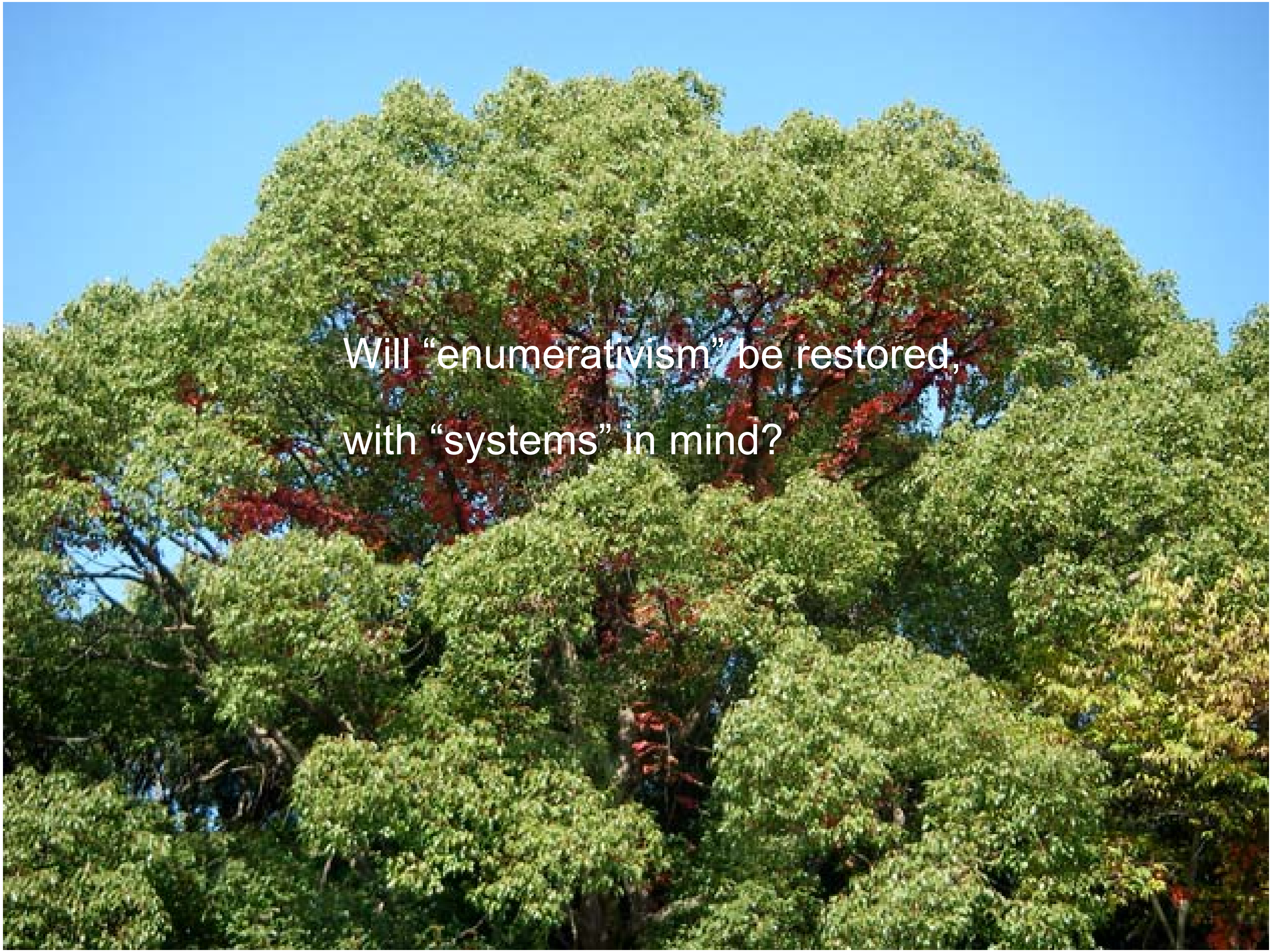
One of the achieved goals to be noted is custom-made prescription to suit individual difference in the effect of therapeutic medication.

Conventionally, therapeutic medication has been roughly administered as "equal to all," on the assumption that a mechanism "common to human beings" exists, without any consideration to individual differences, only except weight and sex. However, neither the number of medical accidents, nor the degree of those tragedies due to such medication should be neglected.

Individuality and diversity are practically very important points for living organisms.

Biology is now finally going to be released from the groundless inferiority complex resulting from lacking in a unifying principle.

Biology based on diversity and contingency is indeed **real science**.


Will “enumerativism” be restored,
with “systems” in mind?