UNDERSTANDING OF POPULATION GENETICS AND EVOLUTION AMONG UNIVERSITY STUDENTS

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ABSTRACT: This research examined university students' understanding about various concepts of population genetics and how they integrate that knowledge to explain the theorie of Evolution. A mixed study method was used to explore the students' understanding of different factors that affect evolution. Data were collected by questionnaire and interview and were analyzed qualitatively. The results indicate that the majority of students know how can natural selection and mutation affect allele frequency in a population but they have difficulties to understand how act Genetic drift on the evolution of allele frequencies. They had also misconceptions of some concepts related to evolution like speciation. The majority of students don't believe to Human evolution but they accept the theory of evolution for the other species.

Key words: genetic population, misconceptions, evolution, natural selection, genetic drift.

INTRODUCTION

The scientific and technological developments in genetics have had a considerable impact on different areas of everyday life (agriculture, medicine...). A scientifically literate public is essential if citizens are to engage effectively with policymakers on issues of scientific importance (Dougherty 2009). Genetics is also one of important biology basic courses, it is very important to many other subjects. Genetics is one of the most difficult subjects in the biology curricula at university levels (Agorram, 2010, 2015; Kindfield, 1994). Studies in other countries have shown that understanding of genetics and its various aspects is poor among students of various levels (Lewis and Wood-Robinson, 2000).

The Population genetics field develops more quickly. However, many Students find numerous difficulties in assimilating this course because it is a specialized course with abstract and difficult knowledge (Agorram 2015). Population genetics is a field of biology that studies the genetic composition of biological populations and the changes in genetic composition that result from the operation of various factors, including natural selection. Population geneticists pursue their goals by developing abstract mathematical models of gene frequency dynamics, trying to extract conclusions from those models about the likely patterns of genetic variation in actual populations, and testing the conclusions against empirical data (Okasha 2015). Population genetics is concerned with the genetic basis of evolution. It differs from much of biology in that its important insights are theoretical rather than observational or experimental. It could hardly be otherwise.

To the best of my knowledge, almost no reports in Morocco have examined students' knowledge and understanding of biology topics related to population genetics. Hence the importance of this research, which aims to analyze Moroccan university students' understanding of population genetics, is to identify their most common misconceptions.

BACKGROUND

Population genetics is concerned with the origin, amount, and distribution of genetic variation present in populations of organisms and the fate of this variation through space and time. Population genetics has always played a central role in evolutionary biology as it deals with the mechanisms by which evolution occurs within populations and species, the ultimate basis of all evolutionary change. However, despite its importance, genetics is considered difficult to teach and difficult to learn (Finley et al. 1992). Students typically dislike learning about Hardy–Weinberg equilibrium as they frequently find it confusing, boring, and irrelevant to their lives (Soderberg & Price 2003).

In contrast to classical genetics and molecular genetics, the population genetics is more difficult. This impacts negatively on learning because (i) a proper understanding of microevolutionary processes requires some understanding of Population genetics beyond Hardy Weinberg equilibrium; (ii) Population genetics offers opportunities to generate and test hypotheses using quantitative methods; and (iii) Population genetics is one of the few subjects that introduces students to stochastic processes. Also, with the arrival of the "post-genome" era, Population genetics methods are increasingly important in medical genetics research (Reich et al. 2001). Misunderstanding of Population genetics is widespread, and part of the problem can be attributed to lack of appreciation of stochastic processes (Kliman 2001).

Population Genetics and Microevolution

Hardy-Weinberg Equilibrium Law

It's the central law in population genetics. The Hardy-Weinberg equilibrium principle describes the unchanging frequency of alleles and genotypes in a stable, idealized population. In this population, we assume there is random mating and sexual reproduction without normal evolutionary forces such as mutation, natural selection, or genetic drift. In the absence of these evolutionary forces, the population would reach equilibrium in one generation and maintain that equilibrium over successive generations. By describing specific ideal conditions under which a population would not evolve, the Hardy-Weinberg principle identifies variables that can influence evolution in real-world populations. If a population is not in a state of equilibrium, at least one of the evolutionary forces is at work causing change in the population. Further investigation can determine which variables are influencing the changing population.

The Hardy-Weinberg equilibrium principle is also one of the more difficult topics for biology students to understand and for teachers to teach. One reason for this difficulty is the students' mathematical background. More problematic than lack of manipulative skill is the difficulty of understanding why the principle is true and understanding how the principle applies to specific populations or more importantly, the value of its application. Many of these students wonder about the relevance of the Hardy-Weinberg principle to understanding evolution.

Natural selection

Natural selection as a mechanism of evolution is a central concept in biology, it is a non-random difference in reproductive output among replicating entities, often due indirectly to differences in survival in a particular environment, leading to an increase in the proportion of beneficial, heritable characteristics within a population from one generation to the next. It is one of the core mechanisms of evolutionary change and is the main process responsible for the complexity and adaptive intricacy of the living world (Gregory 2009). A growing list of studies indicates that natural selection is, in general, very poorly understood—not only by young students and members of the public but even among those who have had postsecondary instruction in biology.

Natural Selection is so difficult to understand for two reasons: The first is that understanding the mechanism of natural selection requires an acceptance of the historical fact of evolution, the latter being rejected by a large fraction of the population. Numerous studies indicate that rates of acceptance already are much higher than levels of understanding. And, whereas levels of understanding and acceptance may be positively correlated among teachers, the two parameters seem to be at most only very weakly related in students (Shtulman 2006).

The second reason is that most people simply lack formal education in biology and have learned incorrect versions of evolutionary mechanisms from non-authoritative sources (e.g., television, parents). Inaccurate portrayals of evolutionary processes in the media, by teachers, and by scientists themselves surely exacerbate the situation. However, this alone cannot provide a full explanation, because even direct instruction on natural selection tends to produce only modest improvements in students' understanding (Finley 1992; Nehm and Reilly 2007).

Genetic Drift

Genetic drift is defined as random changes in allele frequencies in a population. The mechanism is so named because the pattern shows the drift of allele frequencies, up and down over time—there is no predictable directional component to change from generation to generation. Genetic drift occurs in all populations that are not infinitely large. It has especially strong effects when populations are small over several generations. Because genetic drift is based on a random sampling process rather than deterministic process, students often have a difficult time understanding and appreciating its role in Evolution (Staub 2002).

There are numerous misconceptions cited in the literature as:

- “Genetic drift is due to random mutations; genetic structure can change over time.”
- “Genetic drift is when the population moves to a location more suitable to its characteristics.”
- “Genetic drift occurs due to isolation of a population or species by whatever means.”
- “Genetic drift occurs when a sect of a species is separated from the other and changes to adapt to their new environment.”
- “Genetic drift is a change in genes caused by an isolated event, often a catastrophe.”
- “Genetic drift is genetics in a smaller population.”
- “Genetic drift generally happens when part of a species population is separated and become distinguished and change” (Andrews et al 2012).

Misconceptions of and attitude toward Evolution

Students bring a diverse array of ideas about natural phenomena to their science classes and many of these ideas are often at variance with the scientifically accepted views. Numerous studies conducted in recent decades identify multiple biological evolution-related misconceptions held by select groups of students. These groups include secondary students (Kampourakis & Zogza, 2009) or undergraduate students (Nehm & Reilly, 2007; BouJaoude et al, 2009). These studies repeatedly indicate that students of all ages and with varying educational backgrounds have difficulties accurately understanding the concepts constituting Evolution. These misconceptions are tenacious and pervasive ranging from minor misunderstandings to complete theory rejection. Common biological evolution misconceptions seem to have a life of their own with some of the most pervasive ones having persisted for decades despite all efforts to correct them (Mead, 2010; Yates & Marek, 2015).

Use and Disuse is one of the common misconceptions: Many students conceive of evolution as involving change due to use or disuse of organs. This view, which was developed explicitly by Jean-Baptiste Lamarck but was also invoked to an extent by Darwin, emphasizes changes to individual organisms that occur as they use particular features more or less. For example, Darwin invoked natural selection to explain the loss of sight in some subterranean rodents, but instead favored disuse alone as the explanation for loss of eyes in blind, cave-dwelling animals: “As it is difficult to imagine that eyes, though useless, could be in any way injurious to animals living in darkness, I attribute their loss wholly to disuse.” This sort of intuition remains common in naïve explanations for why unnecessary organs become vestigial or eventually disappear. Modern evolutionary theory recognizes several reasons that may account for the loss of complex features, some of which involve direct natural selection, but none of which is based simply on disuse.

Other misconceptions were inventoried : Change due to need, tendency toward improvement, inheritance of acquired characteristics, mutations caused by environmental changes, adaptation as positive change rather than selection against maladaptive traits, individual organisms change, Primarily change in response to need, Organisms changing in response to need or in an attempt to adapt, “fitness” relating to physical condition, minimal variation within populations, only beneficial traits are passed on, Beneficial physical changes in parents are passed on to offspring, Heritable differences between parents and offspring are due to improvement in response to needs. Organisms change over their lifetimes to become better able to survive and pass these changes on to offspring. Any differences between parent and offspring will be in the direction of further improvement. The entire species transforms in response to need (Demastes et al 1995; Bardapurkar 2008; Gregory 2009; Nehm & Reilly 2007).

Population Genetics in Moroccan curriculum

In secondary school, a course of Population genetics was integrated in the last reform of the educatif system. The concepts treated in this course are: Genetic Variation in natural populations and its estimation; Hardy-Weinberg Law; deviations from Hardy-Weinberg equilibrium; evolutionary forces (Mutation, Migration, Natural selection and Genetic drift); speciation; example of microevolution (evolution of Horse). The Human evolution is not mentioned in the curriculum or in textbooks.

In the university level, Populations genetics is treated in the third year (baccalaurat + 3 years) as a complete course of 50 hours. The program is the same as that taught in secondary education but more in detail with some lab. Human evolution is treated in some courses of the university curriculum.

METHODS

This study is mainly qualitative, our methodology was mixed. We used a questionnaire and interview. These qualitative analytical methods were supplemented with statistical analysis to identify students' misunderstanding in Population genetics.

Students sample: All students surveyed in the study were enrolled in a graduate science program at the University, the sample is composed of 86 Graduate Students (baccalaureate plus 3 years of study) and 20 Master' students (baccalaureate plus 4 or 5 years). The mean age of students was 24 years (range: 22 to 37 years). Females comprised 46 percent of the sample.

The questionnaire: We composed a questionnaire to acquire information on several key issues: (a) the students' understanding of population concept, Hardy-weinberg law, genetic structure, (b) the students' understanding of the mechanisms by which evolutionary change occurs, and (c), the level of acceptance of evolution among science graduate students.

Some of the questions were inspired by previous studies (Shtulman 2006, Kampourakis and Zogza 2009); however, we developed many new questions appropriate for students at the graduate level. In this article, we only analyze the students' responses in respect of two evolutionary forces: natural selection and genetic drift.

The interview: Interview was conducted on eight voluntary participants. The interviews lasted approximately 30 minutes. Thematic interview questions are used to explore in greater detail the most commonly held misconceptions identified by the questionnaire analysis. The Interview was recorded and a coding rubric was used to score student responses.

RESULTS

Genetic variation and Hardy-Weinberg law (equilibrium law)

Genetic variation describes naturally occurring genetic differences among individuals of the same species. This variation permits flexibility and survival of a population in the face of changing environmental circumstances. Consequently, genetic variation is often considered as an advantage for populations (Klug and al 2012).

Nearly half of students think that existing variation among individuals are rare and unimportant for Evolution. The existing genetic variation within and between populations is an important factor for Evolution, without variation, there isn't Evolution. For these students, the fact of belonging to a species is opposed to the existence of genetic variation between individuals of this species.

Students are familiar with the statement of the Hardy-weinberg law (H-W) and the conditions of its application but a student out of four believes that this law is only valid in the case of diploids organisms (table 1). In interviews, we asked the students to show and explain this central law of population genetics. Over a third of students are unable to link this law to reproduction and they are unable to use the chessboard of gametes (Punnet square) to find the genetic structure of the offspring. Other students do not understand why they use gametic frequencies different of the Mendelian ones (1/2; 1/2).

The genetic variation of natural populations is constantly changing from genetic drift, mutation, migration, and natural and sexual selection. The Hardy-Weinberg principle gives scientists a mathematical baseline of a non-evolving population to which they can compare evolving populations. If scientists record allele frequencies over time and then calculate the expected frequencies based on Hardy-Weinberg values, the scientists can hypothesize the mechanisms driving the population's evolution (Boundless Biology 2016).

Seven students out of ten think that the Hardy-Weinberg law cannot be applied in the case of natural populations. This is can be explained by the fact that no natural population does comply with the conditions of the ideal population described by Hardy-Weinberg law (natural populations are a finite size, there are mutations, gene flow and selection) One of the specific difficulties of the H-W law is that it is what would happen to allele frequencies in the absence of any evolutionary parameter. This is counterintuitive for most students. H-W law is the standard by which evolution can be measured.

It is a strange fact that the most basic law of population genetics, which is attributed to Hardy and Weinberg, is poorly understood by majority of students and many scientists who use it routinely. One of misconceptions is that random mating and Hardy-Weinberg proportions are inextricably linked. Stark (2006) shows that, provided the population has discrete and non-overlapping generations, Hardy-Weinberg proportions can be attained in one round of non-random mating and that random mating is a single point in a continuum of such possibilities.

Table 1. Students' Understanding of Variation and H-W Law (In %)

	Statement	1	2	3	4	5	6
Q 6	Variation among individuals within a species is important for evolution.	12	33	12	8	22	13
Q 27	Existing variation among individuals are rare and unimportant for Evolution.	19	29	2	35	12	3
Q 32	The Hardy-Weinberg law can not be applied in the case of natural populations	22	45	9	14	8	2
Q 33	In the Hardy-Weinberg law, $p^2 + 2pq + q^2$ are the genotypic frequencies	28	54	7	4	7	0
Q 36	HW Law is valid only in diploids	5	37	13	17	23	5

1 I Strongly agree 2 I agree 3 Neutral 4 I disagree 5 I Strongly disagree 6 Non-answer

Acceptance and understanding of Evolution among students

About 84 % of the students who completed the questionnaire don't identified Evolution as an established scientific fact supported by overwhelming evidence and think that there is lots of evidence against Evolution. More than 92% of students surveyed assert that Apes and man have not a common ancestry and that the theory of Evolution doesn't explain the development of life (about 86% of students surveyed). Nevertheless, they accept the statement that Humanity came to be through Evolution, which was controlled by God (37%) (Fig 1).

This attitude toward the theory of evolution is explained by the fact that all these students are Muslims and that the majority of them are believers. Many researches have found similar results (BouJaoude et al, 2009; Clément & Quessada, 2008; Miller et al, 2006*)*.

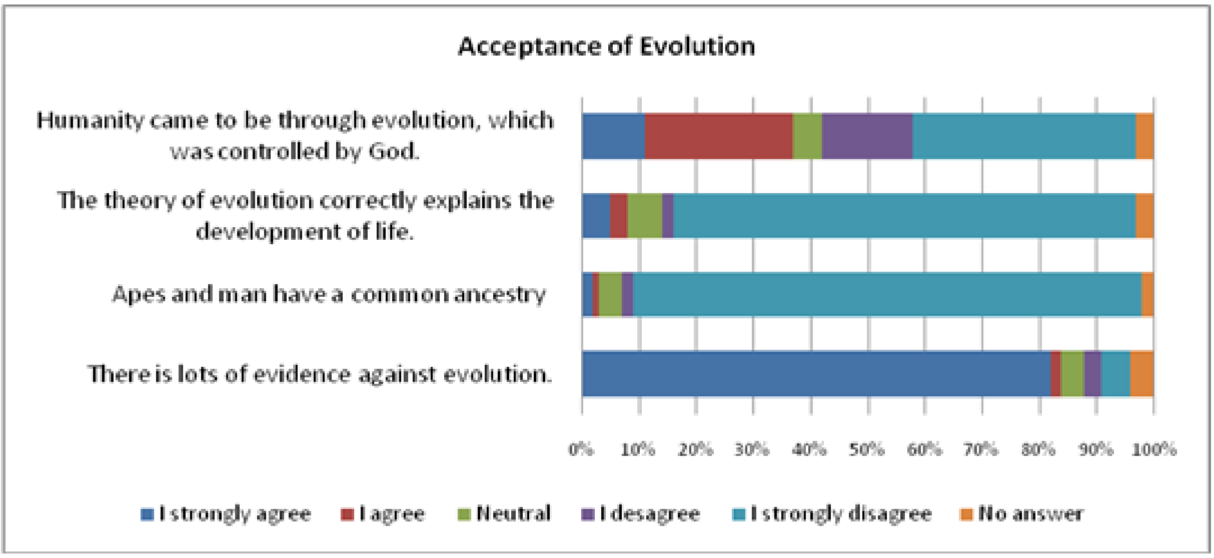

Figure 1. Students' Attitude Toward Evolution Theory

Evolution: Lamarckism versus Darwinism

Table 2. Students' Understanding of How Evolution Occurs (In %)

	Statement	**1**	**2**	**3**	**4**	**5**	**6**
Q 5	If two light-skinned people moved to a sunny location and got very tan, their children would be more tan than they (the parents) were originally.	3	16	11%	7	59	4
Q 8	A species evolves because individuals want to.	2	14	8	12	58	5
Q 24	Evolution is always an improvement.	20	32	8	18	10	12
Q 10	A species evolves because individuals need to.	20	34	8	5	25	8
Q 18	All individuals in a population of ducks living on a pond have webbed feet. The pond completely dries up. Over time, the descendants of the ducks will evolve so that they do not have webbed feet	14	33	11	12	23	7
Q 30	"Survival of the fittest" means basically that "only the strong survive".	11	39	6	11	26	7
Q 13	New traits within a population appear at random.	8	25	10	43	9	5
Q 14	The environment determines which new traits will appear in a population.	11	41	11	12	18	7
Q 22	Evolution cannot work because one mutation cannot cause a complex structure (e.g., the eye).	17	31	10	22	12	8

1 I Strongly agree 2 I agree 3 Neutral 4 I disagree 5 I Strongly disagree 6 Non-answer

- One student out of five imply that acquired traits can be inherited (19 % for question Q5), and more than the half of students (54%) think that a species evolves because individuals need to. About one student out of two implies that a trait is developed as a result of loss through disuse of the trait (Q 18). The ideas of ‘‘use and disuse’’ and of ‘‘the inheritance of acquired traits’’ are associated with Lamarck. ‘‘Lamarck asserts that the need of organisms to adapt to environmental demands and their innate drive towards better, more complex, organizations drive the evolution of new species’’(Samarapungavan & Wiers, 1997).Numerous elements charachterizes lamarckian conceptions : individual organisms are changing in response to "need" ; change through conscious efforts toward improvement, and enhancement or loss of features as a result of use or disuse ; inheritance of acquired characters (Gregory, 2009 ; Kampourakis and Zogza 2009).
- Only one student out of three states that new traits within a population appear at random (33% for Q13).

These results show the existence of two antagonistic conceptions:

- Individual organisms are changing in response to "need"; change through conscious efforts toward improvement, and enhancement or loss of features as a result of use or disuse. These changes are passing on to the offspring (more than 50% of surveyed students): "Lamarckian" conceptions (Gregory, 2009; Kampourakis and Zogza 2009).
- Species evolve by mechanisms, which are based on over production, chance mutation, and nonrandom survival and reproduction as influenced by the heritable traits of organisms. Only random processes produce new traits or a change in existing traits. The following environmentally directed influences do not cause a change in genetic traits (Darwinian conceptions).

Mechanisms of Evolution

Natural selection

Four students out of ten say that the two most important factors that determine the direction of Evolution are survival and reproduction (Q12) wich are the cause of the various fitness (66% for Q38). But, the majority of surveyed students do not understand the differents models of selection and their actions on genetic variation (Q35). They confound these different types of selection (Directional, Disruptive, and Stabilizing). They also say that dominant alleles are always selectively advantageous (63% for Q31), "Survival of the fittest" means basically that "only the strong survive" (50% for Q30), they also say that Natural selection can not act when genetic drift occurs (37% for Q23) (Table 3).

Survival in the struggle for existence is not random, but depends in part on the hereditary constitution of the surviving individuals. Those individuals whose surviving characteristics fit them best to their environment are likely to leave more offspring than less fit individuals. The unequal ability of individuals to survive and reproduce will lead to gradual change in a population, with the proportion of individuals with favorable characteristics accumulating over the generations.

Table 3. Students' Understanding Of Natural Selection

	Statement	1	2	3	4	5	6
Q 24	Evolution is always an improvement.	20%	32%	8%	18%	10%	12%
Q 11	I have a clear understanding of the term "fitness" when it is used in a biological sense.	2%	25%	5%	43%	8%	16%
Q 12	Two of the most important factors that determine the direction of evolution are survival and reproduction.	16%	24%	10%	27%	11%	11%
Q 15	Directional selection occurs when natural selection favors both the homozygous genotypes	16%	27%	23%	7%	11%	16%
Q 16	Disruptive selection can lead to two new species.	14%	29%	14%	17%	11%	14%
Q 21	Stabilizing selection occurs when natural selection favors the intermediate states of continuous variation.	34%	10%	6%	23%	16%	11%
Q 23	Natural selection can not act when genetic drift occurs	10%	27%	11%	20%	13%	18%
Q 25	If webbed feet are being selected for, all individuals in the next generation will have more webbing on their feet than individuals in their parents' generation.	14%	26%	12%	16%	24%	8%
Q 28	Disruptive selection occurs when natural selection favors both extremes of continuous variation.	9%	27%	10%	14%	23%	16%
Q 30	"Survival of the fittest" means basically that "only the strong survive".	11%	39%	6%	11%	26%	7%
Q 31	Dominant alleles are always selectively advantageous	24%	39%	2%	10%	17%	8%
Q 34	The mutation is an effective evolutionary strength	35%	22%	7%	21%	13%	2%
Q 35	Natural selection always decreases genetic variation	24%	41%	7%	7%	21%	0%
Q 37	individuals have different fitness because of their different phenotypes	19%	28%	21%	10%	15%	7%
Q 38	survival rate and fertility are the cause of the various fitness	23%	39%	6%	12%	11%	9%

1 I Strongly agree 2 I agree 3 Neutral 4 I disagree 5 I Strongly disagree 6 Non-answer

Genetic Drift

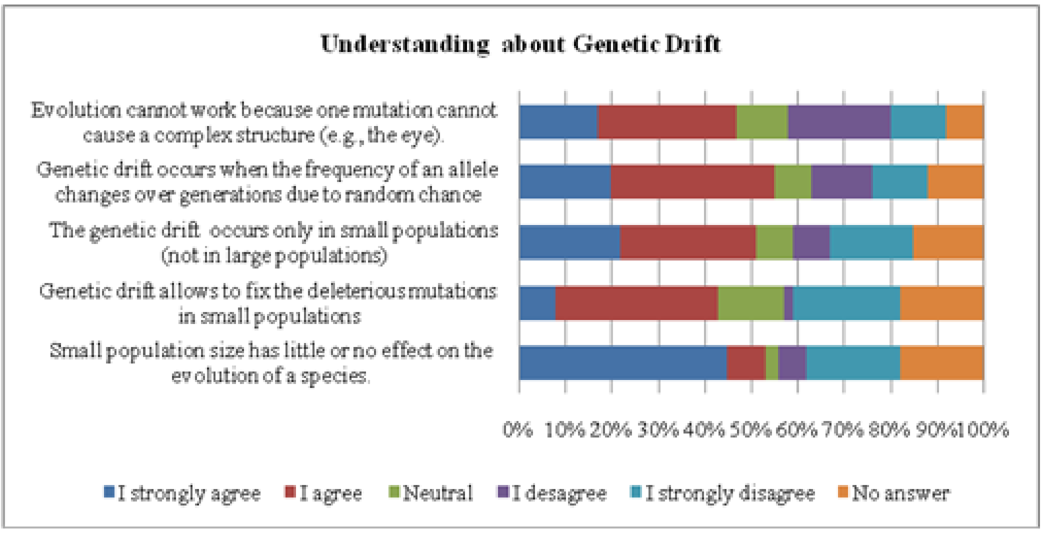

Figure 2. Students' Understanding About Genetic Drift

More than half of surveyed students say that the genetic drift has no effect in small populations (53%) and that the drift does not occur in large populations (51%) (Table 3). This is strange because more than half of the students correctly identify Genetic drift as a random phenomenon which causes a change of allele frequencies over generations.

The effects of genetic drift are all the more important as the population is small, because the observed differences of allele frequencies from one generation to the other are all the more noticeable. Genetic drift concerns mainly neutral alleles that confer no selective advantage or disadvantage. Genetic drift is a major mechanism of Evolution.

DISCUSSION AND CONCLUSION

The results show that the majority of surveyed students reject the theory of evolution, this can be explained by the fact that these students are Muslims. These results accord well with recent polls regarding the acceptance of evolution in numerous countries despite the differences in cultural and religious contexts between these countries (Clément, & Quessada 2008; Angus Reid GlobalMonitor 2007; Miller et al. 2006, Gallup 2009).
Among the factors contributing to students' low score in accepting Evolution are poor understanding of Population genetics, the politicization of science and the literal interpretation of the sacred books of each religion (Miller et al. 2006).

The results show also that the majority of surveyed students have difficulties in understanding the basic concepts of Population genetics. Analysis of the questionnaire results and interviews allow to identify some misconceptions. Thus, the most common students' misconceptions relate to the fact that if an organism changes during life in order to adapt to its environment, those changes are passed on to its offspring, these changes are made by what the organisms want or need. Evolution happens according to a predetermined plan and that the results have already been decided. Such views have often been labeled "Lamarckian".

But, this was commonly mixed with a semi-Darwinian notion of "advantage," implying at least a basic appreciation of variation among individuals and competition for resources. Numerous students say that organisms, even of the same species, are all different and that those which happen to have variations that help them to survive in their environments survive and have more offspring. The offspring are born with their parents' helpful traits, and as they reproduce, individuals with that trait make up more of the population. Such misconceptions have been identified in students by other researches (Gregory 2009).

Most students had a basic understanding of the process of Evolution by Natural selection. Their ideas about how and why Evolution occurred differed from those accepted by biologists. Biologists recognize that two distinct processes, fundamentally different in cause and effect, influence traits exhibited by populations over time. New traits appear by random charges in genetic material (random mutation or sexual recombination) then theses traits survive or disappear due to selection by environmental factors (natural selection). The results of this study show that many students fail to recognize the existence of two processes and they fail to maks a distinction between the appearance of traits in a population and their survival over time.

The results show also the existence of many misconceptions about Genetic drift. Misconceptions about random processes" emerged as factors contributing to student difficulties in learning evolutionary and molecular biology (Garvin-Doxas and Klymkowsky, 2008). This is not surprising, because probability and randomness perplex students of all ages (Lecoutre et al., 2006). Students are challenged by both the terminology associated with random evolutionary processes and the conceptual complexities of these processes (Mead and Scott, 2010). Despite these obstacles, understanding random processes such as genetic drift is essential for a deep understanding of the theory of evolution. In contrast to natural selection, Genetic drift is nonselective and therefore results in nonadoptive changes in populations. Genetic drift occurs in any finite population and therefore occurs in every population all the time (Staub 2002).

The Population genetics is a challenging topic for students to learn. These students have complex and strongly held scientific misconceptions wich are an obstacle to understanding Evolution. Genetic drift and Natural selection are the most topics which present learning difficulties for students. The results suggest that most presently used methods of teaching about Evolution by natural selection are ineffective for this population of students. Even university students who had taken more than three years of biology generally showed little understanding of the evolutionary process. Efforts should be made by instructors to develop strategies to facilitate student learning of Population genetic.

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