Chapter 1

Introductory Chapter: Challenges and Advances in Animal Genetics

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1. Introduction

Genetics is a science which studies the mechanisms and biological laws that provide stability of the features during generations, meaning heredity on the one hand and the variation of inherited characteristics on the other hand [1, 2].

Genetics studies the three main fundamental properties of the living organisms such as heredity, variability, and reproduction [1].

The term heredity comes from Greek (*gr. Hereditas*), which means to inherit. Biologically, heredity refers to the inheritance of some "features and characters" from the parents to the descendants. In fact, not the characters themselves are inherited, but the potentiality of their apparition, intermediated by some material particles named genes (*gr. genan = to produce, to give birth*). The resulted gametes do not possess the parental characters, but they possess the parental genes which are transmitted to the future organism. The resulted zygote will form a new organism which will have particular features and characters, which will only resemble the parents to a certain extent.

Basically, the characters concerning the species are inherited, but not the features which are specific to each individual. This phenomenon represents the basis of variability of the living creatures. Reproduction assures the substrate of heredity and variability of the living world, determining at the same time the evolution of life.

Genetic processes are fundamental in order to understand life itself. Genetic information is stored in the DNA molecules since the formation of the first cell—the zygote, which controls all cellular functions, determines the external appearance of all organisms, and serves as a link between generations in all species. So, it is obvious that understanding of genetics is essential to fully understand life in all its aspects [3].

Whether we like it or not, heredity is a phenomenon linked to the existence of living matter, and it is one of the fundamental expressions of life, manifesting itself all over nature as long as life will exist [3].

2. The main branches of animal genetics

Classically, animal genetics is considered to be divided into a few important branches, such as:

Basic genetics—which enframes **Cytogenetics** and **Mendelian genetics**. **Cytogenetics** basically studies the chromosomes and the cell life (cell cycle, mitosis, and meiosis), and **Mendelian genetics** refers to the application of the Mendelian laws and their exceptions in animal inheritance.

Molecular genetics—studies the molecular basis of the heredity such as nucleic acids, proteins (biological active molecules), and the relations between them.

Genetic engineering—is defined as an ensemble of methods and technologies made with genes, chromosomes or even entire cells, on the purpose of obtaining new genetic structures with deliberate hereditary features.

Heredopathology (medical genetics)—refers to the study of illnesses, syndromes, and genetic abnormalities. Another important branch related with Heredopathology is **genetic prophylaxy**, which tries to elucidate the etiological factors which determine a genetic disorder and its organism-environment relation. **Immunogenetics** is also considered as a branch of medical genetics that explores the relationship between the immune system and genetics.

Population genetics—studies the inheritance pattern of different features which are manifested and transmitted in different populations of animals.

In recent years, new concepts are developed, based on what generally is named "systems biology" which represents the biological research which is mainly focused on the systematic study of complex interactions in biological systems by using integration models [4]. This concept of system biology is directly linked to "Omic sciences and omic technologies" and to the general concept of "systems genetics" which combine genetics and system biology [5].

The omic sciences and technologies are considered to be consisted of some new concepts which are linked together, such as **genomics, genome; transcriptomics and transcriptome; proteomics and proteome; metabolomics, metabolome and metabolomics** and omic experiments.

Genomics studies the structure, function, and expression of all genes in an organism [4]. The term **genome** was introduced by German botanist Hans Winkler and represents the total number of the chromosomes in ova or spermatozoa in humans or animals [6], or in other words, the genome means the total DNA of a cell or organism [4] or the total genes of an organism. The **transcriptomic** studies the formation, maturation, and role of mRNA in a cell or in an organism, and the **transcriptome** is the total mRNA which results in a cell or an organism

[4]. As an analogy with the term genomics, another term is defined as **proteomics** meaning the large-scale study of proteins regarding their formation, structure, and function in a cell or an entire organism as a system. The **proteome** represents the set of all expressed proteins in a cell, tissue, or organism [4].

Metabolomics studies the global metabolite profile in a biological system under a given set of conditions [4]. The **metabolome** is represented by the total quantitative collection of low molecular weight compounds (metabolites) which are formed and are present in a cell or organism that are directly involved in metabolic reactions. It also includes those metabolites taken in from external environment or provided by symbiotic relationships [4]. **Metabonomics** represents the measure of the fingerprint of biochemical perturbations caused by diseases, drugs, and toxins (**Figure 1**) [4].

Beside what happens in the interior of a cell or of an organism, the external factors from the environment must also be taken into considerations when we discuss about the exteriorization of a genotype. This is mainly the reason why a new term was introduced into the genetical studies such as **epigenetics**. The term "epigenetics" was introduced to the lexicon in the year 1942 by the developmental biologist and evolutionist Conrad H. Waddington by combining the word "genetics" with "epigenesis" in order to describe the influence of the environmental cues on the development of specific phenotypes due to the genotype-environment interactions [7, 8]. In 2008 at Cold Spring Harbor meeting [9], the epigenetic trait was defined as "a stably heritable phenotype resulting from changes in a chromosome without alterations in the DNA sequence" also considered as synonym for "epigenetic inheritance" (**Figure 2**) [8].

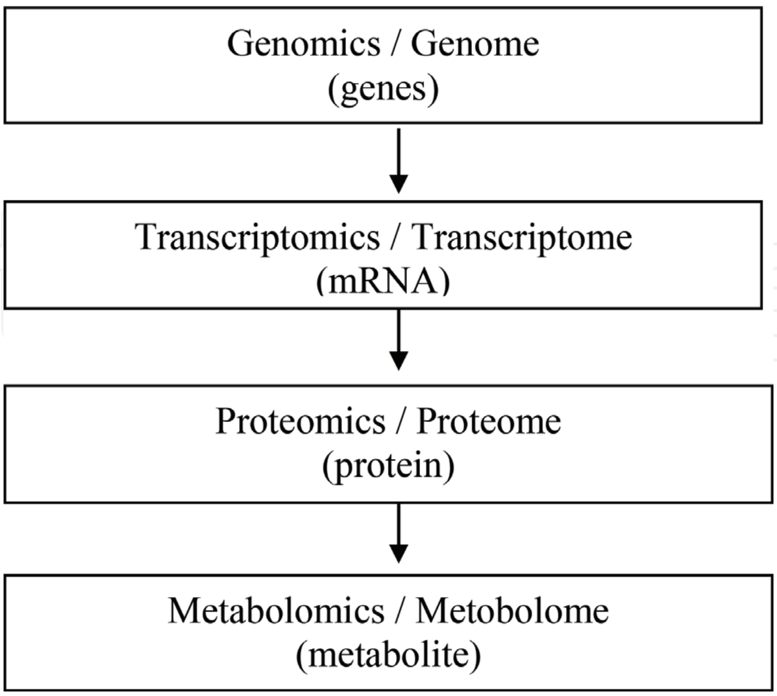

Figure 1. Omic sciences and their interactions. The flow of biological information is bidirectional [4].

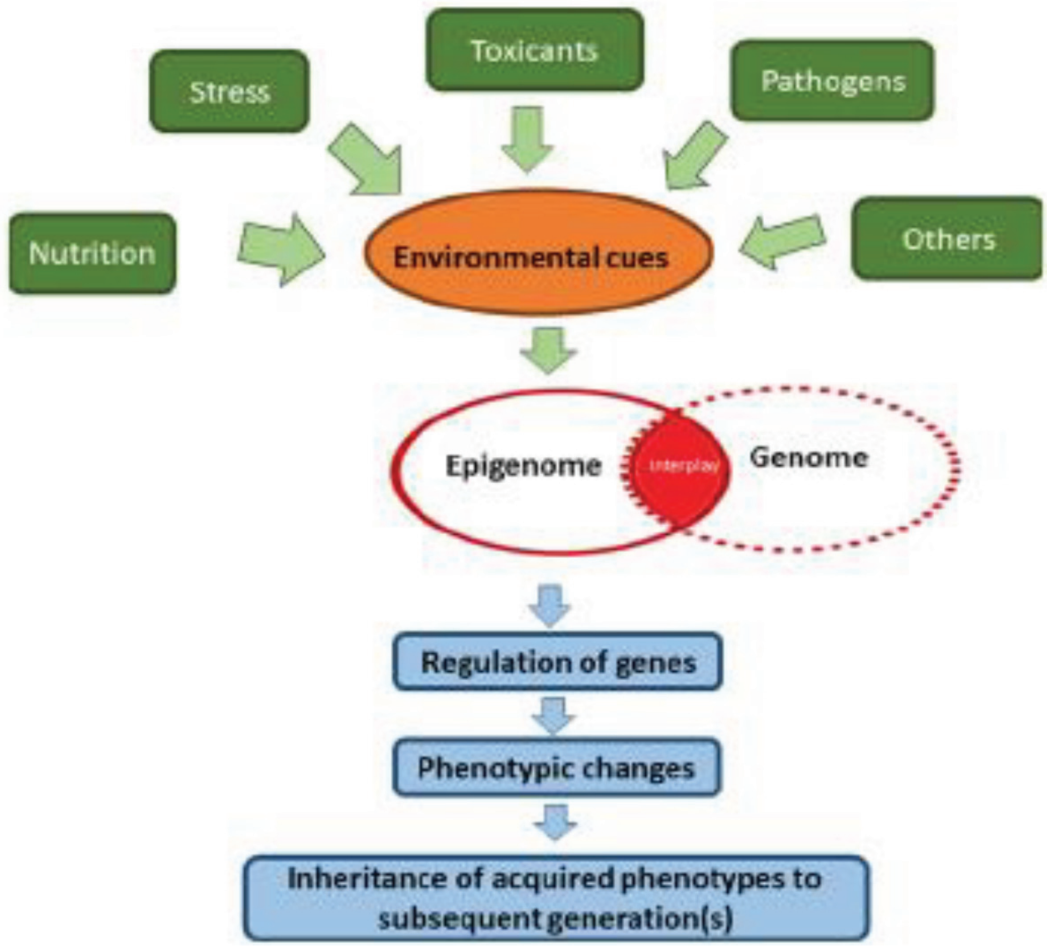

Figure 2. Graphical abstract of epigenetical inheritance [8].

Behavioral genetics is also a new part of genetics of the twenty-first century which studies "whether and how much genetic factors influence behavior to ask questions about development, about relations among traits, and about the interplay between nature and nurture. The identification of specific genes associated with behavior will make it possible for behavioral scientists to ask more precise questions about how genotypes become phenotypes" [10].

3. The role of animal genetics

Animal genetics, at present, is considered as a science with important theoretical and practical significance in order to find answers for the actual problems of mankind, related to the need for food, food with improved features, improvement of animal populations, and also for solving different issues related to human and animal health.

Genetics field supports the understanding of the process of inheritance during generations, the changing of genetic structures of different animal populations, and also the quantitative and qualitative improvement of animal productions [3].

The morphological and functional inheritance features are generally considered as being specific to each species, on the condition that the animal development is made under the same environmental conditions. In reality, in the environment, there are permanent changes and challenges, which will lead to different particular phenotypical manifestations in the frame of the individuals belonging to the same species, breed, or even line [3].

The inheritance pattern is given by the trinity of molecules: DNA, RNA, and proteins [8]. The DNA represents the genetic material in mammals, which is organized into genes which store the genetic information since the formation of the zygote. The genetic information stored into different parts of DNA is first transferred to a closely related mRNA and then into the cytoplasm of the cell, where the ribosomes are. There, the information stored in the RNA is translated into amino acids, which will be linked together to form the proteins with structural and functional role. The diverse functions of proteins determine the biochemical identity of cells and also determine the expression of inherited traits [8].

So, life is based on the process of storage and expression of genetic information, which is encoded in the individual DNA since the beginning of its life and it is permanently influenced by the environment [3].

Omic technology can be applied on one hand to better understand the physiological, normal processes in the entire body system, and, on the other hand to screen, diagnose, prognose, and understand the etiology of a disease [4]. The omic investigation is also used in drug discovery and assessment of their toxicity and efficacity, especially in cancer and cardiac therapies [4].

The discovery of new techniques and technologies generally related to omic sciences opens new perspectives and new discoveries in the study of the molecular mechanisms of the organisms, but there are also some limitations, both regarding the techniques themselves and the interpretation of the data.

4. Conclusions

1. Animal genetics as a science is a relatively new field of biology studies.
2. Classically, some fields of animal genetic studies are described, such as basic genetics (cytogenetics and Mendelian genetics); molecular genetics, genetic engineering; medical genetics (heredopathology); and population genetics.
3. During the last decades, new fields of animal genetics were developed, mainly due to the integrated concept of system genetics, considering the cell, tissue, and sometimes the entire organism as an integrated system.
4. System genetics is directly linked to omic sciences and omic technologies, which comprise the complex and bidirectional relations between genomics and genome; transcriptomics and transcriptome; proteomics and proteome; metabolomics and metabolome; and metabolomics and omic experiments.

5. The interactions on the genotype produced by the environment are studied by behavioral genetics and epigenetics in a complex inter-relation resulting in the changing in the phenotype.

6. The new discoveries in animal genetics are opening new perspectives regarding animal breeding, control, prevention, and treatment of animal diseases.

7. The new techniques and technologies have some limitations regarding the technologies themselves and also regarding the interpretation of the results.

8. In conclusion, we can say that the new genetic approaches are solving some important problems, but also at the same time, science must face the new problems which are arisen by the application and interpretation of the new genetic technologies.

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