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From genes to behavior: analyzing behavior at different levels of education at Faculty of Biology, University of Belgrade, Serbia

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ABSTRACT

The major streams of research in behavioral genetics are concerned with the causes of variation in different animal and human behaviors. Knowledge about complex gene interactions in the complex milieu of an environment, in more than “big four” model-systems (*Caenorhabditis elegans*, *Drosophila melanogaster*, mice, humans) is a growing challenge in the near future. In order to transfer to students current knowledge in the field of animal and human behavioral genetics, Faculty of Biology, University of Belgrade, Serbia, have introduced a range of courses at all education levels. Here we present teaching process related to such behavioral topics after implementation of new reformed programs (started from 2012/2013) at Undergraduate Academic level (*Animal Behavior* course), Master level (course *Principles of Genetic Research of Complex Traits*), Specialist Academic studies (module *Genetics, Human Behavioral Genetics* course) and Doctoral, PhD studies (module *Genetics, Behavioral Genetics* course). The basic, *Animal Behavior* course is organized by two chairs, *Chair of Genetics and Evolution* and *Chair of General Physiology and Biophysics*, while other courses are carried out by *Chair of Genetics and Evolution*.

Key words: genes, behavior, education, teaching process

Introduction

Behavior is one of the most intriguing topics, being studied in different areas of biology (physiology, neurobiology, genetics, ecology, evolution), which use different approaches and methods in an attempt to describe and explain such a complex phenotype. In addition, human behavior is subject of study in medicine, psychology, special education, then in sociology, ethnology, anthropology, etc. Scientific progress in behavioral sciences, psychiatric medicine, as well as development of modern molecular-genetic techniques in forensics is followed by media attention and has led to interest in these issues not only in academic circles, but also in the general public. In this respect, the one of major streams of behavioral genetics is concerned with the causes of variation in human behaviors, such as cognition, personality, psychopathology and addictions (Maxson, 2007). Knowledge about gene structure and function and how they interact with each other, in the complex milieu of an

environment, and their further effects on brain - behavior relationship is a growing challenge in the near future (Figure 1). Furthermore, behavioral genetics in 21. century should include more than “big four” model-systems (the most commonly used in the first century of behavioral sciences, i. e. nematode *Caenorhabditis elegans*, *Drosophila melanogaster*, mice, humans), toward comparing the behavioral effects of homologous genes across species (Maxson, 2007).

In order to transfer to students current knowledge in the field of animal and human behavioral genetics, Faculty of Biology, University of Belgrade, Serbia, have introduced a range of courses at all education levels. As noted in our previous paper, Faculty of Biology, University of Belgrade, started with implementation of new reformed programs according to Bologna process (European reform process aimed at creating the European Higher Education Area) from 2007/08 academic year (Pavković-Lučić et al., 2010).

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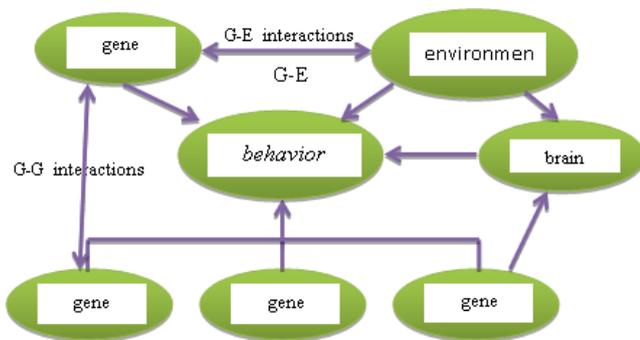


Figure 1. Complexity of studying the behavior.

Beginning of the implementation of Bologna process involved “3 + 2” system of studying, i. e. Undergraduate Academic studies (Bachelor degree) included 3 years of education, while Master studies lasted for 2 years. However, Faculty of Biology, University of Belgrade, changed system of studying from 2012/13 academic year, when “4 + 1” system was implemented (Undergraduate studies lasts 4 years, Master studies lasts 1 year). Beside, our Faculty also offers Specialist Academic studies (which include 3 modules, namely *Genetics*, *Microbiology* and *Immunology with Microbiology*, last one year) and doctoral, PhD studies (in *Biology*, *Ecology*, and *Molecular Biology*, last three years) (http://www.bg.ac.rs/eng/education/en_studije-nivoi.php).

In this paper, we present courses at all education levels in which “pathways between genes and behavior” are involved (Figure 2). These courses also include some other, very important aspects of analyzing behavior, like physiological, ecological and evolutionary ones. Furthermore, there are other courses at different educational levels, taught by our colleagues, in which many topics in neurobiology, brain-behavior relations and cellular basis of behavior are offered to students, as well as courses involving approaches to the molecular aspects of human genetics, including psychiatric, neurodegenerative diseases, etc. Some of these courses are compulsory and some of them are elective courses (Pavković-Lučić et al., 2010, www.bio.bg.ac.rs).

Genes and Behavior - Bachelor Level

Bachelor Level (Undergraduate Academic Studies): At the Bachelor level, students of Biology attend *Animal Behavior* course as compulsory course (for short course content see Appendix 1, Pavković-Lučić et al., 2010). This course involves, primarily, physiological and genetic analysis of behavior, as well as the function of behavior, and is

organized by two Chairs (Chair of Genetics and Evolution and Chair of General Physiology and Biophysics).

Bachelor Level	Master Level	Specialist Academic Studies	PhD Level
Course: Animal Behavior (5 ECTS)	Course: Principles of Genetic Research of Complex Traits (6 ECTS)	Course: Human Behavioral Genetics (6 ECTS)	Course: Behavioral Genetics (5 ECTS)

Figure 2. Courses that include genetic aspects of behavioral analysis. Abbreviations: ECTS – the European Credit Transfer System.

When considering relation between genes and behavior, the most important topics include: biological basis of individual differences in behavior, the role of genes and environment in developing behavioral traits, genetic mechanisms of behavioral control, genetic analysis of learning and memory, genetics of circadian rhythms, genetic basis of human behavior (Pavković-Lučić et al., 2010). This course attend, from year to year, about 120 students and it takes 5 ECTS (the European Credit Transfer System) (Figure 2). Beside theoretical lectures, we involved some practical work with fruit fly, *Drosophila melanogaster* as a model system (*wt* and mutant strains), testing its mating behavior (courtship sequences, mating latency, mating success, mating duration, etc.), then observing and quantifying behavioral data, including basic statistics and explanation of the results. Unfortunately, at this moment, we have no possibilities for realization of continuous field and laboratory exercises. Instead, we help students to navigate for information on a particular topic of their interests searching internet resources, books, scientific papers, etc.

Evaluation of students' knowledge: The students' knowledge is checked three times during the course: the first test carries 30 points and checks for the knowledge obtained in physiological aspects of behavior. The second test is organized after “genetic part” of the course is finished; it also carries 30 points (for the form of these tests see Pavković-Lučić et al., 2010). Final exam is written exam; it carries 40 points and tests for all teaching topics from the course. Two tests and final exam give the maximum score of 100 points. Scores are ranking from lowest (51-60 points – grade 6) up to highest (91-100 – grade 10). After finishing course, students carry out evaluation of course and teachers; these information are very useful in improving teaching/education quality.

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Genes and Behavior - Master Level

Master Level: At Master level, during “3 + 2” system of studying, we offered to our students course *Introduction to Behavioral Genetics* (on the module *Applied Genetics*, 4 ECTS). Nowadays, at Master level, there are many modules (see www.bio.bg.ac.rs). After applying “4 + 1” system of studying, genetic analysis of behavior is involved as a part of more complex course, *Principles of Genetic Research of Complex Traits* (compulsory course for *Applied Genetics* module, 6 ECTS, 5 - 7 students *per year*, Figure 2). This course is organized by Chair of Genetics and Evolution. The aim of the course is transfer and achievement of contemporary knowledge in genetic investigation of complex traits. This course also takes maximum of 100 points, and analyzing “behavior as a complex trait” carries 30 points. After students learn the theoretical part of the course (www.bio.bg.ac.rs), they have individual work (writing seminars), namely, every student gets topic considering particular behavioral phenotype. It is expected from students to apply their knowledge considering different methodologies and behavior (e. g. in case of human complex behavioral traits and disorders, to overcome quantitative-genetics approaches and molecular-genetics methodology and to present the latest investigations and results from literature, considering given behavior). Some of these topics are presented in Box 1; they involve genetic aspects of analyzing animal (nematodes, fruit flies, rodents, etc.) and, for students often more interesting, human behaviors. In addition, one lecture is devoted to complex genetic dissection of learning and memory in *Drosophila melanogaster* (as practical issue, with special attention paid to learning of olfactory and gustatory information).

Evaluation of students' knowledge: As mentioned above, it is expected from students to overcome methodology, statistical analysis of behavioral data (from theoretical part of the course, as well as from reading textbooks and analyzing scientific papers), and to present the most recent results regarding given behavioral phenotype. The written seminar takes 15 points, as well as public oral presentation of the work. Oral presentation of the work involves discussion among teachers and students. These points (maximum 30) represent part of students' final mark, because students must obtain more points from the other parts of this course.

Final master work: Students also may have experimental, laboratory work, under mentor/ teacher supervision, which results in their final master work obtained from “behavioral

part of the course”. Our the first master student obtained experiment considering relation between behavioral trait (mating success) and wing size and shape of *Drosophila melanogaster* flies reared under different nutritional conditions (Trajković et al., 2013). Furthermore, final master work of students attending other modules sometimes also implements behavioral analyses.

Animal resources and behaviors:	Human behaviors:
<ul style="list-style-type: none"> Genetic analysis of aggression (<i>Drosophila</i>, mice, etc.) Genetic analysis of <i>Drosophila</i> courtship behavior Genetic analysis of learning and memory (different model systems) Genetic analysis of emotional 	<ul style="list-style-type: none"> Personality traits Personality disorders General cognitive ability Cognitive disabilities Genetics of attention problems: <i>ADHD</i> Genetics of <i>Autism</i> Genetics of <i>Anxiety disorders</i> <i>Schizophrenia</i> as a genetically complex phenotype Genetics of <i>Bipolar Affective Disorder</i>

Box 1. Some titles of students' seminars.

Genes and Behavior - Specialist Academic Studies

Specialist Academic Studies: At Faculty of Biology, University of Belgrade, three modules of Specialist Academic Studies have been established, namely *Genetics*, *Microbiology* and *Immunology with Microbiology* (http://www.bio.bg.ac.rs/03_specijalisticke_studije.php).

Every of these study programs is one-year academic program, dedicated to education and training of graduated students in professional and scientific work. Those studies carry 60 ECTS (30 ECTS obtaining through courses and 30 ECTS through experimental, practical work) and, upon completion of these study programs, student acquires the professional title of a specialist biologist (for the certain area). The aim of the Specialist Academic studies in *Genetics* study program, organized by Chair of Genetics and Evolution, is to provide a complete academic education, as well as specific knowledge and understanding of selected specialist areas in the field of genetics (<http://www.bio.bg.ac.rs>).

At *Genetics* module, *Human Behavioral Genetics* is established as an elective course and it takes 6 ECTS (Figure 2). The maximum number of students attending this type of

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study (also course) is 10 *per* year. According to their educational profile, most of these students have diploma in biology, molecular biology and physiology, as well as in medicine, special education or dentistry; most of them are employed in different state or private medical institutions, like hospitals, cytogenetic and molecular-genetic laboratories, etc. In most of the cases, they got further knowledge and skills necessary to work in medical, pharmaceutical, agricultural and other industries. Beside students from Serbia, we also have students from Bosnia and Herzegovina attending these studies/courses. Theoretical part and practical classes of *Human Behavioral Genetics* course are presented in Box 2.

Theoretical part of Human Behavioral Genetics course:

History of Behavioral Genetics. Development of genetical aspects in studying behavior. Definitions of behavior. Behavior as a complex phenotype. Genetic basis of behavior. Types, experimental designs and statistical analyses in human behavioral genetics. Methods in the study of human behavior (family studies, twin studies, adoption studies). Threshold traits. Heritability of liability. Molecular-genetic methods in the study of human behavior. Allelic associations. Linkage analyses. Personality traits. Personality disorders. Disorders of cognitive functions. Mental retardation. Pervasive developmental disorders. Psychiatric disorders. Dementia. Behavioral disorders caused by consuming psychoactive substances. Deviant behaviors. Application of bioethics in genetics.

Practical classes: involves student seminars and mini-projects (working in small groups, depending of the number of students which attend course).

Box 2. Theoretical and practical classes of *Human Behavioral Genetics* course.

Evaluation of students' knowledge: Seminar takes 40 points and final (oral) exam takes 60 points. As in previously mentioned courses, seminar and final exam give the maximum score of 100 points, and grade is ranking from the lowest (51- 60 points – grade 6) up to highest (91-100 – grade 10).

Genes and Behavior - Doctoral Academic Studies (PhD Level)

- Savić Veselinović M. 2013. The influence of induced mutagenesis on reproductive behavior of *Drosophila subobscura* and the role of sexual selection in relation to the level of mutational load. PhD Thesis, University of Belgrade, Faculty of Biology, p. 114 (defended doctoral dissertation)
- Golubović A. 2014. Characteristics of functional morphology and ethology of Hermann's tortoises (*Testudo hermanni*). PhD Thesis, University of Belgrade, Faculty of Biology, p. 90 (defended doctoral dissertation)
- Dimitrijević D. 2014. Influence of extremely low magnetic field (50 Hz, 0,5 mT) on locomotor activity and fitness components of *Drosophila subobscura* (Collin, 1936) (PhD thesis in preparing for defense)
- Filipović Lj. Learning of olfactory information in *Drosophila melanogaster* strains after long-term maintenance on different diets (working title, PhD thesis in preparing)

Box 3. Titles of doctoral dissertations.

Doctoral Academic Studies: At PhD level (module *Genetics*, organized by Chair of Genetics and Evolution), we established course *Behavioral Genetics*, which takes 5 ECTS (Figure 2). The main aims of the course are: introducing students with the genetic basis of behavioral traits in animals and humans, with methods of study, data processing and interpretation of the results, as well as the ability of making ethical attitudes in behavioral genetics research. This is an elective course and is organized mostly through individual work with students, with special attention devoted to behavior of object of their interest (animal model system or humans). When considering animals, most of students work experimentally with fruit flies, like *Drosophila melanogaster* and *D. subobscura* (Savić-Veselinović, 2013), but also with other animal species, like turtles (Golubović, 2014).

In case of higher number of students *per* academic year, teaching methods may involve, beside lectures, thematic panel discussion and seminars. In such cases, evaluation of

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the knowledge is based on the activity in discussions and seminars throughout the course (70%), and presenting the final seminar work (30%).

The titles of some doctoral dissertations considering behavior, not only from students attending *Genetics* module, but also defended on other PhD module (*Morphology, Systematics and Phylogeny of the Animals*) are presented in Box 3. All of these students attended *Behavioral Genetics* course.

Remark: Within PhD module *Entomology*, there is an elective course *Magnetobiology and Insect Behavior*, where, as a part of a course, genetic basis of insect behavior should be considered. Among other topics, attention is devoted to behavior of social insects (ants, wasps, bees), as well as to some insects of medical and economic importance, such as agricultural pests, in relation to the field of applied entomology.

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