# Theory of Biology

Presented at scientific evaluation on Sept. 9, 2013 for SAB of the Institute of Biotechnology, University of Helsinki

Biology is in need of a theory. Data from genomics, transcriptomics, proteomics, metabolomics and phenomics are pouring in, but the data alone will not advance our understanding of life. Yet, my demand for a theory may seem groundless. Do we not already have a theory of life?

Evolution by natural selection is a catching narrative, but when without a firm mathematical form, it does not qualify as a theory, at least not for a physicist. Surely the tenet has transformed since Darwin to the modern evolutionary synthesis, and we hope today that numerous organismal, cellular and molecular details would someday somehow amount to the whole. Strangely though, our increasingly specialized studies seem only to have shattered Darwin's general perception of evolution.

Therefore I claim that the problem is not that our knowledge is not yet precise enough, but the problem is that our knowledge is not general enough. Conceptually we have all along been going in the opposite direction where we should have gone. In other words the deeper we wander into mechanistic aspects of nature, the less we see the forest for the trees.

To find our way on a grandstand view of nature we should not ask ourselves how evolution proceeds, but we should ask why evolution takes place. Some of you surely worry now whether I am after some teleological explanation. I am. Not by rehearsing philosophical arguments, but bringing up compelling evidence that animates differ from inanimate in no way.

In fact we see superb similarity among living and non-living. For example, lengths of genes distribute in the same skewed manner as lengths of words. The functional form is the same, only parameters differ from organism to organism and from language to language. Animal and plant populations, irrespective of a species, spread out in ecosystems in the same manner as economic wealth, irrespective of assets, spreads out in societies. Chemical reactions and economic transactions proceed at times in an oscillatory manner toward stationary cycles such as citric acid cycle and annual cycles of agricultural production. Also, a cyclone whirls in a temperature gradient in the same way as a galaxy spirals in the universal curvature. Moreover, the spiral shell of nautilus has just the same shape as lava flows that have solidified on Martian ground. Ecological succession proceeds in the same way as technological progress, that is, from one step to another along a sigmoid curve. Production of goods fans out in the same way as phylogenic tree of species branches out. Furthermore, neural activity recorded from cortex displays a power-law pattern just as seismic activity recorded from Earth's mantle. A metabolic network across a cell displays the same degree distribution as the nodes of a transportation system across a city or nodes of World Wide Web across the Globe or the network of galaxies across the Universe. And so on, and so on.

The ubiquitous patterns imply to us that there is a universal organizing principle. That supreme law of nature is by no means a mystery. It has been known for a long time and by several names, yet mostly misunderstood. The universal imperative is known as the second law of thermodynamics and as the principle of least action and as Newton's second law of motion. These three laws are often thought to be distinct from one and other, but when given in their original complete forms, it is easy to show mathematically, as we have done, that they are in fact identical.

The universal law of nature simply says that an energy difference of any kind will be consumed in least time. Darwin's tenet, albeit without firm mathematical form, expresses the same. Animates evolve, develop, adapt, etc. as soon as possible. Also in economics we recognize the universal imperative in the law of supply and demand as well as in the law of diminishing returns. In behavioral sciences the universal law is referred to as the principle of least effort. In fact all processes direct according to the natural teleological objective to consume free energy in least time.

So I am saying that evolution as a grand process is by its principle no different from a trivial process where a brook runs down a hill slope. Surely evolutionary mechanisms associated with genes, epigenetics, behavior, etc. are more complicated than those that facilitate the flow of water, but still

Figures: http://prezi.com/wxucdp4e8hla/physical-foundations-of-evolutionary-theory/

they are only mechanisms whereas the governing principle of all processes is the same and therefore the patterns are universal. The brook will vary its course and will naturally select among alternatives the steepest descent along which free energy, that is, gravitational force, will be consumed as soon as possible. Likewise developmental differentiation will direct itself along various forces due to chemical potential gradients, electric fields, light, temperature, gravity or physical tension or any other form of free energy.

If the law of nature is so simple yet universal, as I claim, why has it not been used to explain matters, simple just as sophisticated, as we have now done in our papers? The old law has been shunned because its explanations, while completely consistent with observations, do not meet common expectations of explanations. Namely, we wish to have precise predictions even when there are no premises to predict. And we wish to have deterministic dissections even when determining factors have not yet materialized. So, in hopes of fulfilling our deterministic and reductionist wishes, the old general law has been reduced to particular expressions that account approximately only for a limited scale of phenomena and only for a narrow scope of discipline-specific systems.

For example, you surely recall Newton's second law in the form $F = ma$ whereas Newton himself wrote $F = dp/dt$ which entails two terms namely $F = ma + v dm/dt$. The change in mass $dm$ equates with a change in energy that is liberated, for example, from a chemical reaction. So you realize that the reduced form $F = ma$ does not even explain a chemical reaction, and hence many conceptual problems have risen, whereas there is nothing wrong with the original Newtonian mechanics.

We adore physics for its precision in predictions, and hence we aim for the same in biology. We should not. Physics is able to calculate only stationary trajectories, that is, behavior of systems that do not evolve, develop, adapt or change in any other way. Determinism accounts only for the present, but biology is all about changes that transform past to future. When a description, however precise, contains no arrow of time, it is useless for biology, in fact useless for any discipline.

Revival of old physics is in the hearth of our studies. These total answers to many big questions such as what is life, why did it emerge, what determined chirality standards, why our genomes contain various other elements besides genes, why protein folding is so difficult to predict, what motivates altruism and why did sex evolve, as well as answers to many big questions in physics, mathematics, information sciences, economics and social sciences.

I am not criticizing physics as such. On the contrary its exact and comprehensive concepts, most notably energy and time, can be assigned to everything that exists. In this way physics addresses everything with impeccable mathematical logic. For example, the term fitness equates with the ability to consume free energy in least time. In many circumstances that ability manifests itself as high reproductive rates, but also as high activity in general, intelligence, etc. All attributes of fitness can be commensurably accounted for in energetic terms. Using the general concepts of physics evolution can be given as an equation of motion. And it can be shown to yield the universal patterns of skewed distributions, sigmoid curves and power laws as well as to account for speciation, emergence and chaos.

Yet, the equation cannot be solved in general, only in the cases of stationary systems. The lack of a general solution means that there is no way to predict precisely future or to unravel unambiguously the past. The on-going massive data collection of biological details is implicitly a deterministic and reductionist operation. However, no matter how precisely we will know details, we cannot predict precisely the course of evolution or development or any other process, but only succeed in extrapolating an ongoing trend. When everything depends on everything else, the *ceteris paribus* principle does not hold, as the late Stephan J. Gould noted.

There are good reasons to collect data to learn how things work. However a thing does not dictate but is in service of a process. So to explain a process it takes to comprehend the basic law of nature. Foremost we should not impose mere discipline-specific terminology on students but teach them the universal principle. For example, we should not teach that three-dimensional structure of a protein is determined by its amino acid sequence, since surroundings, that is, temperature, pH, ionic strength, chaperons, etc. have an obvious say too. Likewise, we should not imply that phenotypic variation would arise merely from variation at genetic or epigenetic or physiological level, but that surroundings have a say too. Notably since development itself keeps changing surroundings, there is no way to map causes to their effects one-to-one. This interdependence is pronounced in economic systems, and hence unpredictability is ordinary.

Moreover, we should not mystify the origin of homochirality in amino acids because that selection of handedness is by principle a process no different from when settling to drive on one hand side of road. Likewise, it is no wonder that our genomes contain besides genes also insignificant, redundant and defective elements. Is that not exactly what we find in our wardrobes and garages? Furthermore, it is only natural to see surprises in gene knockout experiments when flows of energy in metabolic systems redirect along new paths of least time. In the same way people will find unexpected routes to pass by a road blockage as soon as possible. It has been most rewarding to realize that a hard problem in a particular field has an easy counterpart in another field, or even better, a parallel in everyday life. Of course we have recognized these parallels for a long time, but deemed them merely as analogies, whereas I am saying they are identical when expressed in energetic terms.

All in all we should not imagine that a phenomenon in a particular system would be somehow special. It is by principle no different from phenomena encountered in other systems. Diversity and complexity in mechanistic details should not distract us from seeing the whole and from explaining everything effortlessly and consistently using the universal law.

Undoubtedly our work is odd compared to contemporary studies. But oddity does not equate with fallacy. On the contrary, the sound revival of the old natural law signifies a major change in the paradigm how we see nature, and hence it will have, as I anticipate, a great impact across all disciplines.

Figures: http://prezi.com/wxucdp4e8hla/physical-foundations-of-evolutionary-theory/