



Evo-devo: an emergence of a new discipline in biology

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Abstract: Evolutionary developmental biology which is known as Evo-Devo is a new discipline in biology which compares the developmental processes of different organisms to infer how different developmental processes evolved. Evolution is unifying theory of biology and defined by Darwin as descent with modifications. Developmental biology or embryology studies the developmental processes of the organisms. This new area of biology is composed of multiple core evolutionary concepts: Darwin's theory of evolution, embryonic development, homology and analogy, Haeckel's law, recombinant DNA technology and homeotic genes regulating development in a variety of eukaryotes, neo-Lamarckian theory and epigenetic changes.

An important revolution in the idea about evolution and developmental biology was initiated in 1977 with the arrival of recombinant DNA technology in genetics, the book *Ontogeny and Phylogeny* by Gould and the paper *Evolution and Tinkering* by Jacob to form Evo-Devo. As such there was a second synthesis which includes embryology, molecular genetics, phylogeny and evolutionary biology to form evo-devo.

Index Terms: Evo-devo, Evolutionary biology, Developmental biology, Recombinant DNA Technology, Ontogeny and Phylogeny, Evolution and Tinkering.

Evolutionary developmental biology which is known as evo-devo is a new discipline in biology which compares the developmental processes of different organisms to infer how different developmental processes evolved. A revolutionary synthesis of evolution and developmental biology is in the process. Darwin defined evolution as descent with modifications. However, evolutionary changes occur not by direct transformation of adult ancestors into adult descendants but rather when developmental processes produce the features in

each generation in an evolving lineage (Raff, 2000). The important two creative processes of biology are evolution and development. It is interesting to mention that both these processes have much different time scales in their operation. Both these processes are intrinsically interwoven. Evo-devo is the scientific study of this interweaving. Its full name is evolutionary developmental biology but it is referred by its nickname evo-devo. It is important because it is essentially the individual animal or plant at central stage in our overall perspective on the process and pattern of evolution. This new area of biology is composed of multiple core evolutionary concepts: Darwin's theory of evolution, embryonic development, homology and analogy, Haeckel's law, recombinant DNA technology and homeotic genes regulating development in a variety of eukaryotes, neo-Lamarckian theory and epigenetic changes.

The birth of evo-devo and a second synthesis: In fact, a drastic change in thinking of evolution and developmental biology was initiated in 1977, when in molecular biology and genetics the recombinant DNA technology was invented, an important book by Gould (1977) on "Ontogeny and Phylogeny" was published and an important paper by Jacob (1977) "Evolution and Tinkering" was published. All these three contributed to the origin of this new area in biology. This was considered as second synthesis after the First synthesis by Huxley (Evolution: the modern synthesis, 1942). The synthetic theory integrated genetics with evolution and giving emphasis on natural selection as the main guiding force of evolution operating on genetic variations in populations (Singh 2023). The second synthesis which led to the emergence of a new discipline in biology. includes embryology as well as molecular genetics, phylogeny and evolutionary biology forming evo-devo. Further, information concerning extended evolutionary synthesis may involve evolutionary innovation which may begin in Lamarckian

way with epigenetic changes of gene regulation or phenotypic generation, subsequently consolidated by changes at the level of genes. Epigenetic changes include modifications of DNA by reversible methylation (Jablonka and Lamb 1995) and nonprogrammed remoulding of the organism by physical and other environmental effects due to the inherent plasticity of developmental mechanisms (West-Eberhard, 2003). Lewis (1978) was first to report the homeotic genes in *Drosophila* regulating embryonic development. Subsequently, McGinnis (see McGinnis and Krumlauf, 1992) discovered homeotic gene sequences in vertebrates such as frogs, birds and mammals. Later on, they were also found in fungi, yeasts and plants. Strong similarities were found in the genes which controlled development in different eukaryotes (Holland, 2013). *Drosophila melanogaster* was used as a model organism to solve the puzzle of embryonic development and its control. The book published by Stephan J Gould in 1977 "Ontogeny and Phylogeny" also contributed to the emergence of this new concept in biology i.e. evo-devo. In his book, Gould has explained the theory of recapitulation which aims to explain the relationship between the embryonic development of an organism (ontogeny) and the evolution of that organism's species (phylogeny). However, there are certain variations in the recapitulation theory, it is mostly claimed that during embryonic development, an organism repeats the adult stages of organisms from those species in its evolutionary history. Certainly, some part of recapitulation theory is important for understanding evolution. This book has two parts: The first part is entitled as Recapitulation which reconstructs the theory of recapitulation proposed by Ernst Haeckel which is also known as biogenetic law and also discusses its demise in first half of the twentieth century. The second part of the book is entitled as heterochrony and pseudomorphosis. In this part, Gould suggests his own concept about the relationship between ontogeny and phylogeny and the manner in which the developmental processes provide the basis to explain evolution. Gould has also discussed the work of Karl von Baer (1828) on embryo who argued against the theory of recapitulation. Von Baer stated that embryos of one species can only resemble embryonic form of ancestors but never their ancestors' adult form. The main argument of von Baer was that the organisms from different species develop from common general form and subsequently diverge from one another in a branching manner as development progresses. Gould had also mentioned about neoteny which is a type of heterochrony where a species retains juvenile characters into adulthood. Gould has also mentioned about ecological significance in relation to heterochrony because primary evolutionary significance of heterochrony may be important in providing immediate ecological advantages to organisms. Thus, the main concepts explored by Gould in his book pertain to ontogeny, phylogeny, recapitulation, heterochrony, neoteny, ecological significance and contribution of von Baer who argued

that the organisms from different species develop from common general form and subsequently diverge from one another in a branching manner as development progresses. The publication of Gould's book, certainly influenced and provided the basis of biological approach in the field of evolutionary developmental biology or evo-devo which integrated evolutionary and developmental biology.

The paper of Francisco Jacob published in 1977 in *Science* on Evolution and Tinkering has also contributed in the initiation of evo-devo as a new discipline in biology. The mode of operation of evolution as tinkering has several aspects in common with the process of evolution. Jacob suggests that without any long term defined project, the tinkering gives his materials unexpected functions to produce a new object. Evolution behaves like a tinkerer such as a wing is made from a leg, or a part of ear from a piece of jaw. Obviously, it takes a long time. He concludes that evolution behaves like a tinkerer which does not produce results from scratches rather it works on what already exists either transforming a system to give it new functions or combining several systems to produce a more elaborate one. It was mainly a reorganization of what already existed. Further, at the molecular level, natural selection also has tinkering aspect which is very apparent because the organisms exhibit a remarkable unity of chemical structures and functions. Through out the living world, the consequences of tinkering is quite apparent at every level. Certainly, such effects of tinkering is also found in humans. For example as in many mammals, humans also show very complex processes responsible for different functions as blood coagulation, inflammatory reactions against foreign bodies and the immunological defenses mediated by the so-called complement system. There is an example of tinkering in early human embryonic development. Human brain is also taken as an example of tinkering. The human brain was formed by superposition of new structures on old ones.

Researchers during past 3-4 decades have revealed how studies in evo-devo highlighted the mechanisms that link genes (genotypes) with structures (phenotypes). This is really important because genes do not make structures. Developmental processes make structures using roadmaps provided by genes but using many other signals such as physical factors and interaction with other species. Further, there is importance of epigenetics using mechanisms that are not encoded in DNA of genes. In fact it is expected that there may be expansion of evo-devo into other areas of biology such as ecology, physiology and behavior or absorption of evo-devo by evolution or a unification of biology in which evo-devo contributes an important role (Hall, 2012).

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