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Interdisciplinary Nature of Genetics: Educational Implications

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ABSTRACT *The article deals with issues related to the interdisciplinary nature of genetics as an area of knowledge and a subject of teaching. Worldwide attempts to introduce the content of genetics onto lower and lower stages of education are evident. These attempts are directly addressing the need for a basic scientific and technological literacy. An interdisciplinary model of education coupled a problem- solving strategy are becoming the norm among European Union countries and worldwide. Thus, it is also important to familiarize teachers with these emerging issues. The article is an attempt to demonstrate a way forward by exemplifying how different sciences could be used to portray the future direction of science on the basis of interdisciplinary knowledge, and research methods and skills that are common to different areas of knowledge.*

KEY WORDS: *genetics, interdisciplinary, methods of teaching*

Nature of Genetics: New Developments

Research carried out in the past two centuries allowed people to study corpuscular-wave nature of matter and structure of atomic nucleus. Significant laws of cellular organism structure, mechanisms of evolution, and principles of heredity have been investigated and, to a certain extent, decoded. Genetics have been developed on the basis of changeability issues, and thus are connected with problems regarding the formation of new species in the world of plants and animals. These are basic issues in science dealing with the evolution of organisms.

Until the middle of the 20th century, general laws related to heredity characteristics in plants and animals had been explained. The achievements of those years, now called the period of classical genetics, were significant. But, genetics remain dependent on breeding, and its hypotheses were abstract (Berg & Singer, 1997). The true breakthrough in molecular research of life foundation occurred in the second half of the 20th century. At that time, the structure of molecules of living cells, their functions and important relations within the cell were studied. In the nineteen sixties and seventies, the mechanisms through which genetic information indicated biological structure and function were discovered – genetic code was broken and the methods of information flow in the cell were studied and confirmed though experimentation. Darwin's theory of evolution was mainly based on morphological science that dominated biology at that time. The development of physiology and biochemistry not only did not shatter this concept, but it allowed its deepening. The notion of evolution became an important issue in science, and great biological discoveries within this area of knowledge and attempts to answer how these new discoveries shed more light and provided rich information related

to principles of life on earth. At present, most research relates to molecular genetics, which deals with the translation of genetic information into systems ensuring control of metabolism as well as the development and reproduction of hereditary characteristics.

The roots of molecular genetics are in the classical genetics as well as in the genetics of microorganisms and in biochemistry. During the last 20 years, there has been a revolution in our understanding of the processes responsible for maintaining, transferring and expression of genetic information at molecular level – that is in the understanding of the very bases of life (Turner, McLennan, Bates, & White, 1999). Progress in genetics led to the fact that the variety of information recorded in genes took on usable value. There appeared the notion of gene resources, which, for instance in case of crops, means the sum of all the genetic combinations produced in the process of natural or artificial selection.

Apart from genetic research that deals with genes as far as their molecular structure is concerned, their role in cellular metabolism and their role in the processes of growth and differentiation of an organism in the course of development from one-cell zygote were also studied. Research in which genes were considered as sets of alleles within the whole set of organisms of a given species, that is, in the population, was also carried out. Population genetics deals with the study of mathematical models regarding changeability and heredity phenomena as well as the phylogenetic tendency at the population level, and it constitutes the basis for considering both evolution and breeding processes.

Progress in understanding the role played by genetic factors in pathological processes shifted attention to the role of genetic research for the development medicine. Biochemical genetics is a branch of genetics studying the chemical essence of heredity factors and how they these operate during the development and the physiological activities of an organism. Thus, it became possible not only to study hereditary diseases better, but to also develop ways of prenatal diagnosis of these diseases that contribute a lot towards improved genetic counseling and better health conditions for many people suffering from hereditary diseases. The important issues in the development of contemporary genetics include research on diagnosing and treating hereditary diseases, cancer, AIDS, gene therapy in people, or cloning.

The branch of science that deals with genetically conditioned characteristics of people and investigates the reasons for their occurrence and the way they are transferred from generation to generation is referred to as genetics of people. Among many technological and methodical achievements pointing to a real explosion of scientific knowledge and understanding, one should mention the possibility of taking specific part of DNA from a given organism, performing any manipulation on it, and then introducing it back to the same or another organism. The essence of DNA recombination technology, which was basically investigated following this pattern, resulted in the development of a new branch of molecular biology. Genetic engineering is a conscious manipulation of genetic material using available (contemporary) methods in molecular biology. The interest of molecular biology lies with macromolecules and macromolecular complexes of DNA, RNA, and proteins, as well as the processes of replication, transcription, and translation of genetic material. New experimental technologies used for manipulating these molecules

became very important for contemporary molecular biology, as they provide information on the molecules and have enormous practical application for production of new safe drugs, vaccines, food stuffs, and in diagnosing genetic diseases and gene therapy. Biotechnology is developing and implementing effective production of biological material using available genetic knowledge and biologic methods as it is shown in Figure 1.

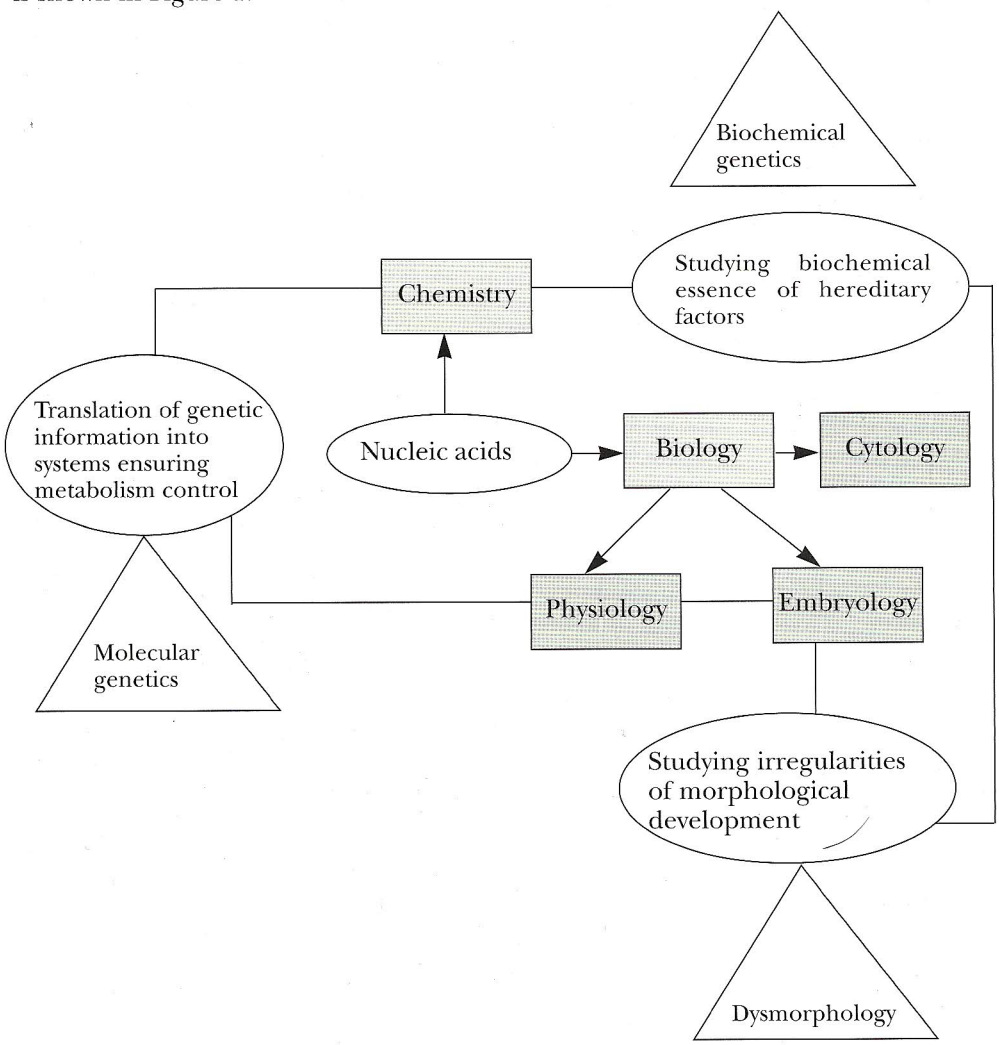

Figure 1. Interdisciplinary Nature of Genetics Using the Example of Issues Connected with Structure and Function of Nucleic Acids (prepared by the author)

Technological progress is associated with extensive, and specialized scientific research. Thus, new scientific sub-disciplines have been developed that permeate each other and signify a close connection among other scientific fields. Based on the systematic division of organisms, one can distinguish, for instance, microorganism genetics, fungi genetics, plant genetics, etc. Contemporary animal genetics cannot be developed without knowledge of their physiology because physiological

features constitute the basis for breeding effectiveness. That is why modern breeding is based on molecular biology and cognitive research based on physiological genetics.

The role of genetics for the development of medicine, agriculture, horticulture, and animal breeding has been known for a long time. The contribution of genetics to modern psychology and pedagogy, and the need for updating knowledge on hereditary factors and heredity mechanisms are more and more frequently discussed. There exists a view that changes in the structure of people's societies have their genetic consequences. Although research had been dealing for a long time with mutual relations between social and genetic factors, it was only when the innovative paper by Prof. P.E. Becker and Prof. H.W. Jorgen was presented in Marburg in 1970 that this branch of genetics was named social genetics. The authors of this paper expressed the belief that that genetic selection occurs not only due to the operation of natural conditions in the environment, but also thanks to the conditions created in the environment by the process of civilization. As civilization progresses, genetic influence increases in connection with sudden changes in social structure and new norms of its behavior. It is connected with the influence of new technologies on all the areas of life in the 21st century society (Gronicz, 1973). In view of numerous ethical and moral problems regarding the safe application of genetics in various areas of science and life, there appears a need for broad discussion not only among professionals (geneticists and doctors), but also among specialists in other areas of science (philosophers, lawyers, sociologists, psychologists and theologists).

The aim of schooling in contemporary society should be to equip students with systematic, long-lasting and operational knowledge and create conditions conducive to independent acquisition of further knowledge and understandings. Thus, appropriate models of learning and teaching need to be applied. This concerns any area of science including genetics. Genetic issues related to organism heredity are regarded as some of the most difficult ones to be learned in schools, because they concern submicroscopic biological structures and complex processes that operate within them. There are also very significant issues related to creating biological awareness of the contemporary society. They include forming the attitude of responsible use of scientific achievements and creating the basics of "scientific literacy".

Progress in technology and science is unavoidable, and it unavoidably transforms the structures of social life and mentality of the members of any society (Fukuyama, 1996). In this context, the importance of genetic knowledge is becoming more important and a lot questions regarding its place in school curriculum at particular stages of education are continuously raised.

Different approaches to overcome boundaries among particular areas of science (genetics, medicine, physiology, embryology, ecology, or philosophy), and intensive development of science at the borderline between various fields affect the process of biology teaching and learning. They enforce the integration of knowledge acquired by students. Analysis of the content of teaching related to cytology and genetics throughout the twentieth century seems to indicate that less emphasis should be given to classical Mendelian genetics and more emphasis on information regarding molecular genetics, cytogenesis, and genetic engineering

(Stawinski, 2000). Articles published in numerous scientific and popular-scientific magazines have been a source of knowledge about the current achievements in these areas for teachers for many years. The interdisciplinary nature of research in the field of genetics and its achievements are continuously emphasized.

Educational Implications

Finding a balance between regular science in a given area of knowledge and learning in an interdisciplinary way seems to be the proper solution. The purpose of teaching biology in an interdisciplinary way relates to the whole popularization of 'specialization in associations' (Popp, 1997). What is meant here is that students in the course of their learning are not only expected to become 'specialists' in one area. They must be supported in understanding the links between different subjects of teaching and areas of knowledge. While learning these interdependencies, students develop the capability to comprehend the close connections among their own everyday problems, which are often complicated and exceed the boundaries of single subjects as they are traditionally understood (Simonneaux, 2000).

Teaching genetics means an integration of contents from various areas of knowledge (chemistry, medicine, mathematics, physics) and biology itself (cytology, embryology, microbiology, immunology, morphology) in order to develop a better understanding of genetics as it is exemplified in Figure 2.

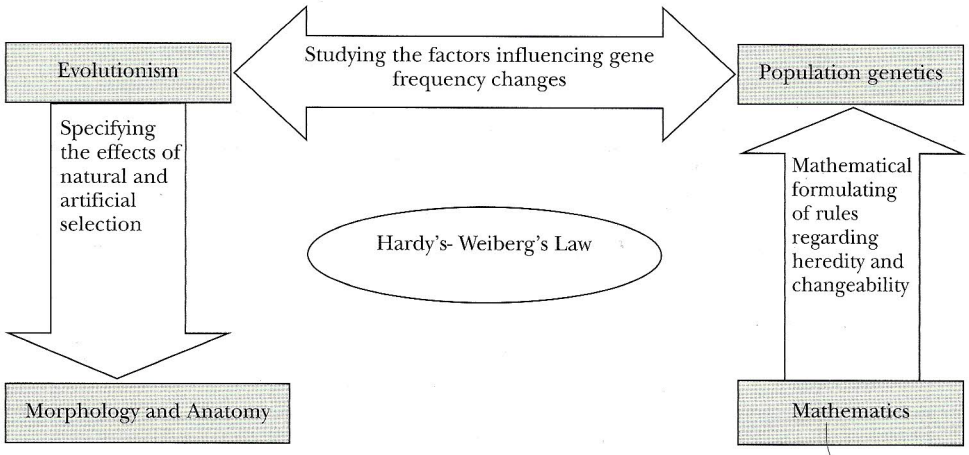

Figure 2. Interdisciplinary nature of genetics using the example of issues connected with Hardy-Weinberg Law (prepared by the author)

For instance, Human Genome Project in itself is an interdisciplinary project. It includes various aspects of science; there are biological, biochemical, chemical and medical elements in it. Moreover, there are technological problems connected with it, and as far as possibilities of its results and applications are concerned, one should include ethical, social, and legal aspects as well. The European Union project – European Initiative for Biotechnology Education (EIBE) predicts (EIBE journal and the Internet pages) a number of topic units – examples of interdisciplinary genetics teaching. The European Initiative for Biotechnology Education undertakes the initiative of supporting new methods of teaching in school and teacher

education for deepening the understanding of biotechnology and raising the awareness of society by encouraging, frequent public debates on this field (Harms & Bay Huber, 1999; Stricken & Polygala, 2001).

Apart from acquiring information and skills in the field of biotechnology, students should be encouraged to actively participate in discussions related to new genetics technologies and achievements. These issues usually involve application of techniques exceeding one area of knowledge. The Internet chat groups can play an informative-interactive function for information exchange among many Internet users. Preparation for responsible use of information technology constitutes another important task for school.

Information Technology (IT) as a new field is progressively understood as a set of means (computers, their peripheral equipment and computer networks) and tools (software), as well as other technologies (like telecommunications) that serve the comprehensive use of information. Information technology exceeds computer science and includes information, computers, and communication. There come up questions concerning ways of deepening knowledge on scientific subjects regarding biology and latest achievements in this area on the basis of reliable sources of information while using IT.

Genetic issues are currently worked on at the level of junior high school and high school. In junior high school, students should be gradually acquainted with complex processes and mechanisms of inheriting characteristics, because later comprehension of their interdisciplinary nature and significance depend on appropriate starting knowledge. In view of the lack in basic knowledge in biochemistry, tackling the molecular basis for biological phenomena in the first or second grade of junior high school seems unjustified. Yet, the necessity for explaining the phenomena that students encounter in press and on TV every day regarding the application of latest genetics achievements indicates the need for such an approach to teaching that would allow students to comprehend these issues on the basis of scientific knowledge.

New technologies should be integrated in genetic education at various levels of education. Remote learning, virtual laboratories, and interactive tasks using computers are only some of the possibilities related to IT development. Computer programs employing animation make it possible, for instance, to follow mechanisms of cell division or DNA replication. Text charts with interactive dictionary facilitate looking up and ordering information, and sets of tasks play control and corrective role (Potyrala & Chorazki, 2002). The condition for educational use of computer software mainly relates to adequate structuring of contents and adapting their range to students' abilities. The teacher often has to face the task of choosing the contents for a given teaching unit or even selection of data. Computer-aided teaching of genetics requires versatile ways of explaining the contents, like presenting knowledge in the form of structures, applying schemes, models, choosing examples of objects and contents illustrating the issues, introduction of additional explanations and descriptions, and simplifying biological knowledge. Only those computer programs that take into consideration stages and ways of didactic transformation of genetic content onto a given level of education are suitable for use in school practice. Exercises performed through IT tools constitute the basis for introducing theoretical problems and facilitate the acquisition of a number of

practical skills, such as, for instance:

- Ability to perform microscopic preparations and microscoping and the ability to use laboratory equipment (introduction into cytogenetic study technique in virtual laboratories)
- Ability to perform structure and biological processes models (introduction to the spatial relations analysis among particular cell structures and dependencies between the structure and function of these structures, due to computer animations or three-dimension models)
- Ability to use symbols used in genetics (introduction to problem solving – genetic crossovers – interactive task sets and control tests).

The importance of genetics in medicine, chemical industry, agriculture, innovative technology of the future, is frequently the subject of articles in newspapers, magazines, as well as television reports. However, media present the problems in a simplified manner and authors show only some aspects of this field of knowledge. In spite of numerous scientific achievements and universal availability of knowledge about it, its superficiality and distortions keep increasing (Stawi_ski, 1994). The direct effect of such an image of genetics in the media is the fact that people, and youth in particular, develop distorted views on genetics and they often feel confused about this complex area of knowledge (Gebhardt & Bayrhuber, 1998). Another effect involves students' difficulty in forming responsible opinions on genetics, biotechnology, genetic material manipulation and using this knowledge in a responsible way (Hossle 2000; Sternicka, 1999). Ethical problems in genetic engineering may also constitute the leading thought in interdisciplinary teaching.

In conclusion, the society of the 21st century will mainly depend on comprehensive and interdisciplinary science, such as genetics. Responsible use of genetics will lower the risks and increase the fruitful opportunities that the new generations will face (Gebhardt & Bayrhuber, 1998). The new generations will be members of an information society that is such, an organization that lasts and develops thanks to general access to information. Consequently, students' preparation for active involvement and democratic participation for such a future society is a challenging issue facing educational systems.

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