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Evo-devo - the synthesis of developmental biology and evolution

Evo-devo research has led to completely new ideas concerning the evolution of animals, their tissues and organs. The huge variety of animals on the planet is the result of changes in the activity of a limited number of master genes that control early embryonic development. These master genes have been highly conserved throughout evolution, which is why their analysis allows conclusions to be drawn concerning the evolution of multicellular animals and their different body plans.

The combination of evolutionary research and developmental biology is not new. Darwin observed that there is a relationship between development and evolution, and Ernst Haeckel, an enthusiastic supporter of Darwinian thought, proposed that evolution could be studied in embryos because "ontogeny recapitulates phylogeny". Many biologists later refuted Haeckel's "biogenetic law" according to which embryogenesis is the short and incomplete repetition of phylogenesis. However, it should not be forgotten that in Haeckel's time, researchers were looking for "natural laws"; exaggerations and simplifications were frequently used to increase the acceptance of the revolutionary new field of evolutionary biology. Today, Haeckel must be credited for having paved the way for modern evo-devo research, which has, over the last few years, achieved great success.

The term evo-devo, which is short for "evolutionary developmental biology", was coined in the USA and relates to research at the interface of ontogenesis and phylogenesis, i.e. the biology of individual development and evolutionary biology. In its modern form, evolutionary developmental biology largely stems from molecular genetic research on the fruit fly, Drosophila. This led to the identification of numerous genes and gene families that control early embryonic development, the determination of body axes and body segments, as well as essential differentiation patterns of tissues and organs. Groundbreaking work in this field was carried out by Edward Lewis from the California Institute of Technology in Pasadena, and, of particular note, by Christiane Nüsslein-Volhard and Eric F. Wieschaus at the European Molecular Biology Laboratory in Heidelberg between 1978 and 1981. Nüsslein-Volhard and Wieschaus continued this work when they moved on to the Max Planck Institute of Developmental Biology in Tübingen and Princeton University, respectively. Lewis, Nüsslein-Volhard and Wieschaus were awarded the Nobel Prize in Physiology or Medicine in 1995 for their achievements. The figure above shows three such genes in a Drosophila embryo (see article entitled "The discovery of homeotic genes").

Evo-devo achieved a breakthrough as an independent discipline with the discovery of the Hox genes in the laboratory of Walter Gehring in Basel, Switzerland. Gehring's group found that such genes are not only present in fruit flies, but in all animals with true tissues (eumetazoans), and that these genes are conserved in animals as morphologically different as threadworms (Caenorhabditis elegans) and humans. They are all governed by the same morphogenetic principles: embryonic development and the patterning of body parts is controlled by homologous master genes, including the developmental genes discovered by Nüsslein-Volhard and Wieschaus. These genes form a "tool box" of genetic elements that bind to DNA and switch on and off the expression of genes into proteins according to a predetermined pattern as the embryo develops; or in other words, these homeobox (Hox) genes provide the construction plan for the development of animals by controlling the transcription in all cells. The discovery of the Hox genes has led to completely new ideas about the evolution of animals and their organs. The huge variety of body plans and patterns in animals have evolved from a small number of ancestral themes.

Over the last few years, evo-devo research has made considerable progress. It has also brought together scientists from completely different disciplines (molecular genetics and palaeontology) who previously had very little in common. Something that previously seemed completely impossible or led to fierce debates, has become possible with evo-devo research: our current knowledge on how developmental genes control the morphogenesis of animals can now be used to explain the characteristics, organs and entire animal groups for which no fossil evidence is available – for example the evolutionary relationship of basal eumetazoans, gastrulation in early embryogenesis, the development of insect wings, eye development and colour vision. This dossier deals with some of these new findings.

27-Aug-2012