Biological hierarchy, determinism, and specificity

Professor Ute Deichmann from Ben-Gurion University of the Negev studies the impact of philosophical and scientific concepts as well as scientific personalities on the development of modern life sciences. Her recent work argues the importance of three biological concepts: hierarchy, genomic determinism, and specificity, which underpin the foundations of modern biological experimentation and theories. These concepts are relevant to understanding the causal role of genes in the conservation of species differences and early development. Professor Deichmann makes a case for the importance of these concepts for the future trajectory of research.

Biological hierarchy refers to the systemic organisation of organisms into levels, such as the Linnaean taxonomy (a biological classification set up by Carl Linnaeus). It organises living things in descending levels of complexity: kingdom, phylum, class, order, family, genus, and species. Hierarchies are important to inform evolutionary biologists on the way living systems are organised throughout history and theorise how extinct animals function based on their positions on the hierarchy. Hierarchy is also a property of gene-regulatory networks that play a central role in the development of organisms. Philosopher Michael Morange postulates that to understand “the logic of life, we need to understand its structural hierarchy.”

Biological or genetic determinism is the idea that basic biological characteristics, such as animal body plans, are largely genetically determined. However, it does not refer here to the determinative role of genes in character traits, such as intellectual abilities. It also does not mean that every physical trait is fully determined by a particular gene. Rather, the genome determines the range of possible phenotypic variations of an organism for different environments. Biological determinism became more pronounced in the 19th century, and forms the basis of cell theory, Mendelian genetics, and molecular genetics.

Biological specificity states that each organism, species, and successful rank in taxonomy are unique and different from other entities of the same rank. This is because each group of organisms expresses different sets of genes, resulting in different body structures and developmental growth.

Hierarchy, determinism, and specificity are basic principles of life and underpin our understanding of biology. Professor Ute Deichmann from Ben-Gurion University of the Negev argues that the emergence of modern experimental science in the 19th century is closely linked to the introduction of these three concepts into the foundations of biological research. In her 2017 paper published in History and Philosophy of the Life Sciences, Professor Deichmann provides arguments and examples for these three concepts and counterarguments to the strong criticisms, such as the marginalisation of these concepts in holistic approaches.

Development of Modern Biology

Before the 18th century, the belief that different species could emerge from another species (transmutation) over the generations, innainate objects or decaying life forms was widespread. Biological hierarchy, determinism, and specificity – are basic principles of life and underpin our understanding of biology.

Moreover, until the late 19th century, it was widely thought that environmental factors influence germ cell development and hereditary traits, such as eye colour. Biological and genetic determinism was only widely accepted by the scientific community after August Weismann’s germ plasm theory in the late 19th century, which states that inheritance only takes place by germ cells (egg and sperm cells) that are separated from other cells of the body (somatic cells) early in development.

The discovery of the DNA double helix structure in 1953 further supported the idea of genetic determinism and specificity; genetic information and gene regulation influence cellular function and largely determine biological specificity, such as conserved body plans across different species. With the help of novel molecular techniques, such as polymerase chain reaction and genetic sequencing, molecular underpinnings of diseases and development were discovered. Now, biological phenomenon is explained by underlying simpler parts such as genes and macromolecules and their interactions.

These three concepts – hierarchy, determinism, and specificity – are basic principles of life and underpin our understanding of biology.

Classification systems are important to inform evolutionary biologists on the way living systems are organised throughout history and theorise how extinct animals function based on their positions on the hierarchy.
Behind the Research

Professor Ute Deichmann

Professor Deichmann’s research explores the origin and change of concepts in modern experimental biology and the impact of various philosophies and ideologies on scientific practice.

Research Objectives

The foundations of life and medical research can be further developed using the concepts of biological hierarchy, determinism, and specificity.

The same species sometimes over millions of years, which is determined by the genome in early development. The genome acts as a guiding genetic programme for early development to occur, as it is consistent across a species and independent of the environment in which it occurs. This is the same body plan over evolutionary times.

Therefore, Dr Deichmann argues that such proposition of holism and rejection of genetic determinism, specificity, and hierarchy are unable to explain the basic principles of development and evolution.

Epigenetics is another example where questionable ideas arise as a result of the marginalisation of the principles of biological specificity, hierarchy, and genomic determination. Some biologists and social epigeneticians (sociologists and behavioural scientists) attribute developmental features and reactions to environmental stress to unspecified molecules and events, such as supposedly environmentally triggered DNA methylation and histone modification. They thereby ignore that development requires the highly specific, and often unique, genetic control provided by the genome. Enzymes that methylate DNA cannot provide this specificity: every gene appears absolutely the same to them. Thus, specific regulatory protein complexes and not specific proteins or enzymes are necessary to target these enzymes to specific DNA sequences. Deichmann holds that research in epigenetics is only successful when it takes into account the established fields of genetics and cell biology as well as the known principles of gene regulation based on hierarchical gene networks and specific regulatory proteins.


References

Professor Deichmann believes that they continue to underpin our basic understanding of how life develops, functions, and evolves. They have been important throughout the history of science to develop new theories and propel us into the age of genomic sequencing. Combining these big data of genomics and collaborative experimental studies, the foundations of life and medical research can be further developed using the concepts of biological hierarchy, determinism, and specificity.

What attracted you to study the history of science, broadly and more specifically the concepts of hierarchy, determinism, and specificity?

I first studied the impact of Nazi policy on biology and chemistry, the response of scientists in Germany and the fate of Jewish scientists. I became interested in the three concepts through my research on the concept of the causal role of chromosomes and genes in heredity and development and on the opposition that it received from the 19th century till today. Politically, this opposition culminated in Lysenko’s campaign against genetics in Stalinist Russia. Studying Peter’s and Davidson’s book ‘Genomic control process: Development and Evolution’ (2015) made me aware of the relevance of these concepts in present-day systems biology and evolution; they became a new focus of my work, which was underpinned by discussions with Eric Davidson (sl 2015) on this topic.

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Bio

Personal Response

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