Knowledge of Biological Evolution of Maltese Undergraduates

Sheryl Xerri

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ABSTRACT

Sheryl Xerri

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The principal objective of this study was to explore the range of misconceptions about evolutionary thought harboured by Maltese biology undergraduates. A mixed-methodology approach was used, where information was collected from undergraduate students of Biology in Malta through 15 interviews and 66 questionnaires. Analysis of the data identified 42 misconceptions present at different frequencies. There was no relationship between the undergraduates’ academic experience, self-assessed level of knowledge and level of acceptance of evolutionary thought. Instruction in genetics did aid students to gain a better understanding of evolution, but some misconceptions persisted even in students who participated in a study unit about evolution. The results indicated that whilst evolution as a process, is widely-accepted, knowledge of evolutionary processes tends to be superficial or incomplete. This suggests that more emphasis on the study of evolutionary biology is required as this would then facilitate the understanding of other aspects of biology.

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KEYWORDS: EVOLUTION, MISCONCEPTIONS, UNDERGRADUATES, MALTA.
STATEMENT OF AUTHENTICITY

I, the undersigned, declare that the following research ‘Knowledge of Biological Evolution of Maltese Undergraduates’ is my original work and supervised by Dr Sandro Lanfranco.

______________________________
SHERYL XERRI

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I dedicate this Dissertation to my Parents who supported me in every step of the way
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CHAPTER 1

INTRODUCTION
1 Introduction

1.1 The Motive and Aim of this Study:

The story of the giraffes that grew longer necks to reach leaves higher on trees was the first thing to come to mind upon hearing 'evolution', when I was a student. Indeed, I never quite understood it well in fact I used to perceive evolution as a complex and difficult concept.

While discussing a title for a new dissertation, it was my tutor who suggested that I should base my dissertation on the concept of evolution. Initially, during our discussion, my tutor suggested that I should explore attitudes of Maltese undergraduates in evolution. Indeed, when I started reading about evolution I noticed how little I knew and sometimes what I knew was wrong. While reading literature about misconceptions in evolution, I was curious to see how many of these misconceptions I hold. Besides it helped me acquire a better understanding of evolution. I thought that if I could explore misconceptions in evolution among Maltese students, my research would be very interesting and also useful to both biology teachers and the students themselves.

Primarily, the aim of my research was to identify evolutionary misconceptions held by Maltese biology undergraduates. Additionally, the presence of misconceptions cited in the literature was assessed, noting which among these are most common, least common or not present at all. Consequently, helping teachers to address these misconceptions during instruction as well as helping students to identify their own misconceptions attaining a more scientific understanding. Additionally, through such research I would like to promote evolution as the unifying character of biology, and instil awareness among teachers and students of the significance of learning biology through an evolutionary perspective. Indeed, when I was a student I considered each topic in biology as separate from another. On becoming a teacher, I will teach biology in terms of evolution assuring a better understanding of biology.
In the literature some argued that several factors such as academic experience, knowledge and acceptance of evolution, influence the students’ understanding of evolution. In this study, the relationship between such factors was measured, providing an analysis of how such factors contribute to students’ misconceptions in evolution.

1.2 Outlining the research study:

Chapter 1 outlines the motive, aims and reasons behind this research, enabling readers to become acquainted with the purpose of the study and the study itself.

Chapter 2 is an account of the literature reviewed while doing the research. It provides an explanation of biological evolution and it also outlines important historical events with regards to evolution. Subsequently, a number of evolutionary misconceptions cited in the literature are presented. It further explains what misconceptions are and how conceptual change can be achieved.

Chapter 3 describes the methodology by which the research was conducted. It starts by describing the research design, the research question and the sample and target group used. Moreover, it provides a detailed account of how the data was collected and analysed. Reliability and validity of the methods used is also discussed in this chapter.

Chapter 4 is a representation of the findings attained after analysing transcripts and questionnaires collected. These findings were supported with literature and discussed in Chapter 5.

Chapter 6 highlights the major findings of this research. Additionally, the limitations of the study were outlined together with recommendations for further research.

1.3 Reasons for this research:

The main focus of this research is to provide a number of commonly-held misconceptions as a framework upon which learning objectives can be based so
to promote conceptual change. Meanwhile factors which contribute to these misconceptions are analysed and the relationship between them is measured. Indeed, as Dobzhansky put it “Nothing in Biology makes sense except in the light of evolution” (Dobzhansky, 1973, pp. 125). Consequently, it is highly significant to develop an understanding of the Maltese biology undergraduates’ knowledge in biological evolution if we expect our students to regard biology in terms of evolution to develop a better understanding of biology.
2 Literature Review

2.1 The Theory of Biological Evolution

The Theory of Biological Evolution is a crucial aspect in the learning of biology. In fact, Dobzhansky said that: “Nothing in Biology makes sense except in the light of evolution” (Dobzhansky, 1973, pp. 125). The theory of evolution is the backbone from which all other biological concepts diverge. In this sense, many biologists and biology educators consider it to be the “unifying” concept in biology. (Maynard Smith, 1993; Bishop and Anderson, 1990; Farber, 2003)

The theory of biological evolution provides an understanding of the formation of species and justifies how different species interact together in the environment to drive this process. Likewise, it explains why all living organisms possess the same genetic material, deoxyribose nucleic acid (DNA), even though they differ in their forms and structures. (Farber, 2003) Therefore, the theory of evolution serves as a link between the different biological concepts.

In order to interrelate between the different biological concepts first our students have to gain an understanding in the theory of evolution (Demastes, Settlage and Good, 1995). Understanding the theory of evolution helps students resolve matters concerning the ‘nature of science’ (Hermann, 2008, pp. 1012) and ‘modern biology’ (Jensen and Finley, 1995, pp. 147).

Consequently, as outlined by the National Research Council (1990) (cited in Trowbridge and Wandersee, 1994) the Committee on High School Biology Education suggested that the theory of evolution becomes an integral part in our teaching of biology.

On the other hand, only those students who are capable of ‘abstract thinking’ (Keown, 1988; cited in Trowbridge and Wandersee, 1994, pp. 459) can attain a good understanding of the concept. This is because the theory constitutes a
number of related concepts that become increasingly complex as one proceeds from one to another (Trowbridge and Wandersee, 1994). In fact, in his book ‘Why Evolution is True’, Coyne (2009) said that even though his students have been exposed to the theory of evolution in their high schools still they enter University with little or no knowledge of evolution. In relation to this a minute difference was reported in the understanding of evolution between major and non-major students in a research held by Alters & Nelson (2002).

2.2  Darwin’s Theory of Evolution

It was in 1859, when Charles Darwin published his book ‘On the Origin of Species’ (Darwin, 1859). In his book, Darwin described the theory of biological evolution as “descent with modification” which occurs in populations of species rather than in an organism (1859, pp. 193).

Evolution occurs when the genetic material of some organisms in a population of a species, mutates. A mutation is a change in the genetic material of an organism resulting in genetic variation. If these mutations confer a relative reproductive advantage on the organism carrying them, then this genetic variation is passed on to future generations causing the population to evolve. (National Academy of Sciences Institute of Medicine, 2008; Futuyma, 1997; Coyne, 2009)

Moreover, such changes in the genotype of a population not only determine the phenotype of that population but it also influences the behaviour of the organisms in that population. (Ridley, 2004)

In his book, Coyne (2009) said that more or less all living species evolve in their existence. However, species do not evolve at the same rate. While some species evolve at high rates others evolve at a slower rate. It was observed that over the course of millions of years the horseshoe crabs as well as the gingko trees have changed very little if at all (pp. 4). In contrast, bacteria and viruses are able to evolve at very high rates and this enables them to develop resistance to antibiotics (pp. 4). He further argued that, the rate at which different species
evolve depends on several factors such as the duration of each generation and the environment in which they live.

Furthermore, biological evolution is driven by three mechanisms. These are; mutations, natural selection and genetic drift. Indeed, these will be explained in further detail in the following sub-sections.

2.2.1 Genetic variation arises from mutations

Mutations are changes which occur randomly (Mayr, 2001) in the genome of an organism.

When a gene mutates, the likelihood is that it changes the trait or characteristic for which it codes. By such changes individuals may either gain or be harmed. In some other cases mutations do not affect the individual. Hence, mutations can either be beneficial, harmful or it will have no effect on the individual. (National Academy of Sciences Institute of Medicine, 2008)

In a population, mutations occur in a number of individuals. This leads to genetic variation in a population (Mayr, 2001). As said in the previous section, genetic variation in a population leads to evolution (Ridley, 2004).

2.2.2 Natural selection leads to adaptation

Natural selection acts on the phenotype of a population, which is genetically determined by the genotype of that population (Ruse and Travis, 2009). However, natural selection can only occur if there is genetic variation among the individuals of a population (Coyne, 2009). As discussed earlier, genetic variation in a population arise due to mutations (Ruse and Travis, 2009).

In the book ‘Science, Evolution and Creationism’, natural selection is described as: “the differential reproductive success of organisms with advantageous traits” (National Academy of Sciences Institute of Medicine, 2008, pp. 5). This means that, in a population some individuals are capable to produce more offspring than others (Ridley, 2004).
These individuals may possess characteristics and traits, which help them, survive better in their environment than other individuals in the population. Consequently, these individuals survive and reproduce more offspring, passing on such beneficial characteristics to their future generations. (National Academy of Sciences Institute of Medicine, 2008) As these beneficial traits are passed on from one generation to the next, the genes coding for these desirable traits will increase in frequency with each generation, becoming more common in the population. (Ridley, 2004)

In each subsequent generation, the genes that code for traits that best suit the individuals to their environment are selected from the gene pool of the population and passed on to the next generation. Consequently, with every generation the population will become more adapted to its environment. (Coyne, 2009) Indeed, natural selection is the only process that leads to adaptation of a species to a particular environment (Futuyma, 1997; Coyne, 2009).

On another note, the concept of natural selection was initially proposed by Charles Darwin and Alfred Russell Wallace (Coyne, 2009). Many students regard the concept of natural selection as difficult to understand (Demastes, Settlage and Good, 1995). In fact, research done by Almquist and Cronin (1988) showed that many undergraduates still hold misconceptions in natural selection even after it is explained to them.

2.2.3 Genetic drift

Genes are found at different loci on the DNA. Indeed, a gene which codes for a particular trait can be found in different forms. Different forms of a gene are called alleles. (Ridley, 2004)

Different alleles coding for a particular characteristic may occur in a population. Alleles in a population range in frequency; while some alleles are commonly found in a population, other alleles are very rare. In a population, genetic drift occurs when the frequency of a rare allele increases across generations,

2.3 History of the Theory of Evolution

2.3.1 Pre-Darwinian Times

Before Darwin, there were many philosophers and naturalists who questioned how diverse species came into origin. Such thinking, dates back to the Hellenistic period of Greece (Ruse and Travis, 2009) during which Plato had already come up with the idea of “inheritance of acquired characters” (Ridley, 2004, pp. 7).

Later on, in 1809, in his book ‘Philosophie Zoologique’, Jean Baptiste Lamarck, a French naturalist developed Plato’s ideas into a more structured-concept which we now refer to as ‘Lamarckism’.

In his writings, Lamarck argued that an organism has an ability to produce offspring which are somewhat different from its parent. He describes this ability as an “internal force” (Ridley, 2004, pp. 7). Additionally, as these slight differences accumulate over a number of generations, the organism that develops will be completely different from its ancestor leading to the formation of a new species. Likewise, since a species changes with each generation it will never go extinct and it is not likely that it diverges into another species. (Ridley, 2004)

He further argued, that during a lifetime an organism encounters different experiences such as “accidents, diseases and muscular exercises” (Ridley, 2004, pp. 7). By surpassing such situations, the traits of an organism will change and these modifications are then passed on to the offspring. Therefore, if this will occur in every generation a new species will develop after some generations. (Ridley, 2004)
Besides Plato and Lamarck, there were other naturalists who came up with ideas on evolution. Amongst others, we find Pierre Louis Maupertuis who was a French scientist, and Erasmus Darwin who was an English botanist (Ridley, 2004).

However, none of these ideas were considered reasonable (Ridley, 2004; Mayr, 2001). As a matter of fact, before Darwin’s ideas were introduced, many scientists as well as biologists believed in the account of Creation as presented in the Bible (Mayr, 2001).

2.3.2 Darwin and Evolution

The theory of biological evolution as we know it today was initially proposed by the English naturalist Charles Darwin. In 1859, Darwin published his work in a book called ‘On the Origin of Species’ (Darwin, 1859).

Interestingly, Darwin got inspired after observing a number of different species of birds which he got from the Galapagos Islands. He was struck by how minutely different these birds of different species were from each other:

Many years ago, when comparing, and seeing others compare, the birds from the separate islands of the Galapagos Archipelago, both with one another, and with those from the American mainland, I was much struck how entirely vague and arbitrary is the distinction between species and varieties. (Darwin, 1859, pp. 83)

From this inference, Darwin came to believe that species can change (Ridley, 2004). Additionally, by analysing “individual differences” (Darwin, 1859, pp. 88) including; “embryological relations, their geographical distribution, geological succession, and other such facts” (pp. 17) Darwin concluded that “each species had not been independently created, but had descended, like varieties, from other species” (pp. 17).

In his writings, Darwin did not only explain how species change but one could note that he also strived to understand why different species are so well adapted to their environment (Ridley, 2004). Following his concept of change, Darwin came up with the concept of natural selection explaining how living
organisms are adapted to live in their environment (Ridley, 2004). Therefore, as Darwin (1859) puts it, a species evolves into another species by “means of modification and coadaptation” (pp. 18).

At the time when Darwin published his writings, most of the people were creationists. Hence, many believed that God created all living organisms in their present form and they have not changed since (Mayr, 2001). In contrast, in his theory of evolution, Darwin says that species change. Thus, many failed to accept his theory as they found it conflicting with the teachings of the Bible. (Mayr, 2001; Ridley, 2004)

Meanwhile, many believed that organisms were only able to survive in their environment because of divine intervention. As a matter of fact, when Darwin explained adaptation of living organisms in terms of natural selection, many refused to accept the theory of evolution. This is because they found it conflicting since it negates God’s intervention in the evolution of species. (Ridley, 2004) Additionally, many regarded the theory as irrational and unethical since they could not approve the fact that mankind evolved from other animals (Hokayem and BouJaoude, 2008).

Among different reasons, many rejected the theory of evolution because they assumed that Darwin’s theory was not empirical. Others thought that, it would be unreasonable to explain change in species by observing variations of species across a geographical area when the subject of geographical variation was not well-understood. (Maynard Smith, 1993)

On the other hand, others reject the “blending theory of inheritance” (Ridley, 2004, pp. 12) which Darwin utilised in order to explain the concept of natural selection. In fact, as Ridley (2004) writes:

One of the deepest hitting criticisms of the theory of natural selection pointed out that it could hardly operate at all if hereditary blended. (pp. 12)
Despite all these critiques against Darwin’s theory of evolution, still many biologists such as Thomas Henry Huxley (Ridley, 2004) and Theodosius Dobzhansky (Farber, 2003) acknowledged and supported the theory.

2.3.3 Neo Darwinism

In the early 1920s, Mendel's theory of inheritance was ascertained and this led to a better understanding of genetics (Ridley, 2004; Bishop and Anderson, 1990). Later, R.A. Fisher, J. B. S. Haldane and Sewall Wright promoted a better understanding of natural selection by incorporating Mendel's theory of inheritance with Darwin's theory of evolution (Ridley, 2004). Indeed, today we term the affiliation between Mendel’s theory and Darwin’s theory as ‘Neo-Darwinism’ (Ridley, 2004; Bishop and Anderson, 1990).

Subsequently, Neo-Darwinism encouraged further research both in genetics and evolution. A case in point is Dobzhansky, as he performed experiments on fruit-flies so as to study evolutionary trends. (Ridley, 2004) Besides evolution and genetics, Neo-Darwinism provides insight in other biology fields such as “systematics, palaeontology, and classic comparative morphology and embryology” (Ridley, 2004, pp. 18).

2.4 Evidence for Evolution

As discussed earlier, many refuse to accept Darwin’s theory of evolution in thinking that, it is not based on sufficient evidence (Hokayem and BouJaoude, 2008). In contrast, we find copious amount of scientific evidence which supports Darwin’s theory of evolution. In fact, today, it is considered to be a ‘fact’ (Mayr, 2001).

Much of the scientific evidence was acquired by exploring different fossil records. Many biologists consider fossil records to be authentic since they provide feasible, scientific evidence. By exploring different fossil records, biologists gain insight about extinct species as well as extant species. (Mayr, 2001)
Scientists attain such knowledge by studying fossil records and fossil lineages. A fossil lineage portrays how one species has evolved from another. However, not all fossil lineages are complete (Mayr, 2001). Also, some fossil lineages reveal that the end-point of evolution is extinction (Dobzhansky, 1973). In fact, Dobzhansky (1973) argued that the species living today are only few descendants of the species living in the past, as many of these became extinct.

Furthermore, recent advances in technology, as well as recent discoveries of DNA helped us acquire an understanding of evolution from a molecular perspective (Nelson, 2008). Molecular biologists study evolutionary relationships by analysing biological molecules including species’ DNA (National Academy of Sciences Institute of Medicine, 2008).

Likewise, molecular biology provides feasible scientific evidence which validates Darwin’s theory of evolution (Ruse and Travis, 2009; National Academy of Sciences Institute of Medicine, 2008; Nelson, 2008).

Besides molecular biology, other areas such as ‘comparative anatomy and embryology’ have also provided scientific evidence which proves biological evolution (Dobzhansky, 1973, pp. 128). The National Academy of Sciences Institute of Medicine (2008) wrote that new evidence on Darwin’s theory will progressively emerge in the future.

2.5 Students’ Understanding of Evolution

Poor understanding in the theory of evolution may be the result of ineffective teaching of evolution (Johnson and Peeples, 1987). Moreover, research done by Southerland, Sinatra and Matthews (2001) showed that, the teaching of biological evolution might be in conflict with the students’ beliefs, and this might inhibit the students’ understanding in the theory of evolution.

Furthermore, students’ understanding in the theory of evolution may determine their acceptance of the theory itself. The research of Bishop and Anderson (1990) showed that students who do not understand the theory are less likely to accept it.
Lack of understanding of the theory of evolution is not the only element that hinders students from accepting the theory. In fact, Downie and Barron (2010) said that, since their survey was implemented after teaching evolution, then students’ understanding did not play a role in rejecting the theory.

Although the theory of evolution is considered to be the “unifying” concept in biology (Maynard and Smith, 1993; Bishop and Anderson, 1990; Farber, 2003), many students (Nelson, 2008) as well as teachers, fail to accept the theory of evolution (Trani, 2004).

I won’t teach evolution, I don’t believe in it; besides it is only a theory, and it is against my religion. (Trani, 2004, pp. 419)

As depicted in the quotation above, many teachers as well as students, reject the theory of evolution because it goes against their religious beliefs (Alters and Nelson, 2002; Downie and Barron, 2010). Others adhere to the creationist approach of evolution and disregard the theoretical evidence behind biological evolution (Downie and Barron, 2010).

In contrast to this, not all the students who hold religious beliefs are against the theory of evolution. In fact, half of the cohort that accepted the theory of evolution, in the research held by Downie and Barron (2010) stated that they hold religious beliefs. However, it is more likely that the students who accept the theory of evolution do not possess any religious beliefs. (Downie and Barron, 2010)

Trani (2004) argued that some students prefer to abide with their religious beliefs and reject the theory of evolution, because of their poor understanding of the theory as well as lack of understanding of the nature of science. However, it does not mean that students with strong religious beliefs do not develop an understanding of the theory (Nelson, 2008). A study held by McKeachie, Lin and Strayer (2002) showed that students who accept the theory of evolution develop a better understanding in evolution than those who hold a creationist attitude.
Besides, adhering to a creationist approach (Downie and Barron, 2010) students may fail to accept the theory of evolution because they believe that the theory of evolution is not supported by enough scientific evidence (Hokayem and Boujaoude, 2008; Downie and Barron, 2010). Students’ strong creationist attitudes may influence the students' perception in that they come to believe that the theory of evolution is not proven by scientific evidence (Alters and Nelson, 2002).

Furthermore, research performed by Bishop and Anderson (1990) showed that most of the students accept the theory of evolution. Students who accept evolution agree that it is well supported by scientific evidence and that the biological concepts that make it are relevant and make sense (Downie and Barron, 2010).

Research done by Nelson (2008) showed that, students’ acceptance or rejection of evolution does not influence the students’ understanding in the theory. He said that students are able to acquire an understanding in the theory, even if they do not accept it. On the other hand, the research of McKeachie, Lin & Strayer (2002) showed contrast between students who accept and reject the theory of evolution. In fact, those students who accept it, achieve a better understanding of the theory than those who reject it.

Therefore, as Cobern (1994) argues, in order to achieve the students’ understanding in the theory, a teacher must always take into account the students’ religious beliefs and their attitudes. The teacher should provide opportunities and stimulate the students to discuss relationships between their religious views and their attitudes towards the learning of evolution.

2.5.1 Misconceptions and Evolution

Many science educationalists have engaged in research to investigate students’ understanding in different scientific concepts (Treagust, 1988). Likewise, students’ understanding in the concept of evolution has been of major interest among many researchers.
In their research, some give account of diverse misconceptions which many hold in the concept of evolution. Research reveals that evolutionary misconceptions exist among; high school students (Demastes, Settlage and Good, 1995; Settlage, 1994), college students (Johnson and Peeples, 1987; Hokayem and Bouljaoude, 2008), undergraduate biology students (Bishop and Anderson, 1990; Nelson, 2008; Edgar and Greene, 1990; Nehm and Reilly, 2007; Andrews et al. 2012), medical students (Brumby, 1984) and teachers (Nehm and Schonfeld, 2007).

Moreover, research indicates that the majority of students hold evolutionary misconceptions (Alters and Nelson, 2002; Nehm and Reilly, 2007) which persist even after instruction (Settlage, 1994). Students might have encountered the concept of evolution prior to instruction (Nelson, 2008) constructing misconceptions. Likewise, Marco and Bizzo (1994) said that students fail to link molecular biology, such as genetics, with the concept of evolution. As a result, students develop misconceptions in evolution. This can also be related to, ineffective teaching, in consequence to teachers' lack of understanding in evolution (Chinsamy and Plaganyi, 2007).

### 2.5.2 What are Misconceptions?

Every day, students encounter new situations of which they construct mental concepts (Caramazza, McCloskey and Green, 1981). However, these mental concepts are not real. In fact, as Carey (2000) and Zuzovsky (1994) argued mental concepts are only a representation of the students’ understanding, which is influenced by the situations and experiences students encountered (Novak, 2011). Additionally, these mental concepts become interlinked to form a complex, mental framework known as cognitive structure (Carey, 2000; Bahar, 2003). Thus, cognitive structures are “subjective, tentative, and relative representation” (Zuzovsky, 1994, pp. 558) of knowledge.

Since, mental concepts are human constructions (Clement, Brown and Zietsman, 1989) they might vary from the actual scientific concepts (Carey, 2000). Indeed, educationalists use the term ‘misconception’ to describe students’ mental
concepts which are in contrast to those acknowledged by scientists and science teachers (Treagust, 1988; Bahar, 2003; Nussbaum, 1989; Clement, Brown and Zietsman, 1989; Schmidt, 1997; Andrews et al., 2012). As these deviate from factual scientific concepts then such mental constructs are ‘erroneous concepts’ (Cho, Butler Kahle and Nordland, 1985, pp. 707).

Other terms, such as; ‘existing concepts’ (Cho, Butler Kahle and Nordland, 1985) ‘preconceptions’ (Cho, Butler Kahle, and Nordland, 1985; Clement, Brown and Zietsman, 1989) ‘erroneous concepts’ (Cho, Butler Kahle and Nordland, 1985) ‘naïve principles’ (Caramazza, McCloskey and Green, 1981) ‘intuitive ideas’ (Gil-Perez and Carrascosa, 1990) are interchangeably used with the term ‘misconception’. Out of all these terms, researchers prefer to use the term ‘misconception’ (Bahar, 2003). As such, I will be using the term ‘misconception’ throughout my research.

Furthermore, misconceptions can be an integral part of a student’s cognitive structure. Consequently, these ‘alternative conceptual frameworks’ (Carey, 2000, pp. 14) influence the students’ understanding of the concept (Cho, Butler Kahle and Nordland, 1985). Likewise, as Sinatra, Southerland, McConaughy and Demastes (2003) discussed, the assimilation of new knowledge by a learner is affected by the misconceptions integrated within the learner’s cognitive structure.

Therefore, misconceptions within a student’s cognitive structure limit the students’ understanding and achievement (Clement, Brown and Zietsman, 1989; Bahar, 2003; Sinatra et al., 2003). Considering that, misconceptions are constructed by the students (Edgar and Greene, 1990) as well as integrated within an individual’s cognitive framework (Gomez-Zwiep, 2008) misconceptions are difficult to change (Gomez-Zwiep, 2008; Brumby, 1984; Edgar and Greene, 1990). In fact, students integrate new concepts within their cognitive structures instead of, adjusting their cognitive framework in relation to the newly acquired knowledge (Alters and Nelson, 2002; Gomez-Zwiep, 2008). Consequently, misconceptions persist in an individual’s cognitive framework even after teaching the students the correct scientific concept.
(Settlage, 1994; Andrews et al, 2012). Hence, as Andrews et al. (2012 pp. 250) put it, misconceptions “occur before and after instruction”.

Nevertheless, teachers need to consider students’ misconceptions if they expect their students to achieve meaningful learning of different scientific concepts (Alters and Nelson, 2002; Smith, 1994). Additionally, a teacher should be able to identify students’ misconceptions by utilising a number of different assessment tools such as pencil-and-paper tests or interviews (Treagust, 1988).

In summary, misconceptions are not mistakes (Schmidt, 1997). Misconceptions are an individual’s mental construction which is difficult to change even by instruction (Settlage, 1994; Andrews et al., 2012). Moreover, misconceptions are harboured by different students; children (Gil-Perez and Carrascosa, 1990), high school students (Caramazza, McCloskey and Green, 1981) and university students (Gil-Perez and Carrascosa, 1990). Additionally, misconceptions are harboured by many teachers and found in many textbooks (Barrass, 1984).

2.5.3 Students’ Misconceptions in Evolution

A major misconception found amongst students is that Darwin’s theory of evolution is only a hypothesis and not a fact (Trani, 2004). Most biology undergraduates at the University of Beirut believed that the theory of evolution is not based on sufficient evidence (Hokayem and BouJaoude, 2008). However, Darwin’s theory of evolution is supported by compelling scientific evidence in that now, it is regarded as a fact. In contrast, local research done by Tabone (2011) which explored the attitudes towards evolution of the Maltese general public, sixth form students and University students showed that, many Maltese agree that the theory of Darwin’s evolution is supported by sufficient scientific evidence making it credible. As well, today many biologists acknowledge the theory of evolution and accept it. (Mayr, 2001)

Furthermore, many biology undergraduates make use of their teleological views when explaining change in species associating evolution of species with divine intervention (Edgar and Greene, 1990; Demastes, Settlage and Good, 1995). In
fact, many high-school biology teachers in Ohio held creationist beliefs thinking that God has created Earth as we know it today in six days (Zimmerman, 1987). In contrast, fossil records such as those of cyanobacteria found in Australia, reveal that life on Earth dates back to approximately 3.8 billion years ago (National Academy of Sciences Institute of Medicine, 2008). Tabone (2011) reported that many of the participants involved in his research, believed that life was created by an omnipotent creator and human beings were created differently from all other species, in a special way.

Another misconception which students may hold is that, evolution occurs in individuals rather than in a population of a species (University of California Museum of Palaeontology, n.d.). Besides, some American biology non-majors assumed that natural selection acts upon an individual and not on a population of a species (Demastes, Settlage and Good, 1995).

Darwin described the theory of biological evolution as “descent with modification” (Ridley, 2004, pp. 4) in a population of a species. Genetic variation in a population arises from mutations in the genetic material of some individuals making up that population (National Academy of Sciences Institute of Medicine 2008; Futuyma, 1997; Coyne, 2009). Many high-school students in Brazil (Marco and Bizzo, 1994) as well as undergraduates (Alters and Nelson, 2002) assumed that genetic variation is caused by the environment, or arise as a form of adaptation (Bishop and Anderson, 1990).

Likewise, many biology non-majors did not interlink the concept of genetic variation with that of natural selection (Bishop and Anderson, 1990). In fact, these thought that genetic variation does not play a role in the process of evolution (Bishop and Anderson, 1990; Edgar and Greene, 1990; Alters and Nelson, 2002). Likewise, biology undergraduates may think that mutations occur in all individuals of a population rather than in a group of individuals within that population (Bishop and Anderson, 1990; Alters and Nelson, 2002).

There are three types of mutations; beneficial mutations, neutral mutations and harmful mutations (Mayr, 2001). Many students may assume that mutations
give rise to positive traits only helping the organism to become well-adapted to its environment.

Furthermore, mutations give rise to changes in the traits of an organism. Indeed, dominant traits are more likely to be expressed in an individual’s phenotype than are recessive traits. However, many biology majors in Northeast America (Nehm and Reilly, 2007) misinterpreted dominant traits as fitter than recessive traits.

Another misconception that students hold regarding the concept of evolution is that evolution is a random process (Mayr, 2001). Mayr (2001) argued that, if evolution had to be random then species would never adapt to their environment leading to extinction.

In an environment, some individuals are better adapted to the environment than others. Then, these are capable to survive and produce more offspring. (Ridley, 2004) As a matter of fact, natural selection is the only process that leads to adaptation (Futuyma, 1997; Coyne, 2009). Additionally, biology undergraduates at the University of Minnesota misunderstood that natural selection can only function due to genetic variation in a population. Instead, they assumed that natural selection leads to variation in a population (Jensen and Finley, 1995).

On the other hand, many other students explained adaptation of a species in terms of Lamarckism (Brumby, 1984; Demastes, Settlage and Good, 1995; Edgar and Greene, 1990; Settlage, 1994) also known as the “inheritance of acquired characters” (Ridley, 2004, pp. 7). Even so, some biology majors believed that a trait can be replaced by another according to the need of the organism (Nehm and Reilly, 2007).

Besides mutations and natural selection genetic drift is another mechanism which drives evolution. Genetic drift takes place when a rare allele becomes more common in a population across generations (Ridley, 2004; Futuyma,
1997). However, biology majors in Northeast America, misinterpreted genetic drift as “gene flow between different species” (Nehm and Reilly, 2007, pp. 266).

One common misconception, which many of these biology majors held was that environmental pressures such as climate change are necessary for evolution to take place (Nehm and Reilly, 2007). On the other hand, biology non-majors thought that species evolve as a result of environmental changes (Bishop and Anderson, 1990). Indeed, as reported by Tabone (2011), some Maltese did not believe that species including humans have been changing since the moment of creation while adapting to their own environment.

Consequently, many undergraduates such as those in Brazil (Marco and Bizzo, 1994) assumed that evolution is always beneficial as it leads to better adapted forms (University of California Museum of Palaeontology, n.d.). In contrast, Ohio high-school teachers thought that the major role of evolution is to provide, “higher life forms” (Zimmerman, 1987, pp.119) which perhaps endanger the life of others (Brem, Rannyey and Schindel, 2003).

Students also hold many misconceptions regarding evolution in humans. Primarily, many use teleological aspects concerning human evolution as noted by Christensen & Cannon (1978). In fact, many biology majors believed that human beings did not descend from other species (Nelson, 2008). In contrast, Tabone (2011) found that some Maltese did not believe that human beings are descendants of ape-like species. Additionally, as noted by Volpe (1984) (cited in Trowbridge and Wandersee, 1994), other undergraduates regarded evolution as something which has occurred in the distant past. Consequently, many species such as human species stopped evolving.

Nonetheless, scientific evidence reveals that the present form of Homo sapiens descended from ancestral species (Alters and Nelson, 2002). The discovery of fossils such as that of Tiktaalik in Canada suggests that land-dwelling vertebrate species descended from an ancestral species which existed approximately of 375 million years ago (National Academy of Sciences Institute of Medicine, 2008, pp.3). Even so, fossil intermediates leading to human evolution were
discovered in the 1920s (Liles, 2012) completing the fossil lineage which extends from therapsid reptiles to mammals (Mayr, 2001).

Besides, undergraduates tend to confuse scientific terms with their colloquial meanings (Alters and Nelson, 2002). In fact, many confuse the term ‘fittest’ with the “use of fitness as a measure of strength, athletic ability or intelligence” (Demastes, Settlage and Good, 1995, pp. 536).

2.6 Dealing with Students’ Misconceptions

Learners construct concepts and accommodate them in their mental cognitive structure (Novak, 2011). Additionally, the learner’s understanding of such concepts is influenced by experiences encountered by the learner (Novak, 2011). Consequently, these concepts may vary from the actual scientific concepts (Carey, 2000) arising in misconceptions. Thus, misconceptions are interlinked and embedded in a learner’s cognitive structure (Hokayem and BouJaoude, 2008).

As a matter of fact, students develop concepts regarding natural phenomena prior to instruction (Bishop and Anderson, 1990). In fact, the concept which students hold prior to learning may affect the students’ understanding of that concept (Osborne and Gilbert, 1980).

Moreover, Ausubel (1968) said that learning occurs when new knowledge is assimilated and associated with existing knowledge within a learner's cognitive framework (Novak, 2011). However, students’ misconceptions may interfere with the students’ learning. Thus, prior to instruction it is essential to address students’ understanding of the concept (Osborne and Gilbert, 1980; Carey, 2000). As Ausubel (1968) put it, “the most important single factor influencing learning is what the pupil already knows. Ascertain this and teach him accordingly” (Osborne and Gilbert, 1980, pp. 376). If a student’s misunderstanding of a concept persists, it may hinder the student’s learning in that concept. Additionally, the student may either fail to interlink between
concepts or fail to relate existing concepts with new concepts (Alters and Nelson, 2002).

Besides acquiring new information, learners should be able to remodel their own understanding of the concept attaining a factual understanding of the concept (Osborne and Gilbert, 1980; Zuzovsky, 1994). The process by which, students alter their misconceptions into scientific concepts is known as conceptual change (Nussbaum, 1989; Hokayem and Boujaoude, 2008).

Since, misconceptions are interlinked with other concepts in a student's cognitive structure they may be very difficult to change (Carey, 2000; Bishop and Anderson, 1990; Gil-Perez and Carrascosa, 1990). In fact, as Shuell (1987) (cited in Gil-Perez and Carrascosa, 1990) argues conceptual change may not occur even after addressing the students’ misconceptions prior to learning.

Even so, conceptual change can only be mastered when the teacher gains insight of the students’ misconceptions (Bishop and Anderson, 1990; Edgar and Green, 1990). Indeed, by designing summative tests (Treagust, 1988; Novak, 2011) or by interviewing their students (Novak, 2011) teachers could recognise students’ misconceptions. Then, teachers would be able to devise different teaching techniques and pedagogical tools where by the students could acquire a better understanding of the scientific concept (Smith, 1994; Treagust, 1988; Schmidt, 1997, Jensen and Finley, 1995).

2.6.1 Conceptual Change in Evolution

Research done by Bishop and Anderson (1990) suggested that learners develop understanding of scientific concepts such as evolution and hereditary prior to classroom instruction.

Furthermore, Jensen argued that students’ misconceptions in evolution are difficult to change (Demastes, Settlage and Good, 1995). In order, to achieve conceptual change it is essential if students become aware of their misconceptions before teaching them biological evolution (Hermann, 2008). In fact, when teachers address students’ misconceptions in evolution prior to
instruction it is more likely that the students develop a better understanding of the concept (Hermann, 2008).

On the other hand, to attain conceptual change in evolution teachers should not only address students’ misconceptions, but should also take into account other factors which may influence their learning (Smith, 1994). These factors include the; history, politics, religion of the students (Alters and Nelson, 2002; Smith, 1994). As well as, whether the students accept the theory of evolution and their perception of the biological world (Alters and Nelson, 2002). As a matter of fact, Brumby (1984) depicted that students’ Lamarckian views in evolution serve as a barrier to Darwin’s theory of evolution.

Meaningful learning in evolution can only be achieved if the students’ personal views are taken into consideration (Osborne and Gilbert, 1980). Indeed, it would be unfair to consider students’ religious beliefs as unimportant or a misconception (Hokayem and BouJaoude, 2008; Hermann, 2008).

2.6.2 Effective Pedagogy which leads to Conceptual change in learning about Evolution

Research performed by Nelson (2008) shows that instruction whose main objective is to achieve conceptual change aids in acquiring meaningful understanding of evolution, than traditional learning. Such as to devise the pedagogical tools necessary to promote conceptual change a teacher must first identify the students’ misconceptions in evolution (Brumby, 1984; Jensen and Finley, 1995; Nussbaum, 1989).

Students’ understanding of evolution can be challenged through the use of questioning techniques. In fact, students are more likely to develop conceptual change when adopting an inquiry based learning approach in the classroom. (Demastes, Settlage and Good, 1995) Questioning stimulate the students to think and reflect upon their learning. This way, students identify their misconceptions helping them acquire a better scientific understanding of the concept (Nelson, 2008).
Moreover, through the construction of concept maps learners are able to identify their misconceptions. Likewise, Trowbridge and Wandersee (1994) argued that concept maps are an efficient tool in teaching evolution as they enable students to measure their understanding in evolution.

In contrast, by establishing a problem-solving approach (Jensen and Finley, 1996) as well as by conducting experiments (Gil-Perez and Carrascosa, 1990) students are able to test and investigate their concepts of evolution (Alters and Nelson, 2002). From these experiments, students encounter situations or explanations which contradict their understanding of evolution. By comparing their concept of evolution with scientific explanations attained from the experimental procedure students tend to develop a better understanding of evolution (Alters and Nelson, 2002).

As discussed earlier, when students' personal views are acknowledged it is more likely that the students develop a better understanding of evolution (Osborne and Gilbert, 1980). Smith (1994) said that, history can influence the students' understanding of the concept. Likewise, Piaget favours the idea of integrating historical events which are relevant to the concept dealing with in the classroom (Zuzovsky, 1994). Additionally, Jensen and Finley (1995) suggested that historical events concerning Darwin's theory of evolution should be incorporated in the teaching of evolution. They further argue that, such historical events enable students to develop conceptual change and gain scientific understanding of Darwin's evolution.

Besides, students' understanding in evolution may be influenced by their religious views (Cobern, 1994; Hokayem and Boujaoude, 2008). Indeed, religion is an integral part of the learner's culture (Hokayem and Boujaoude, 2008). Thus, it would be foolish to consider students' religious views as misconceptions (Hokayem and Boujaoude, 2008; Cobern, 1994). To ascertain meaningful understanding in evolution as well as conceptual change a teacher should acknowledge the students' religious views (Cobern, 1994). Hence, teachers should provide opportunities whereby students are able to distinguish...
and differentiate between scientific facts, and religious teachings (Sinatra et al., 2003).

Considering that, knowledge depends on the learner’s perception of the situation (Novak, 2011) a teacher has to manifest various learning techniques whereby learners explore and question their own learning. However, as Demastes, Settlage and Good (1995) argued some misconceptions still persist even after utilising efficient pedagogical tools in the classroom.

The theory of biological evolution has instilled public interest and dispute (Cobern, 1994; Coyne, 2009) since the time it was introduced by Darwin. This is because the theory of evolution justifies the origin of different organisms as well as it denotes how all living species evolved from a common ancestral species (Coyne, 2009). Moreover, the theory of evolution has been described as being “one of the greatest intellectual achievements of Western thought” (Ruse and Travis, 2009, pp. ix) that “unifies the biological sciences” (Hokayem and BouJaoude, 2008, pp. 395).
3 Methodology

3.1 Research Design

In this research, a ‘mixed-methodology’ approach was adopted. While a qualitative methodology was employed through the use of semi-structured interviews, a quantitative methodology was employed through the use of ‘self-complete’ (Williams, 2003) questionnaires.

Interviews were utilised so to acquire a profound understanding of the undergraduates' knowledge and perceptions of evolution. Also, misconceptions other than those mentioned in the literature were elicited, while exploring the diversity of misconceptions.

Questionnaires were designed to measure the frequency of evolutionary misconceptions harboured by Maltese biology undergraduates. Through the use of questionnaires one could attain a larger sample that is representative of the population and use statistical tests to measure relationships between subgroups of the population.

As Weber (1990) (cited in Zhang and Wildemuth, 2009) implied, a mixed methodology was used in “the best content-analytic studies” (p. 2). Additionally, this study has been carried out in nine months.

3.2 Research Question

The aim of this research is to gain an understanding of the undergraduates’ knowledge in evolution and identify misconceptions present in the undergraduates’ cognitive style.

Another objective of this research is to identify which misconceptions are most common and least common. Another is to analyse relationships between subgroups.
In contrast, through the use of semi structured-interviews, misconceptions other than those mentioned in the literature were elicited.

All in all, the aim of this research is to provide a list of misconceptions as a framework upon which learning objectives can be based so to promote conceptual change.

3.3 Research Sample & Target Group

This research involved biology undergraduates who are currently reading for an undergraduate course in either B.Ed. (Hons) Biology or BSc (Hons) Biology and Chemistry at the University of Malta. As such, these undergraduates have an Advanced Level of C or better in Biology. Participants range in age from 19 to 24, and they were selected from different years ranging from first years to fourth years. Although, 130 questionnaires were distributed only 66 questionnaires were returned, giving a response rate of approximate 51%. Even so, 15 interviews were conducted.

3.4 Interviews were used to elicit misconceptions

3.4.1 Collecting Data through Interviews

3.4.1.1 Designing the Interview Guide

Firstly, an ‘interview guide’ of 12 questions was designed. In the first three questions, undergraduates were asked to indicate which relevant study units they have followed and to rate their understanding and acceptance of evolution.

Then undergraduates were asked to describe the theory of evolution and outline the three mechanisms which drive evolution. Additionally, they were asked to discuss the statement ‘fittest species’. After that, with the use of evolutionary terms students had to explain situations which represent evolution in nature.

Moreover, to make the interview-guide more user-friendly and to cater for visual learners, illustrations related to the questions were incorporated.
3.4.1.2 Performing the pilot study

Prior to conducting the interviews a pilot study was performed with two biology undergraduates so to check the effectiveness of the interview guide. After the first interview, extra information was added so to help undergraduates to understand further the questions. Then, the amended interview guide was tested with the second undergraduate.

During the pilot study, participants were asked to comment about the interview guide with concern to the questions involved. Both participants said that the questions were easy to read and understand. They also claimed that the pictures helped them understand the questions better.

3.4.1.3 Conducting Interviews

Each semi-structured interview lasted for 20 to 30 minutes.

During the interviews an interview-guide was used to ensure consistency. However, other questions were asked when needed to either clarify the response given or to ask the participants to further explain their arguments.

The interviews were audio-recorded using a digital voice recorder. Audio recording was preferred over written notes, as it allows researchers to follow and maintain their attention in the interview (Hoepfl, 1997).

Before starting the interview, the participants were asked to sign a ‘recruitment letter’. The recruitment letter explained the objective and motive of the research and assured anonymity of the participant. As outlined in this letter, the participants were able to withdraw from the research at any time, erasing any information provided.

3.4.1.4 Transcribing Interviews

The interviews were transcribed ‘verbatim’ including latent content such as “silence, sighs, [and] laughter” (Elo and Kyngäs, 2007 p. 109). Those questions which were not initially part of the interview guide were also transcribed along
with their responses. After the transcripts were ready, they were checked with the audio-recordings to ensure that the transcripts are trustworthy.

3.4.2 Analysing Interviews

3.4.2.1 Method used for Interview Analysis

In this research, interviews were analysed using qualitative content analysis. This approach is based on grounded theory as thematic categories emerge from the analysis of transcripts (Andrews et al., 2012; Krefting, 1990; Zhang and Wildemuth, 2009). Moreover, data analysis was focused more upon the undergraduates’ knowledge and misconceptions of evolution rather than the context in which they operate.

While reading, different misconceptions were identified and these were ‘coded’ accordingly. Codes included descriptions of the misconception. Such process is known as ‘open coding’ initially proposed by Strauss and Corbin in 1990 (Hoepfl, 1997). After a week the transcripts were re-read so new misconceptions would further be identified.

A list of the codes was generated and codes which correspond to a particular concept were grouped in one category. The process whereby codes are grouped into categories which are in turn grouped into higher categories is known as ‘axial coding’ (Ziebland and McPherson, 2006), which was initially proposed by Strauss and Corbin in 1990 (Hoepfl, 1997).

Codes, or in other words, misconceptions were delineated by using quotes from the transcripts. It is more likely that readers relate with the research when quotes from the transcripts are used (Hoepfl, 1997). In turn, misconceptions together with their percentage frequencies were tabulated, however as White and Marsh (2006) argue, since the sample is small (n=15) the results attained are not representative of the population.
3.4.3 Reliability and Validity of Interviews

As Lincoln and Guba (1985) proposed that qualitative methods can be reliable and valid if ‘credibility’, ‘transferability’, ‘dependability’ and ‘confirmability’ are assured.

3.4.3.1 Credibility

As Kirk and Miller (1986) (cited in Krefting, 1990) discuss, not every participant is willing to share information during the interview. In fact some may share perceptions which they think that will be preferred by the researcher. So to eliminate such bias, other questions were asked or rearranged so to check consistency in the students’ responses. If lack of consistency was observed, the participants were asked to explain their arguments.

To ensure that the categories emerged included all aspects of the data I made use of ‘peer examination’ (Krefting, 1990) in that codes and categories elicited were discussed with this study’s supervisor, along with the transcripts to assure credibility of my research.

3.4.3.2 Transferability

A research with ‘transferability’ is one which entails a clear description of how the research was conducted and provides information about the participants. Consequently, a detailed account of how the data was collected and analysed has been provided. Additionally, information about the participants and how were these selected is also given.

3.4.3.3 Dependability

As previously described, peer examination was used in order to ensure consistency. Indeed, the codes and categories elicited from transcripts were discussed with this study’s supervisor.

Furthermore, so to ensure consistency of the codes and categories the transcripts were recoded after a week to ensure dependability.
3.4.3.4 Confirmability

Confirmability in the research is determined by the ‘neutrality’ of the data (Krefting, 1990). To ensure ‘neutrality’ and eliminate bias questions asked were sometimes rearranged to check if the participants will provide the same answers, and sometimes they were asked to further explain their arguments. To eliminate personal bias, most of the time, the questions asked by participants were only answered using a yes or no answer.

In a summary, the qualitative methodology used in this research assures credibility, transferability, dependability and confirmability (Lincoln and Guba, 1986) of results.

3.5 Quantitative Approach

3.5.1 Designing and Conducting Questionnaires

3.5.1.1 Types of Questions & Responses

A questionnaire of 26 questions was designed using an online tool, Adobe Forms Central.

Questions number 1, 3 and 4 asked information about the students. However, none of the information required was personal. In contrast, such questions were used so to identify different sub-groups in the population.

A ‘5-point’ (Williams, 2003) Likert Scale was used as a response to questions 3 and 4. In question 3 students had to rate their acceptance of the theory of biological evolution, while that for question 4 students had to rate their understanding in biological evolution.

Questions 5 to 26 are a set of closed-questions, which delineate either misconceptions or facts about the theory of evolution. These were elicited from different literature and were reworded and simplified before included in the questionnaire. While, questions 5 to 18 required a ‘yes or no’ answer, for
questions between 19 and 26, students had to choose from three responses that are ‘Always’, ‘Never’ and ‘Sometimes’.

Out of 26 questions, only question 2 was an open-ended question; “How do you define the Theory of Biological Evolution?” Through the use of open ended questions one can attain a number of different responses and views of a particular concept (Williams, 2003). My main objective for including an open-ended question was to acquire the different perceptions and understandings of our biology undergraduates in the theory of biological evolution.

Since, participants can easily become discouraged when asked to write long-answers (Williams, 2003) the use of open-ended questions in my questionnaire was limited to a small number, so as to increase the response rate of the questionnaire.

All the questions making up this questionnaire are one sentence long and the English used was not complex. However, since biological terms were used to refer to certain biological concepts only individuals who acquired good biological knowledge would have been able to understand and answer the questions.

Together with the questionnaire, I included a letter of information which describes the purpose of my research and ensure anonymity and confidentiality of participants. Indeed, students either completed the questionnaire when it was given to them, or they took it with them and completed it elsewhere.

3.5.1.2 Performing the Pilot study

Prior to the pilot study the questionnaire was discussed with the tutor and three biology undergraduates were asked to give their opinions and views about the questionnaire.

The questionnaire was piloted with ten biology undergraduates who were selected at random. Through another questionnaire, the participants were to indicate which questions they did not understand or thought they were too
personal or sensitive. They were asked to indicate if the questionnaire was easy to follow and if enough instructions were given. Also, the undergraduates were asked to comment on what they think the questionnaire is about, so as to ensure validity of the questionnaire.

Indeed, the questionnaire only required small amendments.

Additionally, during the pilot-study, the method of analysis and the statistical tests needed to measure differences between sub-groups were tested.

3.5.2 Analysing Questionnaires

3.5.2.1 Inputting the Data

After collecting a representative sample (n=66) of questionnaires, the data was stored in a Microsoft Excel worksheet. The data was arranged so as to reflect differences between the sub-groups under study. Tables, bar charts or pie-charts were used to summarise trends in the data collected.

3.5.2.2 Relationships between sub-groups

The relationships between different sub-groups were measured using One Way Analysis of Variance. Prior to this test, Shapiro-Wilk normality test and a test for equal variance were applied. When equal variance was not present, a Kruskal-Wallis One Way Analysis of Variance on Ranks was carried out between sub-groups. Such tests were carried out using SigmaPlot Version 11.

3.5.2.3 Analysing Open Ended Questions

The open-ended question was analysed using ‘Qualitative Content Analysis’, as that described in the section ‘Method used for interview analysis’.

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3.5.3 Rigour in Questionnaires

3.5.3.1 Reliability

In this research the questionnaire was standardised as the same questionnaire consisting of the same questions in the same order was distributed. Standardisation of questionnaires ensures reliability (Boynton and Greenhalgh, 2004).

The ‘internal consistency reliability’ (Brumby, 1984) of this test was measured using Cronbach’s alpha coefficient. Cronbach’s alpha coefficient was preferred over other reliability measures, because categorical data was used and more than one response was required for the larger part of the questionnaire.

The Cronbach’s alpha coefficient determines the relationship between the questions contained in the questionnaire (Tavakol and Dennick, 2011). In my study an alpha of 0.2 was achieved. I believe that this is quite reasonable since my questionnaire was devised in order to measure the frequency of various misconceptions, and therefore one response does not influence the response of another. Therefore, in this case a low alpha value reflects the main objective of this study, which is to measure frequency of different misconceptions.

3.5.3.2 Validity

To ensure validity of my questionnaire and avoid deviation, in the pilot study I asked the participants to comment about what they think the questionnaire is about. Indeed, all of the participants recognised that the questionnaire was about evolution. Most added that the questionnaire seeks to measure their understanding or knowledge of the concept. Therefore one can assure ‘face validity’ (Miller, 2013) and ‘construct validity’ (Miller, 2013) of the questionnaire.

Moreover, since the questionnaire was designed purposefully to measure the relationships between different sub-groups, then one can also assure ‘criterion-related validity’ (Miller, 2013).
CHAPTER 4

RESULTS & ANALYSIS OF DATA
4 Results and Analysis of Data

The aim of this study is to gain insight of the knowledge of Maltese biology undergraduates’ in biological evolution. Questionnaires were utilised to measure the frequency of misconceptions among biology undergraduates. In contrast, interviews were used to elicit misconceptions other than those mentioned in the literature.

4.1 Interviews

4.1.1 Profile of Respondents

Fifteen Maltese biology undergraduates, who were selected at random, participated in the interview process. Codes such as ‘Student A’ are going to be used in order to assure anonymity of participants.

Undergraduates might have participated in a study-unit concerning either ‘Genetics’ or ‘Evolution’. Some might have participated in both of these study-units, while others did not participate in either study-unit. Consequently, at the beginning of each interview, undergraduates were asked to indicate, in which study-units they have participated, choosing between ‘Genetics’, ‘Evolution’, ‘Both’ or ’None’. Additionally, they were asked to rate their knowledge in evolution on a 5-point Likert scale; 1 being ‘not knowledgeable’, 3 being ‘knowledgeable’ and 5 being ‘highly knowledgeable’. The following table (table 1) is a summary of the participants’ self-assessed level of knowledge and the study-units in which they participated.

Table 1: Academic experience and self-assessed level of knowledge of each of the participants

<table>
<thead>
<tr>
<th>Student</th>
<th>Academic experience</th>
<th>Self-Assessed Level of Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student A</td>
<td>Genetics</td>
<td>3</td>
</tr>
</tbody>
</table>

39
<table>
<thead>
<tr>
<th>Student</th>
<th>Academic Experience</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student B</td>
<td>Genetics and Evolution</td>
<td>4 to 5</td>
</tr>
<tr>
<td>Student C</td>
<td>Genetics and Evolution</td>
<td>3</td>
</tr>
<tr>
<td>Student D</td>
<td>Genetics and Evolution</td>
<td>5</td>
</tr>
<tr>
<td>Student E</td>
<td>None</td>
<td>3</td>
</tr>
<tr>
<td>Student F</td>
<td>None</td>
<td>3</td>
</tr>
<tr>
<td>Student G</td>
<td>Genetics</td>
<td>3</td>
</tr>
<tr>
<td>Student H</td>
<td>Genetics and Evolution</td>
<td>4</td>
</tr>
<tr>
<td>Student I</td>
<td>Genetics</td>
<td>3</td>
</tr>
<tr>
<td>Student J</td>
<td>Genetics</td>
<td>2</td>
</tr>
<tr>
<td>Student K</td>
<td>Genetics and Evolution</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Student L</td>
<td>Genetics</td>
<td>3</td>
</tr>
<tr>
<td>Student M</td>
<td>Genetics</td>
<td>3</td>
</tr>
<tr>
<td>Student N</td>
<td>Genetics and Evolution</td>
<td>4</td>
</tr>
<tr>
<td>Student O</td>
<td>Genetics and Evolution</td>
<td>3</td>
</tr>
</tbody>
</table>

**Figure 1: Number of interviewees in correspondence to academic experience in evolution**

As this chart (figure 1) illustrates, among the undergraduates interviewed 7 participated in both study-units, which involve ‘Genetics’ and ‘Evolution’.
Meanwhile, 6 participated in ‘Genetics’ and 2 did not participate in either study-unit.

Figure 2: Number of interviewees within each self-assessed level of knowledge

Additionally, with regards to the chart (figure 2) above, more than half of the undergraduates i.e. 9 claimed to be ‘Knowledgeable’ of evolution. In contrast, 3 claimed to be ‘Quite knowledgeable’, 2 said to be ‘Highly Knowledgeable’ and 1 said to be ‘Not very Knowledgeable’.

Figure 3: Illustrating the difference in the number of interviewees, between academic experience and self-assessed level of knowledge in evolution
As depicted in the graph (figure 3) above, undergraduates who claimed to be ‘Highly Knowledgeable’ in evolution have participated in both ‘Genetics’ and ‘Evolution’. Likewise, those who claimed to be ‘Quite knowledgeable’ have also participated in these study-units. In contrast, among those who said to be ‘Knowledgeable’, 5 participated in ‘Genetics’, 2 participated in both ‘Genetics’ and ‘Evolution’ and another 2 did not participate in either study-unit. The undergraduate who claimed to be ‘Not Very Knowledgeable’ participated in ‘Genetics’ only.

Table 2: Academic experience, self-assessed level of knowledge and the number of misconceptions of each of the interviewees

<table>
<thead>
<tr>
<th>Students</th>
<th>Academic Experience</th>
<th>Self-Assessment of Knowledge in Evolution</th>
<th>Number of Misconceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Genetics</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>Both</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>Both</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>D</td>
<td>Both</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>E</td>
<td>None</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>F</td>
<td>None</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>Genetics</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>H</td>
<td>Both</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>I</td>
<td>Genetics</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>J</td>
<td>Genetics</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>K</td>
<td>Both</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>L</td>
<td>Genetics</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>M</td>
<td>Genetics</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>N</td>
<td>Both</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
All in all, 42 misconceptions were elicited during the interview process. Indeed, as indicated in the table (table 2) above, the undergraduate with the largest number of misconceptions is Student B, who participated in both study-units that involve ‘Genetics’ and ‘Evolution. This undergraduate claimed to be ‘highly knowledgeable’ in evolution. Both, Student A and Student F have ten misconceptions. While, Student A participated in the study-unit ‘Genetics’ and said to be ‘knowledgeable’ of evolution, Student F did not participate in either study-unit but also claimed to be ‘knowledgeable’ of evolution. Student O, with the least number of misconceptions i.e. three, participated in both ‘Genetics’ and ‘Evolution’ and claimed to be ‘knowledgeable’.

4.1.2 Number of Misconceptions within each sub-group

4.1.2.1 Outlining the relationship between the undergraduates’ academic experience and the number of misconceptions

Figure 4: Mean number of misconceptions among interviewees in correspondence to academic experience in evolution

As this chart (figure 4) indicates, undergraduates who did not participate in either study-unit involving ‘Genetics’ or ‘Evolution’ had the largest mean number of misconceptions i.e. 9.5. In comparison, undergraduates who
participated in both study-units, ‘Genetics’ and ‘Evolution’ had the least mean number of misconceptions i.e. 7.29. However, these differences are relatively low.

4.1.2.2 Outlining the relationship between the undergraduates' self-assessment of their knowledge in evolution and the number of misconceptions

![Chart showing mean number of misconceptions among interviewees within each self-assessed level of knowledge in evolution]

**Figure 5: Mean number of misconceptions among interviewees within each self-assessed level of knowledge in evolution**

As presented in this chart (figure 5), undergraduates who claimed to be ‘Highly Knowledgeable’ had the largest mean number of misconceptions i.e. 9.5. The mean number of misconceptions of the other groups were relatively similar that is around 7.

4.1.3 Acceptance in Evolution

All of the undergraduates claimed to accept the theory of evolution and provided several reasons of why they accept it. Most said that they accept Darwin's theory of biological evolution because as student N claimed it is “… fundamentally proven with evidence” and as Student C discussed “[it] makes sense based on the science that has been provided”.

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Nonetheless, this does not mean that Maltese undergraduates fully accept Darwin’s theory of evolution, as student O confessed, “but obviously I’m not accepting it blindly”. Likewise, student D argued that “if new evidence had to come to light against evolution then obviously it would have to be revised”.

Even though, all the undergraduates said that Darwin’s theory is supported by scientific evidence, student C expressed thoughts of scepticism about if there is enough scientific evidence and wondered if it is credible, by saying “*Pero’ xorta hemm speċi dubbji fuqha, speċi hemm biżżejjed evidenza li eżistiet din il-biological evolution* jew forsi hemm ‘gaps’ li ma na fux bihom” (“However, I still hold doubts about it, like is there enough scientific evidence which proves that biological evolution existed or maybe there are gaps which we do not know about”).

On the other hand, all undergraduates believed that “at the moment, it’s the best theory we currently have” (student D) as it provides reasonable explanations of how species evolved into another and how they become extinct, as student L discussed, “*Meta nara eżempju l-animali kif kienu qabel u kif inhuma issa u kif evolvew biex huma jkunu jistgħu jgħixu*” (“When I see for example animals how they used to be and how they are today and how they evolved to be able to live better.”) Student G argues that it “does make sense [as] you can see like in fossils. [It is] explanatory in itself why that, that is happened”.

In contrast, student O believed that there is no other theory which provides such reasonable explanations “there is no other kind of explanation behind the evolution of species... explanations which have been proposed, are related to religion... it doesn’t make sense.”

Moreover, student K accepted Darwin’s theory since today many accept it including Catholics: “*Daż- żmien hafna nies saru jaċċettawha... bhala knisja Catholic, Catholics, sa fejn naf jiena, aċċettawha issa, le?!!*” (“Today many people come to accept it... as a Catholic Church, Catholics, as far as I know, accepted it now, no?!”)
Student C further argued that as an undergraduate s/he came to believe in Darwin’s theory of evolution since “most of the time you accept things that are taught to you.”

4.1.4 **Defining the Theory of Biological Evolution**

When undergraduates were asked to describe the theory of biological evolution, most undergraduates explained biological evolution in terms of natural selection as student H said: “the most organisms fit will be selected for *ovjament l-ohrajn ha jmutu imma* those selected for will reproduce and eventually *l-ahjar organiżmi ha jiġu evolved*” (“the most organisms fit will be selected for obviously the others will die but those selected for will reproduce and eventually the best organisms will become evolved.”) Others thought that the theory of biological evolution is in fact natural selection as student M said: “*mela dak naħseb ta’ Darwin, ta’ natural selection*” (“then it is I think that of Darwin, that of natural selection.”) Likewise, most regarded evolution as a means by which species become adapted to their environment as student E discussed: “different species will evolve according to their environment”.

Other undergraduates used concepts of macroevolution when describing biological evolution as student I claimed “there’s a common ancestor and all of the other organisms have arised from this common ancestor.” Also, student O said that the theory of evolution explains “how species evolve... and how species exist.”

4.1.5 **Misinterpretations of the ‘fittest species’**

Most of the undergraduates that is 7 out 15 said that the ‘fittest species’ is “the species that is most adapted to its environment” (Student D). Two undergraduates provided examples supporting such arguments. Indeed, student A said: “If there is a black rabbit, in the ice and in Antarctica, and there is a white one, obviously the white one would be much more adaptable therefore that would be the fittest one.” Likewise, student O said “if for example you have an environment which is very hot and you have a species which tolerates very high
temperatures then that is the fittest compared to other species.” Additionally, student B argued that some individuals are fitter than others because it is more adapted due to having a particular mutation which puts the individual at an advantage over others “an individual in a population which is more adapted to the environment maybe by a mutation.”

On the other hand, student E argued that the ‘fittest species’ is the species which is most capable to survive and become adapted to different environments other than its own: “can adapt itself in its particular environment [and] if placed maybe in a slightly different environment it can still adapt.”

Two undergraduates, Students J and L said that the ‘fittest species’ is the species that is most “able to survive in the environment they have due to the characteristics they have” (Student L) but failed to mention that it is the species which reproduces most.

Nonetheless, student B described the ‘fittest species’ as the species which is able to produce fertile offsprings as s/he said “capable of reproducing and producing offspring which are able to reproduce not for example the mule which is sterile that is not a fit organism.”

Another misinterpretation of the ‘fittest species’ is that undergraduates thought that fitness exists among different species rather than between different individuals within the same species, as student E said: “there is a variety of individuals enough that the species will not die out”. Also, through the use of such interpretation, one could note another misconception, in that undergraduate E thought that the ‘fittest species’ is the species with the most varying individuals.

4.1.6 Common Misconceptions in Evolution

In their explanations some undergraduates used the term animals instead of species “that all the animals, that all the organisms had one common ancestor and then from it, we came into different, into different species, into different animals” (student A) or “Meta nara eżempju l- annimali kif kienu qabel u kif
*inhuma issa u kif evolvew biex huma jkunu jistghu jghixu* (“When I see for example the animals how they were before and how they are today and how they evolved so they could live”) (student A). This indicates that some thought that evolution occurs only in animals. One possible reason is that teachers only mention examples of evolution in animals and fail to acknowledge other living organisms, as student C claimed “this is something we didn’t cover during evolution, like most of the time we deal with animals and we don’t look at viruses”.

Moreover, some undergraduates used the past tense in their explanations, portraying the perception that evolution is something which occurred in the remote past and stopped occurring today, as student K argued “hawn ħafna evidenza illi turik illi speċi li vera seħhet” (“there is a lot of evidence that shows that it [evolution] truly occurred.”) Student H said “primitive organisms li throughout the, the centuries u years, u years u years they evolved accordingly” (“primitive organisms that throughout the, the centuries and years, and years, and years they evolved accordingly”). This comment not only implies that evolution occurred in the past, but it also indicates that students assumed that a lot of years need to pass for evolution to occur, when this is not always the case. Likewise, undergraduate K claimed that evolution is a slow process: “huwa bil-mod ħafna li ssir l evoluzzjoni” (“evolution occurs very slowly”), when again this is not always the case.

Nonetheless, most of the undergraduates, 9 out of 15 believed that evolution in a species occurs due to changes in the species’ environment. In fact student D described biological evolution as “species change as time goes by depending on their environment”. Likewise student L explained “if the environment changes the characteristics change to adapt to the new environment and be able to survive”.

In another way such perceptions portray evolution as a process which leads to adaptation “evolve... they change in order to be more fit to their environment” (student F). This was highly outlined in student I’s explanations “through evolution the cheetahs got adapted to catch their prey at a more efficient way”.
Furthermore, almost all of the undergraduates, 14 out of 15, portrayed evolution as "a consequence not a cause" (student N), a consequence which follows change, “organisms will change phenotypically and genotypically and due to different reasons” (student F). When explaining how mammoths have evolved from less hairy ancestors, student A said “Because these live in the cold regions, they had to have much more hair.... so they had to if they wanted to survive they had to get, more hair so they can keep warm”. Student L described these changes in the same way, “environment was colder so they wanted to protect themselves from the cold so they evolved these characteristics of having really thick and long hair”.

Likewise, when undergraduates were asked to describe why mosquitoes today are resistant to insecticides, many said that "mosquitoes became resistant to the insecticide" (student G). “The first flies were not immune so the first time the insecticide, they were prone to it and it killed them. By time, it can be by chance, mutations occurred and certain flies had the genes which actually created resistance to these insecticides”. As outlined by student F in this statement, many undergraduates failed to recognise that some insects in the population were resistant to the insecticide before it was actually used.

Such perceptions were also outlined in other explanations such as when students were asked to describe how dark coloured peppered moths evolved: “since the peppered moth wasn’t camouflaged due to all the pollution, they changed their characteristics in ways to be better camouflaged themselves by, by turning into a darker colour” (Student L). Again such explanations were given, when undergraduates were asked to explain increase in the population of HIV virus after drug 3TC was given to patients “HIV is a virus and it’s very prone to genetic mutations so coincidentally once it is exposed to a drug there would be viral particles which mutate in a way, that withstands the drug” (student E).

Besides, some undergraduates perceived evolution as a consequence of natural selection “the most organisms fit will be selected for ovjament l- ohrajn ha jmutu imma those selected for will reproduce and eventually l- ahjar organiżmi ha jiġu evolved” (“the most organisms fit will be selected for obviously the
others will die and those selected for will reproduce and eventually the best organisms will become evolved”) (student E).

Almost half of the sample that is 8 out of 15 provided Lamarckian explanations. Most argued that species “get adapted to the various changes in the environment either by morphologically or physiologically and behaviour as well” (student B). Then with “such changes these species get more adapted to the environment and therefore, they survive more” (student B). These physiological changes that occur in individuals of a population are then passed on to the generations that follow as outlined by student G “an organism would change to benefit, that organism’s lifestyle, the organisms that would come after it would inherit that trait.” Also, through such explanations undergraduates portrayed another misconception in that evolution occurs through changes in the phenotype rather than changes in the genotype as student J highlighted “m’ ghandhiex x’ taqsam eżatt mal- genes” (“it doesn’t have to do with genes”).

4.1.6.1 Genetic Variations and Mutations

Some undergraduates used the term mutation to refer to genetic variation in a population “jirreproducing (sic!) flimkien u hekk u l-mutation tipo baqghet tikber u baqghet teżisti” (“they reproduce together and so and the mutation kind of increases and remained in existence”). However, this might imply that undergraduates assumed that genetic variation arises only by mutations as outlined by student B: “mammoths which were initially woolly due to mutations.” In fact, none of the undergraduates mentioned the concept of ‘genetic recombination’ or ‘shuffling of alleles’.

Withal, some assumed that mutations are always beneficial and advantageous as noted by student G “an organism would change to benefit... the organisms that would come after it would inherit that trait.” In contrast, others thought that mutations or genes which put individuals at an advantage are stronger, as student B said “the strong genes that made them to run more, faster.”
Again, many assumed that mutations which occur in the somatic cells of the parents are also passed on to the next generations: “the mosquitoes became resistant to the insecticide… that mosquito or fly was probably more resistant due to a mutation, it’s a good mutation, so that mutation would be more selective, the generations to come would have that” (student G).

Indeed, when some undergraduates were asked how come dark coloured peppered moths were not observed before pollution increased, some said that it was because having a dark colouration was coded by “a recessive mutation” (student D). Therefore, some of the undergraduates believed that a trait which is less observed in the population is coded by a recessive allele “the gene still existed it was recessive” (student F). In contrast, others assumed that when an allele codes for a dark-coloured trait than it is always dominant “since the dark colour is more dominant, most of the offspring will be darker” (student F).

4.1.6.2 Natural Selection

Although natural selection acts on the phenotype some undergraduates thought that it acts on the genotype as outlined by student K “genes illi huma aktar adaptive ghall- environment li jghix fih ha jiġu favoured against l- oħrajn” (“genes that are more adaptive to the environment in which they live are going to become favoured against the others.”) Likewise others assumed that advantageous traits which puts individuals at an advantage over others influence the survival of the individuals but fail to acknowledge the fitness that is the reproductive success of the individuals as outlined by student C “those that survive have more hair and eventually, the more hair you have the more you survive and pass their characteristics to the offspring” and student B “were more capable at running and these survived more than the others”.

Most undergraduates thought that individuals which are least adapted to their environment will die and failed to recognise that some lucky ones are still able to survive and reproduce “and so eventually with time the faster cheetahs remained alive while the slower cheetahs died out because of starvation”
(student E). Similarly, student N said: “the light coloured variation got exterminated from the population.”

Furthermore, almost all of the undergraduates failed to acknowledge the fact that natural selection occurs in every generation until reaching an optimum. Most assumed that natural selection occurs in one generation, producing more adapted organisms “those two insects or how many there are the only ones to reproduce and so you end with a population which is completely resistant to the insecticide” (student D). Or as also claimed by student E: “even if few individuals survived were capable to withstand the insecticide used, then those individuals were able to reproduce and so the population would grow again. And this time it consists of individuals who can withstand that insecticide.”

Many thought that natural selection leads to the formation of perfect organisms rather than most adapted organisms “eventually l- aħjar organiżmi ħa jiġu evoluted” (“eventually the best organisms will be evolved”) (student H).

4.1.6.3 Conclusion

The following table (table 3) is a summary of the evolutionary misconceptions harboured by Maltese undergraduates as elicited from the interview process.

Table 3: Number of interviewees holding each misconception with regards to those elicited in the interview process

<table>
<thead>
<tr>
<th>Misconception in Evolution</th>
<th>Number of undergraduates holding misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution occurs very slowly and in a long period of time.</td>
<td>3</td>
</tr>
<tr>
<td>Evolution occurred in the remote past.</td>
<td>2</td>
</tr>
<tr>
<td>Evolution occurs only in animals.</td>
<td>3</td>
</tr>
<tr>
<td>Evolution leads to adaptation.</td>
<td>3</td>
</tr>
<tr>
<td>Organisms evolve so as to become more adapted to the environment.</td>
<td>7</td>
</tr>
</tbody>
</table>
Evolution regarded as a consequence which follow a change. | 14
---|---
Evolution regarded as an outcome to natural selection. | 4
Evolutionary changes regarded as phenotypic changes. | 7
Uses Lamarckian explanations. | 5

- **Genetic Variation and Mutations**

Mutations are always beneficial or advantageous. | 1
Advantageous traits are stronger. | 1
Mutations which occur in the somatic cells of parents are passed on to the next generation. | 3
A trait which is less observed in the population is recessive. | 2
A trait which codes for a darker colour is always dominant. | 1

- **Natural selection**

Natural selection acts on the genotype. | 1
Advantageous traits increase the survival of individuals but do not affect their reproductive success. | 2
Least adapted individuals will die off rather than decrease. | 6
Natural selection occurs in one generation. | 12
The perfect organisms are formed rather than the most adapted. | 1

As outlined in the table (table 3) above almost all undergraduates regarded evolution as a consequence which follow a change. Again, a large number of undergraduates assumed that natural selection occurs in one generation rather than in every generation that follows until reaching an optimum. Indeed, some misconceptions were commonly found amongst undergraduates, such as thinking that evolutionary changes are changes in the phenotype, the use of Lamarckian explanations, and assuming that least adapted individuals are all eliminated from the population in one generation. In contrast, some other
misconceptions were not very common in fact harboured by one or two undergraduates.

4.1.7 Misuse of Words in Undergraduates’ Explanations

In their explanations, most undergraduates used the phrases “with time” (Student B, C and N) or “as time goes by” to explain evolutionary trends that occur across generations. This was highly reflected in the following statement, “primitive organisms [that] throughout the, the centuries u years, u years u years they evolved accordingly” (student H).

Many others used the term ‘characteristics’ in order to refer to traits or alleles, as student C said “change in the characteristics of a population”. Likewise, some of the undergraduates used the term ‘species’ instead of individuals, “those insecticides which didn’t kill some species then those species passed on their characteristics to their offspring” (student C) or “the hairier species always” (student E). Another misuse of term is that of ‘mutation’ in fact, some used the term ‘mutation/s’ in order to refer to genetic variation as indicated in student G’s statement: “The ones that could run faster [are] most likely to survive and therefore that mutation remained in the, species” or in that of student M “jirreproducing (sic!) flimkien u hekk u l-mutation tipo baqghet tikber u baqghet teżisti” (“they reproduce together and so and the mutation gradually increased and continued to exist.”)

4.2 Questionnaires

4.2.1 Profile of respondents

66 Maltese biology undergraduates participated in this questionnaire.

4.2.1.1 Number of undergraduates participating in each credit

In the questionnaire, undergraduates were asked to indicate whether they have participated in study-units involving ‘Genetics’ or ‘Evolution’. Of course, some
might have participated in both of these study-units or did not participate in either study-unit, thus these options were also given.

Figure 6: Number of respondents in correspondence to academic experience in evolution

From this chart (figure 6), one can note that most of the undergraduates i.e. 30% participated in both study-units involving ‘Genetics’ and ‘Evolution’. In contrast, 29% did not participate in either study-unit. Now, while that 24% participated in that of ‘Genetics’, only 17% participated in ‘Evolution’.

4.2.1.2 Number of undergraduates in each level of knowledge

Moreover, respondents were asked to rate their level of knowledge on a 5-point Likert scale; 1 being ‘Not Knowledgeable’, 3 being ‘Knowledgeable’ and 5 being ‘Highly Knowledgeable’.
As this chart (figure 7) outlines, more than half of the undergraduates i.e. 56% claimed to be 'Knowledgeable'. On the other hand, only 3% claimed to be 'Highly Knowledgeable' while that 32% claimed to be 'Quite Knowledgeable'. As 9% said to be 'Not Very Knowledgeable' none said to be 'Not Knowledgeable'.

4.2.1.3 Number of undergraduates in each level of acceptance

Again, by using a 5-point Likert scale undergraduates were asked to rate their acceptance in evolution ranging from 1 being “I do not accept it”, 3 being “I accept it” and 5 being “I highly accept it”.

Figure 8: Number of respondents within each level of acceptance in evolution
Indeed, all Maltese biology undergraduates accepted the theory of evolution. In fact, while more than half i.e. 55% highly accept it, 20% accept it and 26% are between accepting it and highly accepting, as presented in the chart (figure 8) above.

4.2.2 Analysing relationships between the sub-groups

4.2.2.1 Is there a relationship between the level of knowledge and the study-units in which the students participated?

![Figure 9: Illustrating differences in the percentage number of respondents, between academic experience and self-assessed level of knowledge in evolution](image)

As this graph (figure 9) illustrates, 3% of the undergraduates who claimed to be ‘Highly Knowledgeable’, participated in both study-units involving ‘Evolution’ and ‘Genetics’. In contrast, among the 32% who said to be ‘Quite Knowledgeable’, 17% participated in both of these study-units, 8% participated in ‘Genetics’, 6% did not participate in either study-unit and 2% participated in ‘Evolution’. Again, among those 56% who claimed to be knowledgeable, 23% did not participate in either study-unit, 14% participated in ‘Genetics’, 11% in ‘Evolution’ and 9% in both of these study-units. Indeed, 9% said they are ‘Not very knowledgeable’ in that 5% participated in a study-unit involving...
'Evolution', 3% participated in the study-unit involving 'Genetics' and 2% participated in both of the study-units.

One would expect that since 47% participated in the study-unit of 'evolution' there would be a higher percentage of undergraduates who claimed to be 'Highly Knowledgeable'. But as outlined in the pie-chart above undergraduates' academic experience did not influence the students' self-assessed level of knowledge, such that among 47% only 3% claimed to be 'Highly Knowledgeable'. As a matter of fact, differences between these two sub-groups were relatively low in that there is no statistically-significant difference between them. Consequently, the level of knowledge of undergraduates was not determined by the study-units in which they participated.

4.2.2.2 Is there a relationship between the students’ acceptance of evolution and the study-units in which they participated?

![Figure 10: Illustrating differences in the percentage number of respondents between academic experience and level of acceptance in evolution](image)

As depicted in the graph (figure 10) above, among the undergraduates who highly accepted evolution, 21% participated in the study-units of 'Evolution' and 'Genetics', 15% participated in 'Genetics', 11% did not participate in either
study-unit and 8% participated in ‘Evolution’ only. Indeed, out of those who ‘accepted’ evolution 6% participated in a study-unit involving ‘Evolution’, 5% in ‘Genetics’, 5% in both of these study-units and another 5% did not participate in either study-unit.

Those who were in between accepting it and highly accepting it, 14% did not participate in either study-unit of ‘Genetics’ or ‘Evolution’, 5% participated in both of the study-units, another 5% participated in that of ‘Genetics’ and 3% participated in ‘Evolution’.

Again the differences between these two sub-groups were relatively low such that there is no statistically-significant difference between them.

4.2.2.3 Is there a relationship between the students’ level of knowledge and students’ acceptance?

Figure 11: Illustrating differences in the percentage number of respondents, between self-assessed level of knowledge and level of acceptance in evolution

From this graph (figure 11) it can be noted that all those who claimed to be ‘Not Very Knowledgeable’ ‘accepted’ evolution. Among those who claimed to ‘Highly Knowledgeable’ 2% highly accepted evolution and another 2% were in between accepting it or highly accepting it. Then 23% of those who claimed to be ‘Quite
knowledgeable’ highly accepted evolution. In turn, 2% accepted it and 8% were in between accepting it and highly accepting it. In contrast, most of those who highly accepted evolution i.e. 30% also claimed to be ‘Knowledgeable’ of evolution. Indeed, 17% who claimed to ‘Knowledgeable’ are in between and 9% accepted evolution.

Moreover, differences between these two sub-groups were relatively low, such that there was no statistically-significant difference between them.

4.2.3 Undergraduates’ Misconceptions in Evolution

4.2.3.1 A Representation of the Responses Acquired

The set of closed-questions in the questionnaire, presented a number of misconceptions or facts regarding the concept of evolution. Questions 5 to 18 required a ‘Yes or No’ answer while that for questions 19 to 26 the undergraduates had to select from a range of three responses that are ‘Always’, ‘Never’ and ‘Sometimes’.

The following table (table 4) shows the total number of students and the percentage frequency of students who answered ‘Yes’ or ‘No’ in questions 5 to 18.

Table 4: Number of respondents together with the percentage frequency of respondents who answered ‘Yes’ or ‘No’ for questions between 5 and 18

<table>
<thead>
<tr>
<th>Question</th>
<th>Number of students who answered 'No'</th>
<th>Number of students who answered 'Yes'</th>
</tr>
</thead>
<tbody>
<tr>
<td>God created Earth and the Universe in 6 days. He created all life forms as we know them today.</td>
<td>62 (94%)</td>
<td>3 (5%)</td>
</tr>
<tr>
<td>Life was only created once. No evolution or extinction occurred since the moment of creation.</td>
<td>66(100%)</td>
<td>0(0%)</td>
</tr>
</tbody>
</table>
The theory of biological evolution is supported by enough scientific evidence to make it credible.  

<table>
<thead>
<tr>
<th>Statement</th>
<th>Agree (%)</th>
<th>Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution is always beneficial as it always leads to progress and forms improved organisms.</td>
<td>35(53%)</td>
<td>30(45%)</td>
</tr>
<tr>
<td>All life forms evolved from a common ancestor.</td>
<td>19(29%)</td>
<td>46(70%)</td>
</tr>
<tr>
<td>Scientific evidence shows that <em>Homo sapiens</em> evolved from an ape-like ancestor.</td>
<td>0(0%)</td>
<td>65(98%)</td>
</tr>
<tr>
<td>Humans stopped evolving.</td>
<td>64(97%)</td>
<td>2(3%)</td>
</tr>
<tr>
<td>All genetic traits of an organism help it to adapt to its environment.</td>
<td>42(64%)</td>
<td>24(36%)</td>
</tr>
<tr>
<td>Mutations are always beneficial.</td>
<td>66(100%)</td>
<td>0(0%)</td>
</tr>
<tr>
<td>All mutations are favoured by natural selection.</td>
<td>61(92%)</td>
<td>5(8%)</td>
</tr>
<tr>
<td>Genetic mutations occur at random and are not influenced by the needs of the organism.</td>
<td>15(23%)</td>
<td>50(76%)</td>
</tr>
<tr>
<td>Natural selection is the only process that leads to adaptation.</td>
<td>47(71%)</td>
<td>19(29%)</td>
</tr>
<tr>
<td>Natural selection acts on the genotype of an organism.</td>
<td>36(55%)</td>
<td>28(42%)</td>
</tr>
<tr>
<td>Without inheritable genetic variation evolution does not occur.</td>
<td>15(23%)</td>
<td>51(77%)</td>
</tr>
</tbody>
</table>

The following graph (figure 12) is a summary of the table presented above.
Figure 12: Number of respondents who answered ‘Yes’ and number of respondents who answered ‘No’ for questions between 5 and 18

Again, the following table (table 5) shows the total number of students and the percentage frequency of students who answered ‘Always’, ‘Never’ or ‘Sometimes’ in questions 19 to 26.

Table 5: Number of respondents together with the percentage frequency of respondents who answered ‘Always’, ‘Never’ or ‘Sometimes’ for questions between 19 and 26

<table>
<thead>
<tr>
<th>Question</th>
<th>No. of students who answered 'Always'</th>
<th>No. of students who answered 'Never'</th>
<th>No. of students who answered 'Sometimes'</th>
</tr>
</thead>
<tbody>
<tr>
<td>An individual evolves in its life so as to become adapted to the environment.</td>
<td>17(26%)</td>
<td>11(17%)</td>
<td>37(56%)</td>
</tr>
<tr>
<td>Evolution is a random process; usually it is not the fittest that survives but the luckiest.</td>
<td>5(8%)</td>
<td>22(33%)</td>
<td>38(58%)</td>
</tr>
<tr>
<td>Evolution can be rapid and occurs over short period of time.</td>
<td>1(2%)</td>
<td>24(36%)</td>
<td>41(62%)</td>
</tr>
</tbody>
</table>
Climate change is necessary for evolution to take place. | 2(3%) | 7(11%) | 57(86%) |
Humans can influence the evolution of other species. | 8(12%) | 0(0%) | 58(88%) |
The environment determines the expression of a gene for a particular trait. | 10(15%) | 5(8%) | 51(77%) |
Dominant traits are fitter than recessive traits. | 15(23%) | 3(5%) | 47(71%) |
Genetic drift occurs in small populations. | 27(41%) | 6(9%) | 32(48%) |

This table is summarised in the graph (figure 13) presented below.
Figure 13: Number of respondents who answered ‘Always’, number of respondents who answered ‘Never’, number of respondents who answered ‘Sometimes’ for questions between 19 and 26

4.2.3.2 The Most and Least Frequent Misconception among Undergraduates

The following table (table 6) outlines the number of students as well as the percentage frequency of students with a particular misconception.

Table 6: Percentage frequency of each misconception along with the number of respondents per each misconception harboured by Maltese biology undergraduates

<table>
<thead>
<tr>
<th>Number of Statement</th>
<th>Statement</th>
<th>Number of Students holding the Misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>God created Earth and the Universe in 6 days. He created all life forms as we know them today.</td>
<td>3(1%)</td>
</tr>
<tr>
<td>6</td>
<td>Life was only created once. No evolution or extinction occurred since the moment of creation.</td>
<td>0(0%)</td>
</tr>
<tr>
<td>7</td>
<td>The theory of biological evolution is supported by enough scientific evidence to make it credible.</td>
<td>11(3%)</td>
</tr>
<tr>
<td>8</td>
<td>Evolution is always beneficial as it always leads to progress and forms improved organisms.</td>
<td>30(8%)</td>
</tr>
<tr>
<td>9</td>
<td>All life forms evolved from a common ancestor.</td>
<td>19(5%)</td>
</tr>
<tr>
<td>10</td>
<td>Scientific evidence shows that <em>Homo sapiens</em> evolved from an ape-like ancestor.</td>
<td>0(0%)</td>
</tr>
<tr>
<td>11</td>
<td>Humans stopped evolving.</td>
<td>2(1%)</td>
</tr>
<tr>
<td>12</td>
<td>All genetic traits of an organism help it to adapt to its environment.</td>
<td>24(6%)</td>
</tr>
<tr>
<td>13</td>
<td>Mutations are always beneficial.</td>
<td>0(0%)</td>
</tr>
<tr>
<td>14</td>
<td>All mutations are favoured by natural selection.</td>
<td>5(1%)</td>
</tr>
<tr>
<td>15</td>
<td>Genetic mutations occur at random and are not influenced by the needs of the organism.</td>
<td>15(4%)</td>
</tr>
<tr>
<td>16</td>
<td>Natural selection is the only process that leads to adaptation.</td>
<td>47(12%)</td>
</tr>
<tr>
<td>17</td>
<td>Natural selection acts on the genotype of an organism.</td>
<td>28(7%)</td>
</tr>
<tr>
<td>18</td>
<td>Without inheritable genetic variation evolution does not occur.</td>
<td>15(4%)</td>
</tr>
<tr>
<td>19</td>
<td>An individual evolves in its life so as to become adapted to the environment.</td>
<td>54 (14%)</td>
</tr>
<tr>
<td>20</td>
<td>Evolution is a random process; usually it is not the fittest that survives but the luckiest.</td>
<td>27(7%)</td>
</tr>
</tbody>
</table>
Evolution can be rapid and occurs over short period of time. 25(6%)

Climate change is necessary for evolution to take place. 9(2%)

Humans can influence the evolution of other species. 8(2%)

The environment determines the expression of a gene for a particular trait. 15(4%)

Dominant traits are fitter than recessive traits. 18(5%)

Genetic drift occurs in small populations. 38(10%)

Additionally, the table (table 6) above was summarised in the chart provided below:

**Figure 14: Percentage frequency of each misconception harboured by Maltese biology undergraduates**
As illustrated in the graph (figure 14) above, the most common misconception with a percentage frequency of 14% and found among 54 Maltese biology undergraduates is that, many thought that an organism is capable to evolve during its lifetime in order to adapt to its own environment. Additionally many undergraduates, with a percentage frequency of 12% failed to understand that by natural selection only can a population become more adapted to its environment. Another common misconception, with a percentage frequency of 10%, is that undergraduates thought that genetic drift can also occur in larger populations.

In contrast, the least common misconception with a percentage frequency of 1% was only found amongst two undergraduates. These undergraduates did not believe that humans today are still undergoing evolution. Likewise, three undergraduates believed that God has created all living forms as we know them today. Another misconception which was not commonly found was that undergraduates thought that mutations are all selected for during natural selection.

Other misconceptions with a percentage frequency of 0% indicate, that these were not present among Maltese biology undergraduates. Indeed all of the undergraduates believed that evolution is an ongoing process and has been occurring since the origin of life as indicated by statement six. Again, all undergraduates agreed that human beings have evolved from an ape-like ancestor as revealed by scientific evidence. Likewise, all undergraduates knew that mutations are not always beneficial as they can also be harmful or have no affect on the organism.
4.2.4 Undergraduates with Creationist views

![Pie chart showing the number of respondents who answered either 'Yes', 'No', or failed to answer question 5.](image)

**Figure 15: Number of respondents who answered either 'Yes' or 'No' or failed to answer question 5**

From this chart (figure 15) one can deduce that while 62 undergraduates answered ‘No’, three undergraduates answered ‘Yes’ and another undergraduate did not answer. Therefore, three undergraduates believe that God created all living organisms in their present form.

**Table 7: The academic experience, self-assessed level of knowledge and level of acceptance of undergraduates with creationist views**

<table>
<thead>
<tr>
<th>Undergraduate</th>
<th>Academic Experience</th>
<th>Self-assessed Level of Knowledge</th>
<th>Level of Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Genetics</td>
<td>Knowledgeable</td>
<td>Highly Accept it</td>
</tr>
<tr>
<td>30</td>
<td>Genetics</td>
<td>Knowledgeable</td>
<td>Highly Accept it</td>
</tr>
<tr>
<td>47</td>
<td>Both</td>
<td>Quite Knowledgeable</td>
<td>Highly Accept it</td>
</tr>
</tbody>
</table>

As outlined in the table (table 7) above, among these three undergraduates, two participated in a study-unit of ‘Genetics’ and one participated in both study-units involving ‘Evolution’ and ‘Genetics’. Again, while two were ‘Knowledgeable’, one was ‘Quite Knowledgeable’ in evolution. In contrast, all three claimed to ‘Highly Accept’ the theory of evolution.
The following table (table 8) represents the number of misconceptions and the mean number of misconceptions found among creationists and non-creationists undergraduates.

Table 8: The total number of misconceptions and the mean number of misconceptions among creationists and non-creationists undergraduates

<table>
<thead>
<tr>
<th></th>
<th>Number of Misconceptions</th>
<th>Mean Number of Misconceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Creationist views</td>
<td>25</td>
<td>8.33</td>
</tr>
<tr>
<td>Without Creationist Views</td>
<td>361</td>
<td>5.82</td>
</tr>
<tr>
<td>Undecided</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 16: Mean number of misconceptions among respondents with creationist views and without creationist views

Moreover, as illustrated in the chart (figure 16) above undergraduates with creationist views had a larger mean value of misconceptions than those without creationist views.
4.2.5  Undergraduates believing that evolution is not supported by sufficient scientific evidence to make it credible.

Although, most of the undergraduates i.e. 55 answered 'Yes' still there are 11 undergraduates who thought that Darwin’s theory of evolution is not sufficiently based on empirical evidence, as presented in the chart (figure 17) above.

Table 9: The academic experience, self-assessed level of knowledge and level of acceptance of undergraduates who do not believe that the theory of evolution is supported by sufficient scientific evidence

<table>
<thead>
<tr>
<th>Undergraduate</th>
<th>Academic Experience</th>
<th>Self-assessed Knowledge</th>
<th>Level of Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Evolution</td>
<td>Not Very Knowledgeable</td>
<td>Accept it</td>
</tr>
<tr>
<td>2</td>
<td>Evolution</td>
<td>Knowledgeable</td>
<td>Accept it</td>
</tr>
<tr>
<td>11</td>
<td>None</td>
<td>Knowledgeable</td>
<td>Quite Accept it</td>
</tr>
<tr>
<td>12</td>
<td>Evolution</td>
<td>Knowledgeable</td>
<td>Quite Accept it</td>
</tr>
<tr>
<td>18</td>
<td>Genetics</td>
<td>Knowledgeable</td>
<td>High Accept it</td>
</tr>
<tr>
<td>20</td>
<td>Genetics</td>
<td>Knowledgeable</td>
<td>High Accept it</td>
</tr>
</tbody>
</table>
As outlined in the table (table 9) above, among these 11 undergraduates, four participated in the study-unit of 'Genetics', four participated in the study-unit of 'Evolution', one participated in both study-units involving 'Genetics' and 'Evolution' and two did not participate in either study-unit. None claimed to be 'Highly Knowledgeable'. In fact, one claimed to be 'Quite Knowledgeable', seven said to be 'Knowledgeable' and three said they are 'Not Very Knowledgeable'. However, among these undergraduates three 'highly accepted' the theory of evolution. Another three were in between accepting and highly accepting it, while five 'accepted' evolution.

The table (table 10) below outlines the number of misconceptions and the mean number of misconceptions present among those who agree or disagree that the theory of evolution is based on sufficient evidence.

Table 10: The total number of misconceptions and the mean number of misconceptions among undergraduates who believe and do not believe that the theory of evolution is supported by sufficient scientific evidence

<table>
<thead>
<tr>
<th></th>
<th>Number of Misconceptions</th>
<th>Mean Number of Misconceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution based on sufficient evidence</td>
<td>308</td>
<td>5.6</td>
</tr>
<tr>
<td>Evolution not based on sufficient evidence</td>
<td>85</td>
<td>7.7</td>
</tr>
</tbody>
</table>
Figure 18: Mean number of misconceptions among respondents who believe or do not believe that evolution is supported by sufficient scientific evidence

As illustrated in this chart (figure 18), undergraduates who disagreed that evolution is based on sufficient evidence had a larger mean number of misconceptions than those who agreed.

4.2.6 Analysing Differences in the Number of Misconceptions held by each Sub-group

The sample of respondents is heterogenous, such that the number of undergraduates varies in each sub-group. Therefore, one should not rely on the interpretation of total frequencies but use mean frequencies to ensure credibility when comparing between different sub groups.

4.2.6.1 Outlining the relationship between the number of misconceptions and the study-units in which undergraduates participated.

The following table (table 11) outlines the number of misconceptions along with the mean number of misconceptions with respects to the study-units in which undergraduates were involved.

Table 11: Mean number of misconceptions along with the total number of misconceptions in correspondence to academic experience in evolution

<table>
<thead>
<tr>
<th>Study-units</th>
<th>Number of Misconceptions</th>
<th>Mean Number of Misconceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

72
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetics</td>
<td>130</td>
<td>8.13</td>
</tr>
<tr>
<td>Evolution</td>
<td>70</td>
<td>6.36</td>
</tr>
<tr>
<td>Both</td>
<td>93</td>
<td>4.65</td>
</tr>
<tr>
<td>None</td>
<td>100</td>
<td>5.26</td>
</tr>
</tbody>
</table>

Undergraduates who participated in the study-unit involving ‘Genetics’, had the largest number of misconceptions i.e. 130 misconceptions. This group is followed by those undergraduates who did not participate either ‘Evolution’ or ‘Genetics’, with 100 misconceptions. In contrast, those who participated in both of these study-units had 93 misconceptions. Meanwhile, those who participated in ‘Evolution’ had the lowest number of misconceptions that is 70.

All in all, undergraduates who participated in a credit regarding evolution had a sum of 163 misconceptions, while those who were not involved in a credit regarding evolution had a sum of 230 misconceptions.

![Mean number of misconceptions among respondents in correspondence to academic experience in evolution](image)

**Figure 19: Mean number of misconceptions among respondents in correspondence to academic experience in evolution**

As illustrated in the chart (figure 19) above, undergraduates who participated in both study-units of ‘Genetics’ and ‘Evolution’ had the lowest mean value of 4.65 misconceptions. However, this group is then followed by undergraduates who did not participate in either study-unit with a mean value of 5.26 misconceptions. Meanwhile, undergraduates who participated in ‘Evolution’
had a mean value of 6.36 which is less than 8.13, the mean number of misconceptions obtained for undergraduates who participated in ‘Genetics’.

4.2.6.2 Outlining the relationship between the number of misconceptions and the undergraduates’ level of knowledge

The table (table 12) below outlines the number of misconceptions together with the mean number of misconceptions in relation to each level of knowledge.

Table 12: Mean number of misconceptions along with the total number of misconceptions within each self-assessed level of knowledge in evolution

<table>
<thead>
<tr>
<th>Level of Knowledge</th>
<th>Number of Misconceptions</th>
<th>Mean Number of Misconceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Knowledgeable</td>
<td>9</td>
<td>4.50</td>
</tr>
<tr>
<td>Quite Knowledgeable</td>
<td>108</td>
<td>5.14</td>
</tr>
<tr>
<td>Knowledgeable</td>
<td>230</td>
<td>6.22</td>
</tr>
<tr>
<td>Not Very Knowledgeable</td>
<td>46</td>
<td>7.67</td>
</tr>
<tr>
<td>Not Knowledgeable</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Out of the five groups presented above, undergraduates within the group ‘Knowledgeable’ had the highest number of misconceptions of 230 misconceptions. Also, while those being ‘Quite Knowledgeable’ had 108 misconceptions, those being ‘Not Very Knowledgeable’ had 46 misconceptions. Indeed, those who claimed to be ‘Highly Knowledgeable’ only had 9 misconceptions.
Figure 20: Mean number of misconceptions among respondents within each self-assessed level of knowledge in evolution

As illustrated in the chart (figure 20) above, the mean number of misconceptions decreased as the level of knowledge increased from ‘Not Very Knowledgeable’ to ‘Highly Knowledgeable’. Undergraduates who claimed to be ‘Highly Knowledgeable’ had fewer misconceptions, than those who claimed to be ‘Not Very Knowledgeable’. Meanwhile, undergraduates who said they are ‘Not Very Knowledgeable’ had a mean number of 7.67 misconceptions, undergraduates who said they are ‘Knowledgeable’ had a mean value of 6.22, undergraduates who claimed to be ‘Quite Knowledgeable’ had a mean value of 5.14 and those who said they are ‘Highly Knowledgeable’ had a mean number of 4.50 misconceptions.

4.2.6.3 Outlining the relationship between the number of misconceptions and the undergraduates’ acceptance in evolution

The following table (table 13) outlines the number of misconceptions together with the mean number of misconceptions with respect to the level of acceptance.

Table 13: Mean number of misconceptions along with the total number of misconceptions within each level of acceptance in evolution

<table>
<thead>
<tr>
<th>Level of Acceptance</th>
<th>Number Of Misconceptions</th>
<th>Mean Number of Misconceptions</th>
</tr>
</thead>
</table>
As shown in the table (table 13) above, all of the Maltese biology undergraduates accepted the theory of evolution. With regards to the number of misconceptions, undergraduates in the sub-group 'Highly accept it' had 189 misconceptions. Likewise, those who claimed to ‘Accept’ evolution had 92 misconceptions.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Accept it</td>
<td>189</td>
<td>5.25</td>
</tr>
<tr>
<td>4</td>
<td>112</td>
<td>6.59</td>
</tr>
<tr>
<td>Accept it</td>
<td>92</td>
<td>7.08</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Do Not Accept it</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 21: Mean number of misconceptions among respondents within each level of acceptance in evolution

Moreover, as shown in the chart (figure 21) above, undergraduates who highly accepted the theory of evolution had a lower mean value of 5.25 misconceptions, than those who just accepted the theory of evolution with a mean value of 7.08 misconceptions. Indeed, the number of misconceptions decreased with the level of acceptance in evolution. However, one should note that the difference between these sub-groups was relatively low.
4.2.7 Analysing responses for Question 2 “How do you define the Theory of Biological Evolution?”

As discussed in the ‘Methodology’ chapter, question 2 of the questionnaire was an open-ended question, asking students to describe evolution. Indeed, the following table (table 14) represents the misconceptions elicited through coding of responses together with the percentage frequency of students holding each misconception.

Table 14: Percentage frequency of respondents holding each misconception elicited from question 2 (open-ended)

<table>
<thead>
<tr>
<th>Misconceptions elicited</th>
<th>Percentage frequency of students holding misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explain evolution in terms of macro-evolution</td>
<td>18%</td>
</tr>
<tr>
<td>Explain evolution in terms of natural selection</td>
<td>8%</td>
</tr>
<tr>
<td>Explain evolution in terms of genetic drift</td>
<td>1%</td>
</tr>
<tr>
<td>Assume that an individual evolves rather than a population</td>
<td>1%</td>
</tr>
<tr>
<td>Assume that species evolves rather than a population of a species</td>
<td>1%</td>
</tr>
<tr>
<td>Describe evolution as changes in the phenotype rather than in the genotype</td>
<td>10%</td>
</tr>
<tr>
<td>Provide Lamarckian Explanations</td>
<td>4%</td>
</tr>
<tr>
<td>New traits came into existence rather than changes in the genotype</td>
<td>1%</td>
</tr>
<tr>
<td>Mutations which occur in the somatic cells are passed on to offspring</td>
<td>3%</td>
</tr>
<tr>
<td>Evolution is always beneficial</td>
<td>1%</td>
</tr>
<tr>
<td>Evolution due to environmental changes</td>
<td>14%</td>
</tr>
</tbody>
</table>
Change as an outcome to natural selection 5%
Evolution leads to adaptation 25%
Natural selection acts on the genotype 3%
Genes become more improved rather than populations 1%
Dominant traits are fitter than recessive traits 1%
Use term over time instead of across generations 1%

Additionally, the table (table 14) above was summarised in the following figure:

**Figure 22: Percentage frequency of undergraduates holding each misconception as elicited from question 2 (open-ended)**

Primarily, as shown in the figure (figure 22) and table (table 14) above many undergraduates i.e. 18% used macro-evolutionary concepts when describing evolution. In contrast, 8% described evolution in terms of natural selection, while 1% described evolution in terms of genetic drift.
Additionally, 4% made use of Lamarckian explanations and another 10% thought that evolutionary changes occur in the phenotype rather than the genotype of an organism. Besides, rather than thinking that traits change by mutations in evolution, 1% assumed that new traits arise rather than change. Again, 3% thought that mutations which occur in the somatic cells of parents are passed on to the offspring.

Likewise, 14% regarded evolution as a consequence to environmental changes. In fact, 25% believed that evolution precede to adaptation, this being the most common misconception among undergraduates. Then, 5% regarded evolution as an outcome of natural selection, thinking that change in organisms arise after they become adapted to their environment.

On the other hand, 3% assumed that natural selection acts on the genotype rather than on the phenotype of a population, in that 1% thought that genes improve rather than organisms.

All in all, 1% thought that evolution is always beneficial. Another 1% assumed that individuals evolve rather than populations while another 1% thought that species evolve rather than a population. Indeed, these misconceptions are not very common among undergraduates. 1% of the undergraduates thought that dominant traits are fitter than recessive traits while others used the term ‘over time’ instead of ‘across generations’.

Furthermore, out of 66 undergraduates only ten described evolution as “descent with modification”.
5 Discussion

Misconceptions are mental constructs (Clement, Brown and Zietsman, 1989) which vary greatly from the actual scientific concept that they misrepresent (Carey, 2000). The main objective of this research was to explore evolutionary misconceptions harboured by Maltese Biology Undergraduates. As presented in the findings of this research these misconceptions are diverse and new misconceptions other than those mentioned in the literature were elicited. Meanwhile, some of those mentioned in the literature were not found to be present among Maltese biology undergraduates.

5.1 Misconceptions about Evolution among Maltese Biology Undergraduates

5.1.1 Defining evolution as “descent with modification”

Many undergraduates failed to acknowledge that evolution is “descent with modification” (Ridley, 2004, pp. 4). In fact, some undergraduates believed that evolution would still occur regardless of inheritable genetic variation. Some biology undergraduates thought that new traits arise rather than changes in existing-traits occur. Additionally, many undergraduates explained biological evolution in terms of natural selection or genetic drift or even as a means through which species become more adapted to their environment.

Interestingly, others used macro-evolutionary concepts such as ‘speciation’ when describing Darwin’s theory of evolution. However, one cannot consider such explanations as misconceptions because as Farber (2003) put it, Darwin’s evolution seeks to explain how species originated as they evolved from one another.
5.1.2 Evolutionary misconceptions among Maltese biology undergraduates

Some undergraduates believed that individual organisms rather than populations evolve as mentioned in the website of University of California Museum of Palaeontology (n.d.).

As Bishop and Anderson (1990) discussed, many undergraduates believed that evolution is a form of adaptation influenced by changes in the environment. In fact, many undergraduates referred to evolution as a consequence which follows an environmental change leading to adaptation. Meanwhile, as discussed by Nehm and Reilly (2007), undergraduates thought that environmental changes such as climate change or human interference are always needed for evolution to occur. Others assumed that evolution of species is never influenced by such environmental factors.

During the interviews some undergraduates explained how species evolve and change so to become adapted to their environment. Therefore, as Jensen and Finley (1995) reported, undergraduates failed to recognise that genetic variation is needed if natural selection is to occur.

Many Maltese biology undergraduates interpreted evolution in terms of Lamarckian views. Likewise, Brumby (1984), Demastes, Settlage and Good (1995), Edgar and Greene (1990) and Settlage (1994) reported Lamarckian explanations among students in their research. Moreover, Brumby (1984) also argued that such Lamarckian explanations in students inhibit the understanding of Darwin's evolution. In contrast, other undergraduates explained evolution in terms of phenotypic changes rather than changes in the genotype of a population.

Meanwhile, others held the idea that only animals evolve. One reason to this is that many teachers fail to incorporate species other than animals when explaining evolutionary concepts, as many undergraduates confessed during the interviews.
Some undergraduates thought that the rate of evolution differ with species as Coyne (2009) described. While some thought that evolution is always brief and fast others thought that evolution is always slow and last for a long period of time. Additionally, some interviewees failed to acknowledge that evolution is an ongoing process and has been occurring since the moment of creation. Instead they regarded evolution as something which only occurred in the distant past as was also reported in the writings of Volpe (1984) (cited in Trowbridge and Wandersee, 1994).

Mayr (2001) argued that many undergraduates misinterpret evolution as a random process. In contrast, if evolution was not a random process then only the fittest species would survive. However, in terms of luck rather than fitness, it is likely that individuals who are less fit will still survive and produce offspring. While some undergraduates followed Mayr’s arguments in thinking that always the fittest individuals survive others thought that always the luckiest ones survive.

Moreover, as Marco and Bizzo (2004) argued, many biology undergraduates thought evolution is always positive and valuable forming better adapted organisms.

5.1.2.1 Some Maltese Biology Undergraduates hold misconceptions with regards to genetic variation and mutations

As Bishop and Anderson (1990) as well as Alters and Nelson (2002) discussed, many students assumed that mutations occur in all individuals within a population rather than in some individuals in the population. Besides, many also thought that genetic variation arises only by mutations and failed to consider genetic recombination and reshuffling of alleles.

Unlike the expected, none of the respondents considered mutations as always being beneficial. In fact, as Mayr (2001) describes, mutations can be beneficial, harmful or neutral. However, this misconception has emerged in the explanations of some interviewees.
Similarly, while some undergraduates thought that mutations are determined by the needs of an individual only few believed that all mutations are selected for by natural selection.

Many undergraduates especially those harbouring Lamarckian views thought that mutations which occur in the somatic cells of parents are passed on to the offspring.

Furthermore, as reported by Nehm and Reilly (2007), many of the undergraduates thought that dominant traits are fitter than recessive traits. Then, as elicited from the interviews, some thought that alleles which code for a dark-coloured trait are always dominant. Even so, others misinterpreted advantageous mutations as strong.

Withal, while some respondents thought that “All genetic traits of an organism help it to adapt to its environment” only some recognised that the expression of a gene for a particular trait is sometimes influenced by the environment of the organism.

5.1.2.2 Some Maltese Biology Undergraduates hold misconceptions with regards to natural selection

Primarily, the process of natural selection is not easily understood by students (Demastes, Settlage and Good, 1995) in fact Almquist and Cronin (1988) said that many do not comprehend it even after instruction.

Natural selection as defined by the National Academy of Sciences Institute of Medicine (2008) is the “differential reproductive success of organisms with advantageous traits” (2008, pp. 5). However, undergraduates interviewed only mentioned how natural selection influences the survival of the species and failed to acknowledge their reproductive success.

As well, as delineated in their explanations many undergraduates failed to recognise that natural selection occurs in each generation until species become better adapted to its environment as Coyne (2009) discussed. Likewise, many
undergraduates thought that the least adapted forms die out instantaneously, without recognising that some lucky ones still manage to survive and reproduce. Again, as reported in the website of University of California Museum of Palaeontology (n.d.) undergraduates thought that natural selection leads to perfect organisms instead of forming better adapted forms.

Although, natural selection is the only process that can lead to local adaptation (Futuyma, 1997; Coyne, 2009) some undergraduates still believed that evolution lead to adaptation. Likewise, as Ruse and Travis (2009) discussed, some undergraduates thought that natural selection acts on the genotype of a population rather than on the phenotype.

As Coyne (2009) further discussed, natural selection can only take place if genetic variation is present among individuals of a population. Undergraduates thought that genetic variation arises after natural selection has occurred.

5.1.2.3 Some Maltese Biology Undergraduates hold misconceptions with regards to genetic drift

While some undergraduates believed that genetic drift never occurs in small populations others thought that genetic drift can also occur in larger populations.

5.1.3 Misinterpretations of the ‘fittest species’ among Maltese biology undergraduates

Demastes, Settlage and Good (1995) reported how, students associate the term “fitness” with its colloquial meaning “as a measure of strength, athletic ability or intelligence” (pp. 536). However, as outlined in the findings many undergraduates were able to distinguish between its colloquial and biological meaning. Thus one could infer that this misconception is either rarely found or not found at all among Maltese biology undergraduates.

Nonetheless, other misconceptions with regards to the ‘fittest species’ are found among Maltese biology undergraduates. To begin with, some used the term
species in their explanations thus thinking that fitness vary among species rather than between individuals of the same species.

Moreover, many regard the ‘fittest species’ as the most adapted species, sometimes referring to individuals who are able to survive and adapt to different environments other than its own and failed to acknowledge differential reproductive success among individuals.

Others described the ‘fittest species’ as that which is capable to produce fertile offspring or with the most varying individuals.

5.1.4 Misuse of biological terms by Maltese biology undergraduates

As Alters and Nelson (2002) argued, students confuse scientific terms with their colloquial meanings. In fact, many Maltese biology undergraduates used colloquial terms in their explanations of evolution. Primarily, most used phrases such as ‘with time’ or ‘as time goes by’ instead of ‘across generations’. While some used ‘characteristics’ when referring to genotypic traits or alleles, others say ‘mutation’ when referring to genetic variation. Also, some used the term ‘species’ instead of ‘individuals’.

5.2 Factors which contribute to these misconceptions

5.2.1 Academic achievement and misconceptions

Since Darwin's theory of evolution comprises a number of interlinked concepts (Trowbridge and Wandersee, 1994) it is very complex and difficult to understand. Therefore, only those capable of ‘abstract thinking’ can acquire a profound understanding of the concept (Keown, 1988; cited in Trowbridge and Wandersee, 1994, pp. 459). Since, undergraduates who participated in study units involving ‘Genetics’ and ‘Evolution’ are older and more intellectually mature, they are more capable of abstract thinking, in fact they have fewer misconceptions.
Even so, undergraduates who participated in these study-units had fewer misconceptions than those who participated in evolution alone. Thus, obtaining an understanding of genetics helped undergraduates to gain a better understanding in evolution than if evolution was taught alone. Indeed, this conflicts with the findings of Marco and Bizzo (1994) who claimed that students are more likely to develop misconceptions in evolution as they are not able to relate molecular genetics with evolution.

It was expected that undergraduates who did not participate in either of these study-unit would have more misconceptions than those who participated in either ‘Genetics’ or ‘Evolution’. Despite this, undergraduates who did not participate in any of the study-units had fewer misconceptions than those who participated in a study-unit involving ‘Genetics’ or ‘Evolution’.

Moreover, as Coyne (2009) argues, many undergraduates enter University with misconceptions in evolution and as Ausubel (1968) (cited in Osborne and Gilbert, 1980) puts it, such already-existing misconceptions will inhibit the undergraduates’ understanding of the concept. Therefore, it is reasonable if teachers acknowledge undergraduates’ misconceptions prior to instruction (Osborne and Gilbert, 1980; Carey, 2000).

Consequently, if undergraduates’ misconceptions in evolution are not addressed prior to instruction of evolution or genetics, then more misconceptions will develop. Indeed, this is a possible reason why undergraduates who did not participate in either study-unit had fewer misconceptions than those who participated in study-units involving ‘Evolution’ or ‘Genetics’. As a matter of fact, when misconceptions persist undergraduates fail to relate between existing concepts and new concepts (Alters and Nelson, 2002). Additionally, as Hermann (2009) argued, it is more likely for conceptual change to occur when undergraduates’ misconceptions are addressed prior to instruction of evolution.

As depicted in the findings of the research all undergraduates held misconceptions in spite of having followed study units in evolutionary biology. Since conceptual change is rather difficult to achieve (Settlage, 1994; Andrews
et al., 2012) misconceptions will still persist even after instruction (Settlage, 1994; Coyne, 2009).

As a matter of fact, differences among sub-groups were relatively low such that instruction of evolution does not influence conceptual change in undergraduates.

5.2.2 Self-assessed level of knowledge and Misconceptions

Primarily, none of the respondents claimed to be ‘not knowledgeable’ in evolution. This is reasonable because as described in the ‘Methodology’ section all of the participants had acquired a grade C or better in Biology at an Advanced level. Moreover, this also shows that these undergraduates had already encountered the concept of evolution prior to entering University.

Since, the total number of misconceptions reflected the number of participants in each sub-group, it would be more reasonable if the mean number of misconceptions is compared between sub-groups.

Indeed, the mean number of misconceptions decreased as the level of knowledge increased, such that respondents who claimed to be highly knowledgeable in evolution had fewer misconceptions than those who claimed to be less knowledgeable.

In contrast, the level of knowledge assessed by interviewees did not determine the number of misconceptions attained by the undergraduates.

5.2.3 Relationship between educational achievement and self-assessed level of knowledge

It was expected that undergraduates who participated in both study-units involving ‘Genetics’ and ‘Evolution’ would claim to be more knowledgeable than those who participated in one or did not participate in either study-unit.
However, as reflected in the findings of questionnaires, illustrated in figure 9, there was not a statistically-significant difference between academic experience and self-assessed level of knowledge.

In contrast, since seven interviewees participated in both study-units then it was expected that most would claim to be highly knowledgeable in evolution. However, only two undergraduates claimed to be highly knowledgeable.

Even so, Student C who participated in both of these study-units claimed to be knowledgeable like Student E and F who did not participate in either study-unit. As expected, Student C had fewer misconceptions than either Student E or Student F.

As shown in figure 5, undergraduates who claimed to be highly knowledgeable had fewer misconceptions than those who participated in genetics or did not participate in either ‘Genetics’ or ‘Evolution’. This was not always the case as student B who participated in both of the study-units held the largest number of misconceptions.

Consequently, academic experience did not determine self-assessed level of knowledge. Considering, evolution is a very controversial topic and so some undergraduates would find it interesting and may read or watch documentaries about it. In fact, as Bishop and Anderson (1990) said students are more likely to develop scientific concepts before classroom instruction.

5.3 All Maltese biology undergraduates accept the theory of biological evolution

5.3.1 Reasons why Maltese biology undergraduates accept evolution

As the research by Bishop and Anderson (1990) reveals most of the students today accept Darwin’s theory of evolution. In fact, as outlined in the findings of this study all Maltese biology undergraduates accepted the theory of evolution.
Primarily, most argued that Darwin's evolution is credible as it is supported by sufficient scientific evidence. As well, many argued that it provides reasonable explanations to why species change and how different species developed. Such findings were also reported by Downie and Barron (2010).

Nonetheless, Maltese biology undergraduates do not accept it fully. As a matter of fact, Student D who has participated in both study-units agreed that the theory is based on sufficient evidence but further argued that “if new evidence had to come to light than obviously it would have to be revised.”

5.3.1.1 Some undergraduates hold creationist and teleological views

Even though biologists today found fossil evidence indicating that life originated about 3.5 billion years ago (National Academy of Sciences Institute of Medicine, 2008) some students still adhere to creationist beliefs as Zimmerman (1987) discusses.

Contrary to the results of Tabone (2011), only three Maltese biology undergraduates held creationist views even though they claimed to accept evolution. However, as was also shown in Tabone’s research, all Maltese biology undergraduates believed that evolution is an on-going process which has been occurring since life originated. Therefore, in this case creationist views reflect strong religious backgrounds rather than lack of knowledge in evolution. As a matter of fact, one of the undergraduates holding creationist views participated in both study-units involving ‘Genetic’s and ‘Evolution’.

In contrast, one of the interviewees claimed to accept the theory of evolution because today the Catholic Church has come to accept it. As shown by Downie and Barron (2010), some students holding religious beliefs still come to accept the theory of evolution. As a matter of fact, all undergraduates holding creationist views ‘highly accept’ evolution.

Besides, Nelson (2008) argued that students holding strong religious beliefs are less likely to understand the theory. Indeed, undergraduates with creationist
views had a larger mean number of misconceptions than those who do not hold creationist views.

Furthermore, Christensen and Cannon (1978) say that, many undergraduates use teleological aspects when explaining human evolution. In fact, two undergraduates believed that human beings do not evolve, perhaps because they believe that God created human beings in their present, perfect form as reported in the research of Tabone (2011).

On the other hand, in contrast to the findings of Nelson (2008) and similar to the findings of Tabone (2003), all undergraduates believed that human beings descended from an ape-like ancestor. Despite, some undergraduates did not agree that all living species have descended from the same ancestor.

On the other hand, even though undergraduates might not hold creationists beliefs, it does not mean that they are not religious. However, this is not the scope of this research.

5.3.1.2 Sufficient amount of scientific evidence to make it credible

Some Maltese biology undergraduates (11 individuals from the sample) disagreed that Darwin’s evolution is based on sufficient scientific evidence. As a matter of fact, as reported in Tabone (2011) and Hokayem and BouJaoude (2008) many still refuse to accept Darwin’s theory of evolution thinking that it is not based on scientific evidence. In spite, three out of these 11 undergraduates claimed to ‘Highly Accept’ evolution.

Moreover, Downie and Barron (2010), Alters and Nelson (2002) say that, students who reject evolution are more likely to hold creationist views. However, as discussed earlier the three undergraduates holding creationist views ‘highly accept’ evolution.

On the other hand, none of these undergraduates claimed to ‘highly knowledgeable’ in evolution. In fact, undergraduates who disagreed that this theory is based on sufficient evidence had a larger mean number of
misconceptions than those who agreed. As such, one could infer that undergraduates’ with lack of knowledge in evolution are more likely to believe that the theory is not based on sufficient evidence.

5.3.2 Factors which influence undergraduates’ acceptance in evolution

5.3.2.1 Undergraduates’ understanding of evolution and level of acceptance

Since, the total number of misconceptions reflects the number of participants in each sub-group, the mean number of misconceptions was compared between sub-groups.

It is expected that undergraduates who ‘highly accept’ evolution would be more interested and seek to understand it better. In fact, as delineated in figure 39, undergraduates who ‘highly accepted’ evolution had a smaller mean number of misconceptions than those who just ‘accept’ it. In their research McKeachie, Lin and Strayer (2002) showed that undergraduates who accept evolution are more likely to understand the theory of evolution than those who do not accept it. However, such findings conflict with the research of Nelson (2008) who claimed that the acceptance or rejection of evolution does not determine the students’ understanding in the theory.

Moreover, Cobern (1994) says that if teachers expect students to highly understand evolution than they should consider the religious beliefs and attitudes of the students, towards evolution.

5.3.2.2 How does academic experience and self-assessed level of knowledge influence undergraduates’ acceptance in evolution

As outlined in the research of Bishop and Anderson (1990) as well as that of Downie and Barron (2010), students’ understanding of evolution determines their acceptance of the theory. In that, students with lack of understanding in evolution are less likely to accept it.
Therefore, it was expected that undergraduates who participated in both study-units involving ‘Genetics’ and ‘Evolution’ would rate a higher level of acceptance than those who participated in one or did not participate in either study-unit. However as delineated in figure 10, there was no statistically-significant difference between academic experience and self-assessed level of acceptance, in fact 11% of those who ‘highly accept’ evolution did not participate in either study-unit.

However, as discussed earlier, undergraduates’ understanding of evolution is not determined by their academic experience only. Many undergraduates develop concepts about evolution prior to instruction (Bishop and Anderson, 1990).

Following such arguments, one would expect that undergraduates who claimed to be ‘highly knowledgeable’ would rate a higher level of acceptance in evolution. Indeed, as illustrated in figure 11, those who claimed to be ‘not very knowledgeable’ only ‘accepted’ the theory of evolution. However, most undergraduates who ‘highly accepted’ it are only ‘knowledgeable’ of evolution. Additionally, there is no statistically-significant difference between self-assessed level of knowledge and acceptance of evolution.

Consequently, through the findings of this research one could infer that acceptance is not influenced either by academic experience or self-assessed level of knowledge. Indeed, acceptance of evolution is very subjective and is highly influenced by the undergraduates’ beliefs and attitudes. Thus as Cobern (1994) puts it, a teacher should first address such beliefs and attitudes prior to instruction of evolution.
CHAPTER 6

CONCLUSIONS & RECOMMENDATIONS
6 Conclusions & Recommendations

6.1 General Perceptions

Evolution is a unifying concept (Maynard Smith, 1993; Bishop and Anderson, 1990; Farber, 2003) which acts as a framework from which all other biological concepts diverge. In fact, as Dobzhansky puts it, “Nothing in biology makes sense except in the light of evolution” (Dobzhansky, 1973, pp. 125). Therefore, biology would make more sense to students if taught in terms of evolution.

As confirmed in the findings of this study, many Maltese biology undergraduates hold misconceptions in evolution which persist even after instruction. Misconceptions reflect students’ lack of understanding in evolution, which may arise due to ineffective teaching (Johnson and Peeples, 1987). Prior to instruction it is valuable if teachers acknowledge the students’ misconceptions (Bishop and Anderson, 1990; Edgar and Greene, 1990) to steer towards a more scientific perspective achieving conceptual change.

Primarily, 118 misconceptions were elicited while coding the interview transcripts. Most undergraduates regarded evolution as a consequence which follows a change, often an environmental change. Again, most undergraduates thought that natural selection occurs in a single generation and did not recognise that it occurs in every generation until reaching an optimum leading to better adapted forms. Moreover, many provided Lamarckian explanations during the interviews, in thinking that species evolve through changes in the phenotype which are passed on to the future generations.

Lamarckian ideas were very frequent among Maltese biology undergraduates. In fact, as portrayed in the findings of the questionnaire, more than half believed that an organism is capable to evolve during its life to adapt to its environment. Indeed, many disregarded that natural selection is the only process that leads to adaptation. Others thought that genetic drift can also occur in large populations.
In contrast, the least common misconception among Maltese biology undergraduates was that human beings have stopped evolving. Very few believed that all mutations are selected for during natural selection.

Moreover, some misconceptions were not even present among these undergraduates. To begin with, all believed that evolution is an on-going process which has been occurring since the origin of life. Also, all agreed with the scientific evidence that human beings have descended from an ape-like ancestor. Again, none agreed that mutations are always beneficial.

Even so, when respondents were asked to describe evolution, only ten described it as “descent with modification” (Ridley, 2004, pp. 4). Again, most said that evolution occurs due to environmental changes leading to adaptation. Others described evolution as changes in the phenotype of organisms which are then passed on to the offspring.

Few thought that evolution occurs in an individual or a whole species rather than in a population of a species. Again, while some claimed that evolution is always beneficial others thought that genes rather than populations improve. Indeed, another regarded evolution as a process whereby new traits arise rather than changes in already existing traits.

Furthermore, as outlined in the findings many Maltese biology undergraduates explained the ‘fittest species’ as the species which is most adapted to its environment. Also, many failed to acknowledge the differential reproductive success between organisms.

As depicted in the findings, the difference between undergraduates who followed a study unit concerning evolution and those who did not, was relatively low indicating that misconceptions persist even after instruction (Settlage, 1994; Coyne, 2009) especially if they are not dealt with before instruction (Settlage, 1994; Andrews et al., 2012).

In contrast, those who participated in study-units in both genetics and evolution had fewer misconceptions than those who followed study units in evolution
alone. Thus, instruction of genetics allows students to acquire a better understanding of the concept of evolution.

Interestingly, undergraduates who did not participate in either study-unit had fewer misconceptions than those who participated in either evolution or genetics. If teachers do not address undergraduates’ misconceptions prior to instruction of evolution, it is likely that undergraduates will not interlink new concepts with already existing concepts (Alters and Nelson, 2002) developing more misconceptions. In fact, as Settlage (1994) and Andrews et al. (2012) argue that conceptual change can only occur if undergraduates’ misconceptions are acknowledged prior to classroom instruction.

All in all, the undergraduates’ academic experience did not determine their self-assessed level of knowledge. As such undergraduates did not only acquire knowledge in evolution from instruction, but acquired it from other sources such as the media and literature. In fact, as Bishop and Anderson (1990) discussed, students develop concepts of evolution prior to instruction.

Furthermore, all Maltese biology undergraduates accepted Darwin’s theory of evolution. However, while more than half ‘highly accepted’ evolution, others claimed that they do not ‘fully accept’ it and if new evidence running counter to evolution were to be discovered then they would reconsider it.

Amongst those who ‘highly accept’ evolution, three held creationists beliefs, an apparent contradiction. Indeed, such creationist beliefs do not reflect lack of knowledge of evolution but reflect strong religious backgrounds. Nelson (2008) argued that creationists are more likely to develop a poor understanding in evolution such that these undergraduates had a larger mean number of misconceptions than those who do not hold creationist views.

Most argued that they accept evolution because it is based on sufficient scientific evidence and whose explanations of how species evolve make sense. However, some undergraduates believed that evolution is not based on sufficient scientific evidence. Such perceptions of evolution reflect lack of
knowledge and understanding in evolution, having a large mean number of misconceptions.

Indeed, acceptance of evolution is subjective as it is not influenced either by the students’ academic experience or self-assessed level of knowledge. Those who claimed to highly accept evolution achieved a better understanding, having fewer misconceptions than those who accept it. Therefore, as Cobern (1994) argues, it is essential that teachers not only address the undergraduates’ misconceptions but also acknowledge the undergraduates’ beliefs and attitudes towards evolution prior to instruction.

6.2 Limitations of the Study:

No interviewees who only participated in study units on evolution, but not in genetics, were found. Consequently, comparisons of the number of misconceptions between study-units in which undergraduates participated could not be made.

Moreover, the sample size of Maltese biology undergraduates was very small. In fact, the relationships between the number of misconceptions held by each subgroup could not be determined statistically. If questionnaires were distributed and collected through emails rather than by hand the rate of distribution (and, perhaps, the rate of response) would have been greater. However, distributing and collecting questionnaires by hand was preferred due to time limitations.

Nevertheless, if undergraduates were asked to rate the strength of their religious beliefs, one could better identify if creationist views are related to strong religious backgrounds or is indeed a misconception. Moreover, one could determine if the undergraduates’ religious background influence their understanding in evolution. Initially, this question was integrated in the questionnaire but most of the undergraduates who participated in the pilot study claimed that this question was personal and sensitive and as such it was removed from the questionnaire.
6.3 Recommendations:

Primarily, Maltese biology undergraduates should become more aware of the significance of evolution in biology. They should be taught how to perceive each biological concept and mechanism in terms of evolution.

Settlage (1994) and Andrews et al. (2012) claim that conceptual change will only occur if undergraduates’ misconceptions are addressed before instruction. Therefore, it is necessary that biology teachers acknowledge these misconceptions prior to instruction. Indeed, there are different pedagogical tools which aid both teachers and students to remodel misconceptions and attain a more scientific understanding (Bishop and Anderson, 1990; Osborne and Gilbert, 1980). Among those mentioned in the literature there are, inquiry based learning (Demastes, Settlage and Good, 1995), concept maps (Trowbridge and Wandersee, 1994), problem-solving investigations (Jensen and Finley, 1996) and experiments (Gil-Perez and Carrascosa, 1990). Moreover, Jensen and Finley (1995) believe that by incorporating historical events about Darwin’s theory of evolution will help the students acquire a better understanding. Additionally, as Osborne and Gilbert (1980) argue, students are more likely to understand evolution when their personal attitudes and beliefs towards evolution are addressed. Therefore, undergraduates should be encouraged to compare between the scientific facts and their religious teachings (Sinatra et al., 2003).

Even so, many undergraduates claimed that most of the time, during instruction they only deal with evolution in animal species. As such, teachers as well as textbooks should provide examples of evolution in different species other than animals.

Since, genetics help undergraduates with the understanding of evolution it is recommended that genetics is taught before teaching evolution.

As reflected in the findings of this study, many undergraduates acquire knowledge of evolution not only through instruction but from other sources
such as the media and literature. In fact, evolutionary misconceptions are also found in many textbooks (Barrass, 1984). Consequently, it would be ideal if one analyse the credibility of such sources.

Again, as the research of Nehm and Schonfeld (2007) delineates, misconceptions in evolution are also harboured by biology teachers. Thus it would be useful if evolutionary misconceptions held by biology teachers are explored. Additionally, one could compare the evolutionary misconceptions found in Maltese biology undergraduates and non-biology undergraduates.
REFERENCES
References


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Additional Readings


APPENDIX 1

RECRUITMENT LETTER
To whom it may concern,

I am a B.Ed. (Hons.) Biology student at the University of Malta and I am conducting research regarding misconceptions about biological evolution held by Biology Undergraduates in Malta. As part of my research studies, I am conducting a semi-structured interview based on a set of close and open-ended questions.

The aim of my study is to identify common misconceptions regarding evolutionary processes harboured by Maltese undergraduate students. In my research I would like to analyse if a student’s perception of evolution will in any way determine his/her understanding of evolution. This would help biology teachers and professors design appropriate teaching resources and styles to ensure meaningful understanding in evolution.

The interview will not take more than forty-five minutes and participation is optional. Anonymity is assured throughout the whole research process and if you wish to withdraw at any time, the information you have provided is erased. However, all participants are kindly asked to sign a consent form enabling me to make use of the information provided in the interview. Should you have any questions or concerns after participating please do not hesitate to contact me at sherxer92@gmail.com.

I would like to thank you in advance for your time.

Regards

SHERYL XERRI

Name of interviewee: ______________________

Signature: ______________________ Date: _______________

Researcher: ______________________ Date: _______________

Tutor: ______________________ Date: _______________
Dear Participant,

I am a B. Ed Biology student at the University of Malta and I am conducting a research regarding misconceptions about biological evolution held by Maltese Biology Undergraduates. As part of my research studies, I am conducting a questionnaire based on a set of close ended questions.

The aim of my study is to identify common misconceptions regarding evolutionary processes harboured by Maltese undergraduate students. In my research I would like to analyse if a student’s perception of evolution will in any way determine his/her understanding of evolution. Moreover, I will also be finding whether there is a difference between students who participated in credits involving either genetics or evolution, in some cases both, to those who did not participate in such credits. This would help biology teachers and professors design appropriate teaching resources and styles to ensure meaningful understanding in evolution.

Furthermore, anonymity is assured throughout the whole research process. Should you have any questions or concerns after participating please do not hesitate to contact me at sherxer92@gmail.com.

I would like to thank you in advance for your time.

Regards

SHERYL XERRI

1. As an undergraduate student I participated in credits involving (tick where applicable):
   - [ ] Genetics
   - [ ] Evolution
   - [ ] Both
   - [ ] None of the above

2. How do you define the Theory of Biological Evolution?
3. On a scale of 1 to 5 (1 = do not accept it, 3 = accept it and 5 = highly accept it), rate your acceptance in the Theory of Biological Evolution.

<table>
<thead>
<tr>
<th>1 (I do not accept it)</th>
<th>2</th>
<th>3 (I accept it)</th>
<th>4</th>
<th>5 (I highly accept it)</th>
</tr>
</thead>
<tbody>
<tr>
<td>My acceptance in the theory of Biological Evolution</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

4. On a scale of 1 to 5 (1 = not knowledgeable, 3 = knowledgeable and 5 = highly knowledgeable) rate your understanding in the theory of Biological Evolution.

<table>
<thead>
<tr>
<th>1 (Not Knowledgeable)</th>
<th>2</th>
<th>3 (Knowledgeable)</th>
<th>4</th>
<th>5 (Highly Knowledgeable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>My understanding in the theory of Biological Evolution</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

5. God created Earth and the Universe in 6 days. He created all life forms as we know them today.
   ○ Yes  ○ No

6. Life was only created once. No evolution or extinction occurred since the moment of creation.
   ○ Yes  ○ No

7. The theory of biological evolution is supported by enough scientific evidence to make it credible.
   ○ Yes  ○ No

8. Evolution is always beneficial as it always lead to progress and forms improved organisms.
   ○ Yes  ○ No

9. All life forms evolved from a common ancestor.
   ○ Yes  ○ No

10. Scientific evidence shows that Homo sapiens evolved from an ape-like ancestor.
    ○ Yes  ○ No
   ○ Yes  ○ No

12. All genetic traits of an organism help it to adapt to its environment.
   ○ Yes  ○ No

13. Mutations are always beneficial.
   ○ Yes  ○ No

14. All mutations are favoured by natural selection.
   ○ Yes  ○ No

15. Genetic mutations occur at random and are not influenced by the needs of the organism.
   ○ Yes  ○ No

16. Natural selection is the only process that leads to adaptation.
   ○ Yes  ○ No

17. Natural selection acts on the genotype of an organism.
   ○ Yes  ○ No

18. Without inheritable genetic variation evolution does not occur.
   ○ Yes  ○ No

19. An individual evolves in its life so as to become adapted to the environment.
   ○ Always  ○ Never  ○ Sometimes

20. Evolution is a random process; usually it is not the fittest that survives but the luckiest.
   ○ Always  ○ Never  ○ Sometimes

21. Evolution can be rapid and occurs over a short period of time.
   ○ Always  ○ Never  ○ Sometimes

22. Climate change is necessary for evolution to take place.
   ○ Always  ○ Never  ○ Sometimes
23. Humans can influence the evolution of other species.
   ☐ Always ☐ Never ☐ Sometimes

24. The environment determines the expression of a gene for a particular trait.
   ☐ Always ☐ Never ☐ Sometimes

25. Dominant traits are fitter than recessive traits.
   ☐ Always ☐ Never ☐ Sometimes

26. Genetic drift occurs in small populations.
   ☐ Always ☐ Never ☐ Sometimes

Thanks for your participation!
APPENDIX 3

QUESTIONNAIRE USED IN THE PILOT STUDY
Knowledge of Biological Evolution of Maltese Undergraduates

Dear Participant,

I am a B. Ed Biology student at the University of Malta and I am conducting a research regarding misconceptions about biological evolution held by Maltese Biology Undergraduates. As part of my research studies, I am conducting a questionnaire based on a set of close ended questions. The aim of my study is to identify common misconceptions regarding evolutionary processes harboured by Maltese undergraduate students. In my research I would like to analyse if a student’s perception evolution will in anyway determine his/her understanding of evolution. Moreover, I will also be finding whether there is a difference between students who participated in credits involving either genetics or evolution, in some cases both, to those who did not participate in such credits. This would help biology teachers and professors design appropriate teaching resources and styles to ensure meaningful understanding in evolution.

Furthermore, anonymity is assured throughout the whole research process. Should you have any questions or concerns after participating please do not hesitate to contact me at sherxer92@gmail.com.

I would like to thank you in advance for your time.

Regards

Sheryl Xerri

As an undergraduate student I participated in credits involving (tick where applicable):

- [ ] Genetics
- [ ] Evolution
- [ ] Both
- [ ] None of the above

How do you define the Theory of Biological Evolution?


121
Do you accept or reject the theory of evolution?

- Accept
- Reject
- Not Sure

On a Likert scale of 1-5 (1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree) rate your compatibility to these statements.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The theory of evolution is compatible with my personal religious or spiritual beliefs.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
<tr>
<td>The theory of evolution is supported by enough scientific evidence to make it credible.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
</tbody>
</table>

From a scale of 1-6 rate your understanding concerning the theory of evolution.

<table>
<thead>
<tr>
<th>Not Knowledgeable</th>
<th>2</th>
<th>Knowledgeable</th>
<th>4</th>
<th>Highly Knowledgeable</th>
</tr>
</thead>
<tbody>
<tr>
<td>My understanding in the Theory of Evolution.</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
<td>〇</td>
</tr>
</tbody>
</table>

God created Earth and the Universe in 6 days. He created all life forms as we know them today.

- Yes
- No

Life was only created once. No evolution or extinction occurred since the moment of creation.

- Yes
- No

Evolution is always beneficial as it always leads to progress and forms improved organisms.

- Yes
- No

All life forms evolved from a common ancestor.

- Yes
- No
<table>
<thead>
<tr>
<th>Statement</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific evidence shows that <em>Homo sapiens</em> evolved from an ape-like ancestor.</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Humans stopped evolving.</td>
<td>Yes, No</td>
</tr>
<tr>
<td>All genetic traits of an organism help it to adapt to its environment.</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Mutations are always beneficial.</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Natural selection is the only process that leads to adaptation.</td>
<td>Yes, No</td>
</tr>
<tr>
<td>Human beings do not evolve.</td>
<td>Yes, No</td>
</tr>
<tr>
<td>An individual evolves in its life so as to become adapted to the environment.</td>
<td>Always, Never, Sometimes</td>
</tr>
<tr>
<td>Evolution is a random process. It is not the fittest that survive but the luckiest.</td>
<td>Always, Never, Sometimes</td>
</tr>
<tr>
<td>Evolution can be rapid and occurs over a short period of time.</td>
<td>Always, Never, Sometimes</td>
</tr>
<tr>
<td>Climate change is necessary for evolution to take place.</td>
<td>Always, Never, Sometimes</td>
</tr>
<tr>
<td>Humans can influence the evolution of other species.</td>
<td>Always, Never, Sometimes</td>
</tr>
</tbody>
</table>
Dominant traits are fitter than recessive traits.

- Always
- Never
- Sometimes

Genetic drift only occurs in small populations.

- Always
- Never
- Sometimes

Please turn over. At the back you will find questions regarding the format and layout of the questionnaire. Again, thanks for your participation and cooperation.

The Questionnaire

How long did it take you to complete the questionnaire?

What do you think this questionnaire is about?
On a scale of 1-5 (1= Strongly Disagree, 2= Disagree, 3= Undecided, 4= Agree, 5= Strongly Agree) rate the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The questions are easy to read through.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The questions are in good order making it easier to follow the questionnaire.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The language is simple and easy.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>The instructions given are clear and easy to understand.</td>
<td>○</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>I did not feel comfortable when answering some questions, as they are too personal or sensitive.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I understood all the questions.</td>
<td>○</td>
<td>○</td>
<td>○</td>
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</tr>
</tbody>
</table>

If any, indicate which questions you did not understand or were uncertain about. Kindly do so by writing down the number of the question hereunder:

If any, which questions would you change? Kindly give reasons for your answers.
Discuss any problems or difficulties you encountered while completing the questionnaire?

What would you change in this questionnaire?

Thanks for your participation!

Submit
APPENDIX 4

A GENERAL OVERVIEW OF THE RESPONSES ATTAINED FROM QUESTIONNAIRES
As an undergraduate student I participated in credits involving Theory of Biological Evolution on a scale of 1 to 5 (1= do not accept it, 3= I accept it and 5= I highly accept it) rate your acceptance in the Theory of Biological Evolution:

<table>
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<tr>
<th>Student</th>
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God created Earth and the Universe in 6 days. He created all life forms as we know them today. Life was only created once. No evolution or extinction occurred since the moment of creation.
The theory of biological evolution is supported by enough scientific evidence to make it credible.

Evolution is always beneficial as it always lead to progress and forms improved organisms.

All life forms evolved from a common ancestor.

Scientific evidence shows that Homo sapiens evolved from an ape-like ancestor.

Humans stopped evolving.

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All genetic traits of an organism help it to adapt to its environment.

Mutations are always beneficial.

All mutations are favoured by natural selection.

Genetic mutations occur at random and are not influenced by the needs of the organism.

Natural selection is the only process that leads to adaptation.

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Natural selection acts on the genotype of an organism. Without inheritable genetic variation evolution does not occur. An individual evolves in its life so as to become adapted to the environment. Evolution is a random process; usually it is not the fittest that survives but the luckiest. Evolution can be rapid and occurs over a short period of time.

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Climate change is necessary for evolution to take place. Humans can influence the evolution of other species. The environment determines the expression of a gene for a particular trait. Dominant traits are fitter than recessive traits. Genetic drift occurs in small populations.

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APPENDIX 5

INTERVIEW-DESIGN
Knowledge of Biological Evolution of Maltese Undergraduates

Interview Questions:

1. Did you participate in credits involving either genetics or evolution?

2. How much do you accept the theory of biological evolution? Why?

3. Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

4. Describe the theory of biological evolution.
   a. Which mechanisms drive biological evolution?

5. What do you understand by the following statement: “the fittest species”?

6. Explain the following statements:
1. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

2. When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

3. The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.
4. The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed.

A). As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

B). When in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

5. The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.
APPENDIX 6

INTERVIEW-DESIGN PILOT STUDY
INTERVIEW QUESTIONS

1. Did you participate in credits involving either genetics or evolution?

2. From a scale of 1 to 5 (1= least and 5= most); How much do you accept the theory of biological evolution?

3. From a scale of 1 to 5 (1= least knowledgeable and 5= being highly knowledgeable) rate your understanding in the theory of biological evolution?

4. Describe the theory of biological evolution. Which mechanisms drive biological evolution?

5. What do you understand by the following statement: the “fittest” species?

6. Explain the following statements in terms of biological evolution:

   a. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran for 20 miles per hour.

   b. When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient killing less mosquitoes and flies.

   c. The hairy mammoth that lived in the Northern parts of Eurasia and in North America was found to have evolved from ancestors that had little hair, resembling the modern elephants.

   d. In the 18th century only light coloured peppered moths were observed. It was in 1848 when the melanic form that is the darker form of the peppered moth was observed in Manchester. Indeed, the melanic form increased in frequency such that it made up 90% of the population. It was observed that while the melanic form is more common in polluted areas, the light coloured form was more common in unpolluted areas. Research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

   i. When in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

   e. The Human Imuno Deficiency Virus (HIV) enters the human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. Anti- HIV drugs such as drug 3TC inhibit the enzyme reverse transcriptase. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.
APPENDIX 7

TRANSCRIPTS
Student A

INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT A: Yes, the… genetics one, evolution… is coming next year. No?! This year.

INTERVIEWER: Okay!

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT A: I think the theory of biological evolution is a very, very, very, important theory… in what comes biology. As Dobzhansky said... nothing makes sense... unless it's in the light of evolution, and I think it’s very, very, true because I think it is a very... joining aspect from biology... from different aspects of biology. And it does not only affect biology but it affects also like... other aspects, other... subjects like... there were a couple.

INTERVIEWER: Psychology...

STUDENT A: Eżatt

INTERVIEWER: Behavioural...

STUDENT A: Eżatt ...

INTERVIEWER: Anthropology...

STUDENT A: There were a long list...

INTERVIEWER: But do you accept it?

STUDENT A: Yes I do accept it and it think it's very, very, important, if you're a biologist, I think if you don’t accept this theory, I think you shouldn’t be a biologist in my opinion.

INTERVIEWER: Why do you accept it?

STUDENT A: I believe that, there is a lot of, evidence, there is a lot of evidence, that you know, this theory is, is true and it's not just, just Darwin said something... and it’s something not proven.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT A: I think, I’m in the middle, maybe a 3, maybe...

INTERVIEWER: A 3?

STUDENT A: Yes, ‘aha’ a 3, I don’t think I’m highly knowledge. But ehe I think I’m in the middle.

INTERVIEWER: Describe the theory of biological evolution.
**STUDENT A:** Isn't it the one that it come, that all the animals that all the organisms had one common ancestor. And then from it, we came into different, into different species, into different animals.

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT A:** Mutations, I think there's mutations and different geographical areas. The environment, obviously! Mating with different offspring, aaah...emmm... mating with different mates, which create the diversity, as well. I don't know.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT A:** Hmmm... the fittest species in my opinion is that species that is actually very, very, adaptable to that, in point, environment. As in, I don't know, if there is a... if there is a black rabbit, in the, in the ice and in Antarctica and there is a white one, obviously the white one would be much more adaptable therefore that would be the fittest one. Therefore that would be the one that's actually going to be, there for quite a long time. While the black one...

**INTERVIEWER:** Why it is going to be there for quite a long time?

**STUDENT A:** Because the black one would be affected by the environment, therefore it would die off.

**INTERVIEWER:** Okay. I chose a number of statement and research... and I'm going to read them for you and you explain them using... biological evolution. *Mela*, number 1. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT A:** Ma f'hintx.

**INTERVIEWER:** Jiena ghandi dawn l- istatements... u inti kemm... tispjega, tipo billi tuża’... evolutionary terms jw x' tahseb li ġara, anke jekk ma tużax evolutionary terms.

**STUDENT A:** Ara, I think maybe the prey got faster so they had to get faster.

**INTERVIEWER:** Okay.

**STUDENT A:** Maybe they had to run away from... from their predators.

**INTERVIEWER:** And how this like, how do you say, they become faster?

**STUDENT A:** I have no idea.

**INTERVIEWER:** Okay.

**STUDENT A:** Ma nafx. Ma nafx.

**INTERVIEWER:** Question 2: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.
STUDENT A: Aha, this is because... they got resistant to it. 'Emm'... there’s, for example out of 1... out of 10, what did you say, mosquitoes, for example, there is one that is, that’s resistant to the insecticides. All the others die but... that only one doesn’t die and then they become to, they start to....

INTERVIEWER: To reproduce?

STUDENT A: Ehe reproduce... and the resistant gene, would be passed on to more more mosquitoes and these, these mosquitoes then become, the number of mosquitoes which are resistant become much higher, than those which are not resistant, which makes insecticides be, basically...

INTERVIEWER: Less efficient?

STUDENT A: Yeah... not being used

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT A: Found to have evolved from ancestors that had little hair resembling modern elephants.*Reading from the question*.

STUDENT A: Ehe Yes but because they... elephants do not live in... the cold regions, but because these live in the cold regions, they had to have much more hair. Le? So they had to... if they wanted to survive they had to get, more hair so that they can keep warm. Le?

INTERVIEWER: Yes. And how did they get more hair?

STUDENT A: I have no idea! I don’t know

INTERVIEWER: You have no idea?

STUDENT A: I have no idea! Tieghi differenti, tieghi differenti, jien ma nidholx fdawn.

INTERVIEWER: You don’t know?

STUDENT A: No

INTERVIEWER: Okay.

INTERVIEWER: The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation. Can you please, explain what happened?

STUDENT A: Ehe... because of, in the 18th century that was the revolution, like the industrialisation... era. So... that would be, because there would have been more pollution, no? So the tree barks starts to get more black just because with the soot and
stuff. And then when these peppered moths, used to stand by, by the trees, the, their predator would have seen them, le? And then they catch them, therefore decreasing them. But when these, the black, the black ones, they were not noticeable and therefore the number of them would have been much higher than the ones, than the dotted, the whites ones. And obviously they reproduce, and therefore they get much more.

**INTERVIEWER:** When in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

**STUDENT A:** Eżatt, ghax imbaghad… the opposite happened, ‘hux’? They started to… the melanic ones started to get eaten, while the other ones did get eaten as much. Ghax imbaghad, it got, it got whiter no? Ehe.

**INTERVIEWER:** What got whiter?

**STUDENT A:** It cleaned the air, therefore the tree barks would have got white.

**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT A:** Mela hi… taqbad, ma xie? Man- nucleotide cytosine ehe [yes]… however the presence of the … binds to 3TC and not cytosine. [Reading from the question]

**STUDENT A:** Ehe ghax the thing is 3TC ma thallix lil, mhux hekk? Ma thallix lil DNA, lil RNA ssir DNA biex tidhol ġol… dak. Pero’… I think then it gets broken down, apparently, jekk, jekk il-… jiżdied xorta.

**INTERVIEWER:** Ehe imbaghad jiżdied. What gets broken down?

**STUDENT A:** The 3TC… maybe!

**INTERVIEWER:** What do you think happens?

**STUDENT A:** It gets… eqqq… population of HIV decreases exponentially, but then after a few days. This happened once, imma?

**INTERVIEWER:** Le it happens every time, it was a research. It happened every time.

**STUDENT A:** Maybe it got used to it? And it didn't work anymore?

**INTERVIEWER:** What got used to it?

**STUDENT A:** The, the HIV, the HIV virus.

**INTERVIEWER:** And why did it get used to it?

**STUDENT A:** Maybe because it encountered it all the time… and then it changes. Ghax viruses they don’t change, I mean they change, they can change quite easily, no? So, if

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you keep giving something... to a virus then they, then they'll get. It’s like, it becomes a part of them and it doesn’t work anymore. *Jew qed nghid xi ereżija?*

**INTERVIEWER:** What becomes part of it?

**STUDENT A:** The 3TC *ma tibqax tahdem imbaghad*, if you give it to them very frequent, *ma nafx kemm tghodd kemm- il darba tawha l- HIV, ghall- HIV.*

**INTERVIEWER:** Igifieri qed tgħidli it doesn't remain that efficient. Why but? It doesn’t remain that efficient?

**STUDENT A:** Ghax hi, they get used to it, *tiġi, tiġi parti minnhom imbaghad.*

**INTERVIEWER:** It gets part of their part DNA?

**STUDENT A:** Eh!

**INTERVIEWER:** Okay! Okay!

**STUDENT A:** *Din xi haġa li qed inġibhom minn ġo moħhi, igifieri.*

**INTERVIEWER:** Le don’t worry *ghax dawn misconceptions.*

**STUDENT A:** The only thing that...the only thing that... I can’t, I.... *qatt ma smajt biha din, so... that’s the only thing I can explain, I don’t know.*

**INTERVIEWER:** It's okay. U need to add further comments?

**STUDENT A:** I don't think I can add, I don't know.
**Student B**

**INTERVIEWER:** Did you participate in credits involving either genetics or evolution?

**STUDENT B:** Yes I was involved in a study unit concerning genetics and developmental biology, and I also studied a study unit which concerned evolution, phylogeny and also adaptation.

**INTERVIEWER:** How much do you accept the theory of biological evolution... and why?

**STUDENT B:** I accept the theory of biological evolution. Since, I believe that different species arise when you have...the initial species get... emm... get adapted to the various changes in the environment either by morphologically or anc.. even. Emmm... in physiologically, physiologically and behaviour as well. And, by having such changes these species get more adapted to the environment and therefore, they survive more... and will be. It is practically the survival of the fittest, is also placed a very important role because if you have a... an individual in a population which is emm... or adapted to the environment maybe by a mutation, because it has a mutation and makes it different form the other individuals this individual will, will survive more if this mutation makes it more adapted to the different changes in the environment.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT B:** Emm... Four to five.

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT B:** Emm... the theory of biological evolution is practically the survival of the fittest, of the fittest organisms. Emm... it involves the, an individual which is more adapted and hence it will survive more, and it will emmmm... it will reproduce and have an effect, have a contribution in the next generations. And this can be, this can, this is driven by natural selection as well... the process of natural selection.

**INTERVIEWER:** Hemm ghalfejn insaqsihilek, which mechanisms drive biological evolution?

**STUDENT B:** Natural selection.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT B:** The species that is emm... capable of reproducing and producing offspring which are able to reproduce which are, which can, which the offspring is, is emm... can reproduce not for example the mule which is sterile that is not a fit organism.

**INTERVIEWER:** Now, explain the following statements. Okay, number 1... Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.
**STUDENT B:** So, I believe that in the ancestral population there were individuals which had emm... which were more capable at, at running and these survived more than the, than the other emm.. individuals, therefore the, the strong genes that made them to run more, faster were inherited and passed on to the next generations and this continued emm... to have modern, the modern cheetah which run faster than 60 miles per hour. This is also, like the, the, the story of the giraffe where with time the giraffes became with longer necks.

**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT B:** So, I believe that the... the species that the mosquitoes and flies became resistant to these insecticides. Emm... From the initial populations there might have been mosquitoes which had mutations and made them emm... made them resistant to these insecticides and therefore they survived, and these genes which make them emm... which make them resistant to these insecticides were passed on to the future generations and nowadays we have emm... these, these insects which are, which are emm... resistant to these chemicals.

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

**STUDENT B:** So, emm... in the north America and northern parts of Eurasia there might be the climate is very cold and mammoths which were initially woolly emm... due to mutations emm... resisted more and survived more to the, to the cold climate and therefore they were able to, to cope with the environment better. And these contributed, these might have survived and others not and therefore, such genes were then passed on to the next generations.

**INTERVIEWER:** The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation. Emm... can you explain this.

**STUDENT B:** Emm... this is because... these, since these peppered moths are predated by birds, the emm... they have to be seen by the birds so if the tree is dark due to the pollution the dark coloured moth will not be, will not be seen it will, it's like camouflage, it will be camouflaged on the bark, therefore the bird will not pinpoint it and predate it. Whereas the light coloured peppered moth will be more seen, will stick out on the darker barks and therefore, it will, the bird will pinpoint it more and therefore eat it. And this arises in the, in the differences in the populations with time.

**INTERVIEWER:** Emm... so... emm... With time, what emm... what caused these changes?
**STUDENT B:** The population in the industrial revolution that was present... the large amount of pollution which... Which caused the lichens to die on the barks of the tree and therefore, the, the, the barks became darker in colours since the lichens will make the colour of the barks more pale more yellowish and therefore the, the, the light coloured peppered moths would become camouflaged on such barks.

**INTERVIEWER:** Now, when in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

**STUDENT B:** This is because... when measures and regulations were introduced, lichens... could grow, could proliferate since the air was not that polluted anymore. And therefore the, the melanic which are the, the dark coloured peppered moths would now... would stick out on the barks since the barks would be with lichens and therefore the colour, would be paler and these dark coloured peppered moths will, will... will be pinpointed more by the birds and therefore their population decreased.

**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT B:** Ma nafx ta.

**INTERVIEWER:** Ma tafx?

**STUDENT B:** Le

**INTERVIEWER:** Ma jimpurtax.

**STUDENT B:** All right, mela.

**INTERVIEWER:** Emm... trid forsi iżżid xi kumenti ohra jew...

**STUDENT B:** Interestanti... Daqsekk
INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT C: Yes.

INTERVIEWER: Emm... in both or in one?

STUDENT C: In both, yes. Both in genetics and evolution.

INTERVIEWER: Both in genetics and evolution?

STUDENT C: Yes.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT C: Emm... I, I accept it but ehh... basically because most of the time you accept things that are taught to you and because you don’t have time to actually look into the, these things yourself. However, this theory makes sense based on the science that has been provided, so basically I accept it. So that, ma nafx jekk hux ninstema.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT C: 3

INTERVIEWER: 3?

INTERVIEWER: Describe the theory of biological evolution.

STUDENT C: Okay. Emm... (laughs)... emm... basically biological evolution I think its emm... it’s the change in the characteristics of emm... a population emm... so... with time basically it may be because it is not exactly natural selection. I mean evolution because they are different as far as I know. So it’s just the change with time, let’s put it that way.

INTERVIEWER: Which mechanisms drive biological evolution?

STUDENT C: Issa sew. (Laughs). Emm... which mechanisms... Emm... What do you mean, like probably gen... emm... like... maybe changes in the environment emm... changes in mutations in genetics probably as well. Probably those two basically, the most important ones.

INTERVIEWER: What do you understand by the following statement: “the fittest species”?

STUDENT C: Emm... the species that is is adapted most to its particular environment.

INTERVIEWER: Explain the following statements.
**INTERVIEWER:** Okay number 1, cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT C:** Maybe before emm... animals used to run slower so they didn’t need (laughing) to actually run at that speed so once, then as time went by maybe some animals started to run faster and then they passed on that to their, those that run faster survived and those... each time the there's the drive for animals to run faster. I don’t know.

**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT C:** Emm Basicly, emm... probably the insecticides weren't able to eradicate the whole population, so emm... those insecticides which didn't kill some species then those species passed on their characteristics to their offspring and then the offspring were able to continue aw... regenerating aw... increasing population and then the insecticides wouldn't affect them as well. So they would be a greater proportion of the population that would, that would not be affected by the insecticides.

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

**STUDENT C:** Aah... I have to explain why these happened, hux?

**INTERVIEWER:** Yes.

**STUDENT C:** Okay, okay! Emm... maybe they had migrated from another part of the world and when they found themselves in this region, they found that it was colder and so those that had more fur were able to survive and basically, it would have developed that way. Like... Those that survive have more hair and eventually, the more hair you have the more you survive and pass their characteristics to the offspring.

**INTERVIEWER:** The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

**INTERVIEWER:** I’m asking tipo, those changes filli kien hemm light coloured imbaghad gie d dark coloured peppered moth.

**STUDENT C:** So during that time there was the industrial revolution so emm... so insomma you have the graph over there. There was a lot of insomma pollution which aw releases aw the soot or whatever it is and it would cover the trees amongst other things. And so the trees get darker. So then the, the light coloured moths, once they set on these trees or buildings they would appear more and then the birds would be able tosspot them. So the darker their colour the more, the less they would be spotter. So
then these dark coloured peppered moths would survive more and basically they would increase in number.

**INTERVIEWER:** It is by any chance related to evolution or to genetics? Ghax filli kien il light filli dahal d dark?

**STUDENT C:** Well it could be that before maybe, it could have been a mutation however, probably it would already existed a recessive characteristic I’m not sure. I never really read about really into this one and maybe they were only few individuals but the once this happened, this industrial these individuals actually were the ones to survive and so their frequency increase in number and then they start people started noticing in them.

**INTERVIEWER:** So it was either a mutation or a genetic variation.

**STUDENT C:** Emm... The mutation occur before this stage it doesn’t really mean that it occurred here, maybe the frequency increased because of probably got effect by environment condition than mutations. I’m not sure.

**INTERVIEWER:** When in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

**STUDENT C:** Okay, that an obviously the other way round cause emm..., its starts decrease and may be the trees started like the lichens started to grow once again so emm... The light coloured peppered moths would appear camouflaged on the tress once again so emm... whereas the dark ones would be more visible and subset to predation so basically I think they started to decrease because then birds started to see these black moths once again.

**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT C:** So, emm... what it is, what is 3TC exactly?

**INTERVIEWER:** 3TC is like emm... it’s not, it’s not cytosine because when, when the virus enters our cells it... it, it replicates its RNA, its RNA by using cytosine.

**STUDENT C:** Okay.

**INTERVIEWER:** Now emm... it was emm... observed that when the drug 3TC is, is first given to the patients, the population of the virus of the HIV virus decreases because the
virus it stops, is inhibit. But then after some time the population of the viruses start to increase again. How can you explain this?

**STUDENT C:** So... emm... do the patients take the drug like continuously or just... like they have to keep on taking it continuously.

**INTERVIEWER:** Ehe... after sometime of taking the...

**STUDENT C:** So they keep on... Okay. Eeehee... so it inhibits.... This was, this is actually something we didn't cover during evolution, like most of the time we deal with animals and we don't look at viruses so I'm not really sure. Emmm but let me try to invent something. Emm... well probably there would be some viruses that would still bind to some, some cytosine like, I don't know if this drug manages to, emmm... to remove all of them maybe there would, the population as you said decreases it does not go to zero.

**INTERVIEWER:** No it decreases.

**STUDENT C:** So some would still survive.

**INTERVIEWER:** And, why do you think that some would still kind of survive, would be able to survive?

**STUDENT C:** Probably due to some mutations, in this case. I'm not sure. Emm... Viruses emm... they replicate much faster so they are able to, they can achieve mutations much faster than animals. So if a mutation which would benefit them in this case is achieved... like they would be able, to achieve it in a shorter time period so their evolution is faster. So maybe that's why. But probably in this case it would be due to mutations. Probably, but I'm not sure.

**INTERVIEWER:** Okay emmm... do you need to need anything or comment about anything?

**STUDENT C:** No.
**Student D**

**INTERVIEWER:** Did you participate in credits involving either genetics or evolution?

**STUDENT D:** Hmm Yeah, Both.

**INTERVIEWER:** Both? Okay!

**INTERVIEWER:** How much do you accept the theory of biological evolution and why?

**STUDENT D:** Well, I accept it, at the moment so far as it’s the best theory we currently have. So you know if new evidence had to come to light against evolution then obviously it would have to be revised.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT D:** I want to say five.

**INTERVIEWER:** Okay!

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT D:** Issa sew, issa I said five hux?! All right, the theory of biological evolution is that species change as time goes by depending on emm... their environment.

**INTERVIEWER:** I can proceed?

**STUDENT D:** Yeah of course

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT D:** Natural selection, also it would be genetic drift, neutral evolution.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT D:** The species is the species that is most adapted to its environment in that it has the highest reproductive success.

**INTERVIEWER:** Okay!

**INTERVIEWER:** Explain the following statements. Number 1, Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT D:** Well obviously, the cheetahs that were able to run faster in those ancestral days, would catch more prey they lived longer have more baby cheetahs and therefore more cheetahs that were able to run faster will eventually end up in the population and as times goes by they become faster and faster and the fastest one will always reproduces more, and now they run at 60 miles per hour. That’s it.
**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT D:** Yeah, because using insecticides is not going kill off the entire population, there is always going to be one or two insects that are resistant to the insecticides. And once you kill the rest of the insects, those two insects or how many there are the only ones to reproduce and so you end with a population which is completely resistant to the insecticide.

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

**STUDENT D:** Okay, well assuming that the ancestors lived in the same regions... then I would imagine that back then it wasn’t as cold as it was in fact in the woolly mammoths. I am understanding the question, right? That first they were hairy and then they became more hairy?

**INTERVIEWER:** Yes, yes.

**STUDENT D:** Exactly as it got colder, the mammoths that were less protected by hair died and they... so only the hairy mammoths survived.

**INTERVIEWER:** Okay...

**INTERVIEWER:** The peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

**STUDENT D:** Issa, allahares I get this wrong, because this one was in the exam.

**INTERVIEWER:** Laughs

**STUDENT D:** Should I answer that or we, we continue??

**INTERVIEWER:** No, no you should, you should answer that

**STUDENT D:** All right!

**STUDENT D:** Aaah... All right! So as pollution increases as you said that trees become darker so the moths that are darker coloured are better camouflaged against the tree and the other moths the light coloured moths, emm... will be predated upon more because they show up more. So they are less light coloured moths, so the population becomes full of dark coloured moths.

**INTERVIEWER:** But if there were only light coloured moths how come dark coloured peppered moths appeared?
**STUDENT D:** Because it is a recessive mutation, I mean where even though there are only light coloured peppered moths, they can have offspring which are dark coloured so in the normal course of events these dark colour offspring will be eaten very quickly but since their not then they would reproduce and there is higher chance of having dark coloured moths.

**INTERVIEWER:** Now, when in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

**STUDENT D:** As pollution decreases so the tree, the lichens grow again, trees are not as dark and once again the dark coloured moths are vulnerable to bird predation to a greater extent than the light coloured moths.

**INTERVIEWER:** Well I can proceed?

**STUDENT D:** Yes, absolutely.

**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT D:** Okay!?

**INTERVIEWER:** What do you think is happening?

**STUDENT D:** I would think, one of two things, either the HIV virus is undergoing mutation as it is in the, the host. So, first the population decreases exponentially because its binding to 3TC instead of, eeh... to... cytosine so it can't reproduce emm... but some individuals undergo mutation which allow them to bind exclusively to cytosine, and the populations starts increasing again as these individuals live more than those left... or... there are resistant individuals in the first place, rather than being mutated.

**INTERVIEWER:** So emm...so they got genetic variation, kind of?

**STUDENT D:** Yes exactly.

**INTERVIEWER:** Okay?

**INTERVIEWER:** Basically that’s it, if you need to add any comments? Or... 

**STUDENT D:** No. No comments.
Student E

**INTERVIEWER:** Did you participate in credits involving either genetics or evolution?

**STUDENT E:** Genetics not yet however, evolution we did mention it during the credit of emm... ecology. We did mention something.

**INTERVIEWER:** So you didn’t do a particular credit on evolution you just mentioned evolution.

**STUDENT E:** No it was part of another credit but not specifically on evolution.

**INTERVIEWER:** How much do you accept the theory of biological evolution and why?

**STUDENT E:** I think it’s a very valid theory because it shows emm... how organisms change according to the environmental pressures.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT E:** 3.

**INTERVIEWER:** 3?

**STUDENT E:** Laughs

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT E:** Emm... the theory?

**INTERVIEWER:** Yes

**STUDENT E:** Emm... issa sew *laughs*. All right the theory says if I remember correctly emm.. that species different species will evolve according to their environment. It means, which means, that if their environments, the environment create a certain amount of pressure its either the species manages to evolve in order to account for those pressures made or else it will eventually die out because it did not manage to evolve.

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT E:** The pressure which I mentioned, for instance if emm... jien naf... if polarised caps are melting and the temperature is emm... rising in the polar regions the emm... animals there the species there need to adapt according to that change. Unless they do so they will eventually become extinct, because of the changes occurring. Emm... so that is an environmental pressure there may be other pressures such as how they can emm... evolve according to disease if they can withstand the disease or not, the individuals which are immunologically equipped to fight the disease. Those. Well there are others imma I mention them as well? I don’t think I there need

**INTERVIEWER:** If you want you can mention them.
STUDENT E: Le there’s no need.

INTERVIEWER: Okay

INTERVIEWER: What do you understand by the following statement: “the fittest species”?

STUDENT E: The fittest species, okay! Emm... What I understand is that the species which... can adapt itself in its particular environment but and then if placed maybe in a slightly different environment it can still adapt. How fit it is to, how widespread its individuals are, where some individuals might not be adapted and so they will die out, but it, there are, there is a variety of individuals enough that the species will not die out. There are a few individuals which can support that environment, can live in that environment and so the species continues.

INTERVIEWER: So now I’m going through a number of statements. Okay, cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT E: What I understand is that, emm...

INTERVIEWER: You need, you need to explain, actually you need to explain why it happened...

STUDENT E: Why it happened?

INTERVIEWER: Why you think it happened

STUDENT E: Yes.

INTERVIEWER: ...In terms of biological evolution.

STUDENT E: Yes, I think this is, the reason why modern cheetahs run faster, is because their prey started to run faster and... and... Sewwa.. Can I think a bit?

INTERVIEWER: Yes of course.

STUDENT E: *Reading*

STUDENT E: So, okay mela kont tajjeb. So their prey starts to run faster emm... and if the prey runs faster it will escape so the only cheetahs which survived were the cheetahs which managed to catch the prey which ran, who ran fast enough to catch that prey. And so eventually with time the faster cheetahs remained alive while the slower cheetahs died out because of starvation. Their prey emm... their prey, they preyed on faster animals and so they had to adapt to that circumstance. Only the faster cheetahs found the... food.

INTERVIEWER: I can proceed?

STUDENT E: Yes.

INTERVIEWER: Okay.
INTERVIEWER: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

STUDENT E: Emm... at first they were very effective because most of the insects were, were not adapted to live in this condition and they used to die, they were poisoned. However, even if few individuals survived were capable to withstand the insecticide used, then those individuals were able to reproduce and so the population would grow again. And this time it consists of individuals who can withstand that insecticide. And so that is why, nowadays they are not as effective because the insecticide which was used in the past, the mosquitoes have now evolved, in a way, that they are immune to that insecticide. They are no longer affected.

STUDENT E: Yes.

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT E: I think this a reason due to environmental pressures as I had emm... mentioned. Modern elephants live in hot climates and to have a layer of insulation such as hair would be ridiculous because they would overheat and die. They are mammals and so they are emm... hot, aw warm blooded. Emm... however, these elephants lived in colder regions.

INTERVIEWER: You're talking about the woolly mammoth?

STUDENT E: Yes, the woolly mammoth, now the woolly mammoth, First I was talking about the eehhh

INTERVIEWER: The modern elephant?

STUDENT E: Exactly, the African elephant, Asian aw tal- India. Emm... but now the woolly mammoth. The woolly mammoth lived in colder regions so you need a layer of insulation and that layer of insulation was the hairs. They, the hairier species always used to survive and the ones which were not equipped with a good layer of hair used to die out of cold, hypothermia.

INTERVIEWER: I can proceed?

STUDENT E: Yes

INTERVIEWER: The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT E: Exactly, so it is more advantageous to have emm... for the peppered moth to be darker and those were the individuals who survived and were able to reproduce.
The light coloured peppered moths were dying out because of predation. The background which were, they were landing on was darker due to pollution, due to soot and other polluting chemicals and they were easily visible and more vulnerable to predation, they are more easily spotted by predators. However, on the contrary the dark coloured peppered moths were not as conspicuous and the ones who actually managed to reproduce most, mostly.

**INTERVIEWER:** Emmm... now if in the 18th century, it telling us, that only light coloured peppered moth, how come that then the Melanic form, that is the dark coloured peppered moth was observed in 1848 if only the light coloured peppered moth was observed.

**STUDENT E:** It means that at the time in the 18th century the light coloured peppered moth, the phenotype was favoured there was less pollution and maybe the phenotype for, for a black coloured mammoth, emm.. peppered moth was either selected against or it evolved as a result of pollution. Maybe it was there but... no it wasn’t there. It evolved due to pollution probably. Emm... coincidental happened in genetics which ended up to favourable.

**INTERVIEWER:** Do you know what we call those incidents?

**STUDENT E:** Le, tell me.

**INTERVIEWER:** Mutations

**STUDENT E:** Sewwa sewwa ghax *mumbling* okay.

**INTERVIEWER:** When in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

**INTERVIEWER:** Btw jien ghedtlek mutations just to check if were only on the same level taf kif

**STUDENT E:** Yes yes yes

**INTERVIEWER:** Ma tmurx tkun qed tahseb fxi haga ohra

**STUDENT E:** Le, le, le, yes, yes, yes, imam i was thinking li ha taghidli xi tipo ta mechanism mhux just mutations, eeh orrajt mutations like. *Pause* Orrajt ehe. *Reading* Okay! Mela!

**STUDENT E:** With the implementation of the clean air laws emm... the amount of pollution decreased and so now... it is no longer as advantageous as it used to be. Before since, there was a lot of pollution being darker was advantageous. Now that the pollution is decreasing the darker background would, the darker background which used to exist no longer does as much. And so the lighter coloured peppered moth are become more frequent because they are able to reproduce and they are not vulnerable to predation as much as they used to be. Whilst dark colour peppers moths are becoming vulnerable to predation because their background is becoming lighter and so they are more conspicuous.

**INTERVIEWER:** I can proceed?

**STUDENT E:** Yes.
**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT E:** Emm... HIV is a virus and it's very prone to genetic mutations. Emm... so coincidentally once it is exposed to a drug emm... okay the viruses will decrease but the... and the virus, and the decrease would be in the viral particles which are not able to withstand the drug which succumb to it. However, there would be viral particles which mutate in a way, that... withstands the drug and so the only reproducing individuals of HIV which remain alive are those which are resistant to the drug, and that is why after a few days they are seem to increase again in their population number, because the HIV virus has like overcome bypassed the drug.

**INTERVIEWER:** So you're telling me that the virus develop a kind of resistance by mutating?

**STUDENT E:** Exactly, exactly because all the viral particles which were affected by the drug died however there would be a few virus particles which were not killed by the drug and it is those who replicate.
INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT F: Genetics no, and evolution not particularly evolution, ecology and evolution was mentioned, in that credit.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT F: Emm... I think it's very relevant because it supplied with evidence. Emm... for example even biological testing, DNA testing for example of organisms like for example emm... the similarity there is between us and the chimpanzees for example. There, there is a lot of evidence. That's why, I accept it a lot.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT F: 3.

INTERVIEWER: Emm... Describe the theory of biological evolution.

STUDENT F: Okay, so... emm... when you have organisms with change emm... both phenotypically and genotypically and due to different reasons. Emm... basically, the underlying cause is mutations emm... they evolve, usually they evolve emm... to be more fit in their environment so they change in order to be more fit to their environment either phenotypically well genotypically derives the phenotypic, emm... that's why. That is basically, biological evolution.

INTERVIEWER: Which mechanisms drive biological evolution?

STUDENT F: Natur... Selection pressures, either can be natural pressures, artificial selection pressures, like for example a farmer supplying fertilisers. emm... extinction, well that's become natural, a natural selection pressure, those I think.

INTERVIEWER: What do you understand by the following statement: “the fittest species”?

STUDENT F: Emm... when there is competition of species and there is a particular species which can use the resources more efficiently than the other, that is most fit to, to that particular environment and eventually it passes the genes emm... to the gene pool emm... to the rest, to the oncoming species.

INTERVIEWER: Explain the following statements. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT F: emm... obviously through time emm... the modern cheetahs which run faster it was an advantage, it was an advantage because they could get catch their prey faster and maybe even not just in the case of prey even to escape predators or danger themselves, so the faster they are it became an advantage. Emm... so the cheetahs which were faster emm... they survived at a better rate and they passed on, those genes were
passed on to the next generations, and the next generation all the time through reproduction they were resembled obviously their parents, they inherited those genes and they became faster cheetahs.

**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT F:** The first, the first flies were not immune so the first time the insecticide, they were prone to it and it killed them. However, by time even due, it can be by chance mutations occurred and certain flies had the genes which actually created resistance to these insecticides. Eventually by time these were the flies which resisted this so they were the ones which were kept alive and due reproduction they passed on these genes, with the resistance to them, to their offsprings and obviously the, the generations which followed were also resistant to that, to that insecticide.

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

**STUDENT F:** Little hair, little hair obviously was found, *stenna naqra ghax qed nitfixkel.*

**INTERVIEWER:** Iġifieri dawn l-ewwel ma kellhomx suf imbaggad ġew bis- sut.

**STUDENT F:** Okay, aha! Obviously hair, gave them an advantage. *Reading*. Hair gave them an advantage, hair gives an advantage they can be protected more thermal protection against, not protection against temperature, they helped them to keep warm, it can be a protection also in terms of the skin, it can be a protection from irritation or something like that so obviously having fur became *pause* was considered as an advantage in nature and therefore all the elephants developed more hair.

**INTERVIEWER:** I can proceed?

**STUDENT F:** Yes

**INTERVIEWER:** If you need to add any comments...

**STUDENT F:** Okay, okay.

**INTERVIEWER:** The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the Melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the Melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

**STUDENT F:** If pollution is killing lichens, and lichens are those which are making the trees appear darker, the dark moths are going to be more
camouflaged when it comes to predators so those are the ones which are going to, emm... to be less attacked. Those are the ones which are going to live and those are the ones which are going to contribute more to the gene pool, so the rest and since the dark colour is more, is dominant, most of the, the, of the offsprings will be darker and this obviously was an advantage.

INTERVIEWER: Emm... okay.

INTERVIEWER: Issa.. how come that the dark coloured peppered moths emm... came after light coloured peppered moths, like first, only light coloured peppered moths were evolved and then when pollution increased dark coloured peppered moths became in existence, it's not like they, they went into extinction. How come this happened?

STUDENT F: You're saying during pollution there were still light peppered moths.

INTERVIEWER: No, I'm telling. I'm kind of saying li filli kienu bojod sewwa and then pollution increased u f'daqqa wahda ġew suwed, ghalfejn ma ġewx, ma ġewx extinct ghalfejn imbaghad qisu kien hemm form ohra.

STUDENT F: Eh not completely extinct, so when pollution you're saying was removed again they became light coloured, they weren't extinct.

INTERVIEWER: No, no I'm just saying, I'm just asking why li tipo first there was light coloured peppered moths and then emm... a decline was observed due to pollution as you told me they were being seen more by the bird, they were vulnerable to bird predation because they were, they were, they did not camouflage with the tree barks. But how come then the dark coloured peppered moths came into existence, like how come they switched form light-coloured to dark colours.

STUDENT F: The gene still existed, it was, it was recessive maybe and it was, and it wasn't, and I don’t think that the dark coloured peppered moths, they weren't dark coloured peppered moths at all, there were dark coloured peppered moths I think.

INTERVIEWER: Okay.

INTERVIEWER: Now, when in the mid-20th century clean air laws were put forward, the frequency of Melanic peppered moths was observed to decrease.

STUDENT F: Eh obviously, because then, if the, if the pollution decreased the, the lichens started to grow again, the ,the barks weren't dark anymore and those which were, which had melanin the, the lighter shade moth, the lighter coloured moth emm... was better camouflaged then so the reverse, the reverse mechanism happened obviously.

INTERVIEWER: Okay.

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating
AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT F:** HIV is a virus and it has, and it mutates very quickly so, if the genetic, if the genetic... composition changes... it develops resistance to it and it would no longer bind to, *reading*. Obviously the enzyme, *reading*. Aha, if the DNA changes, the drug won’t work anymore because the, the... the DNA of the, of the virus would have changed.

**INTERVIEWER:** Is that it?

**STUDENT F:** Ehe

**INTERVIEWER:** Do you need to add further comments, or you need to go back or something.

**STUDENT F:** No I don’t think so.

**INTERVIEWER:** Okay.
**Student G**

**INTERVIEWER:** Did you participate in any credits involving either genetics or evolution?

**STUDENT G:** Yes, I was in a credit of genetics last year emm... evolution we haven't started the credit yet but genetics was last year.

**INTERVIEWER:** How much do you accept the theory of biological evolution and why?

**STUDENT G:** I definitely accept it the theory of biological evolution, mainly because first of all emm... as you see it from beginning to end it does make sense, simply enough it does make sense. Emm... and secondly you can see, like in fossils and whatever you can actually see the theory of biological evolution taking place and you wonder like why this changed to this and it explained, its explanatory in itself why that, that it happened.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT G:** Emm... I'd say probably 3, in the middle because I'm not very knowledgeable on it... and I don't think, you know like not knowledgeable at all so I'd say in the middle, 3.

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT G:** *Mela* biological evolution. Biological evolution is when things emm... in an organism would change to benefit emm... that organism's lifestyle and the as far as can remember and the organisms that would come after it would inherit that trait, for example the one I'm thinking of right now is giraffes they used to have much shorter necks emm... and then it started happening that they used to get higher leaves the neck would be longer, there was one which emm... evolved to that having that trait and now most giraffes have that length of neck. As far as i can remember.

**INTERVIEWER:** I can proceed?

**STUDENT G:** Yes, yes, yes.

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT G:** What do you mean by mechanisms?

**INTERVIEWER:** Emm... like processes that occur emm... that make evolution happen.

**STUDENT G:** Eh okay. Emm... well, it depends on the environment I guess, like emm... what you mean like the environmental changes or whatever? Okay there is environmental changes first of all and then that leads to for example emm... the offspring would have a different trait, it could be by accident for example, the trait could be by accident during meiosis. I don't know if that's what you want as an answer.

**INTERVIEWER:** No, no you just can, can proceed.
STUDENT G: Emm... and then...

INTERVIEWER: You're talking about mutations?

STUDENT G: Mutations!

INTERVIEWER: Okay

STUDENT G: Sorry, I couldn't remember the world. Maybe a mutation emm... and then I guess is just down to survival of the fittest mainly. That's how...

INTERVIEWER: Do you know the process emm... promoting survival of the fittest?

STUDENT G: What do you mean?

INTERVIEWER: The process, the name of the process that emm... how do you say it, emm... that emm... make emm... the organism that has a particular mutation that you were talking about to evolve, due to environmental pressures. It's okay don't worry, I just can proceed.

STUDENT G: No.

INTERVIEWER: It's okay.

INTERVIEWER: What do you understand by the following statement: “the fittest species”?

STUDENT G: The species would be the species that is most likely to survive, emm... in its environment, not fit as in like it exercises more or whatever, the fittest would be is the most to likely to survive and produce offspring.

INTERVIEWER: Explain the following statements. Mela, these are statements and you need to explain why they happened and what is happening actually. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT G: Mela, okay! So probably, as in, like you want me to explain why this happened?

INTERVIEWER: Yes

STUDENT G: Okay so. The cheetahs used to run 20 miles per hour in the past emm... now probably what happened was that emm... its prey used to run for example at 10 miles per hour and then there was one offspring that had a mutation and used to run at for example thirty miles per hour obviously this offspring was the one that survived because it could outrun the cheetah emm... so that, that mutation remained in the offspring in all offspring that came later, in the generations. Emm... therefore the cheetah emm... began to probably have more mutations and then the one that survived were the ones that could outrun that prey. And therefore that that mutation remained as well this is a clear example of survival of the fittest. The ones that could run faster most likely to survive and therefore that mutation remained in the, species.

INTERVIEWER: Okay... I can proceed?
**STUDENT G:** Ehe.

**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT G:** Okay, so... emm... what probably happened here, is that the mosquitoes emm... became resistant to the insecticide that’s why they tell don’t use too much because they can, become emm... what’s the word? emm... I can’t remember the word

**INTERVIEWER:** Resistant?

**STUDENT G:** Resistant, *ezatt*. They become resistant to the insecticide so if before emm... it would kill the mosquito then there was one mosquito who was resistant to it and therefore and the insecticide would no longer work. Because most the generations to come were probably resistant to that insecticide due to that one mosquito or fly.

**INTERVIEWER:** Why did the generations to come were, were being more resistant?

**STUDENT G:** I didn’t understand the question.

**INTERVIEWER:** *Għax*, you told me that the next generations were becoming more resistant, just from one...

**STUDENT G:** That emm... that mosquito or fly was probably more resistant due to a mutation, now if that is like a good gene, it would, obviously it would help, it’s, it’s a good mutation not a bad mutation obviously emm... so that mutation would be more selective so then emm... the generations to come would have that, obviously I’m saying from the generations to come from that one mosquito, that gene would be selected to carry on being?

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

**STUDENT G:** Let me just re-read it *ta.* *Reading*. So why... I didn’t really understand the statement *ta!* *Reading*. *Mela*, so why did they have like little hair, as in you’re after?

**INTERVIEWER:** Emm... I’m also like, the woolly mammoth it, it has lots of hair kind of it had lots of hair

**STUDENT G:** Ehe

**INTERVIEWER:** But he evolved from ancestors that had little hair

**STUDENT G:** Eee all right, all right, *fhimtek, fhimtek, okay, ghax* I’m saying the woolly mammoth actually has a lot of hair *fhimtek* all right. *Mela* the woolly mammoth as you said in the question itself comes from cold regions emm... so if... like... in a cold region obviously you’re going to need to a lot of insulation so if their ancestors had little hair it could be that during the cold winter months when it was really cold, emm... they would, it could be that they would die due to emm... the cold, now if there is one wooly, one ancestor of the woolly mammoth who had a lot of hair this, this woolly mammoth, *aw* this this ancestor would survive because it would have enough insulation to carry it
forward. Emm... again due to survival of the fittest that woolly mammoth, heq children so to speak its offspring would and then become the woolly mammoth due to in... emm... the...

INTERVIEWER: Inheritance.

STUDENT G: Excess of hair which inherits form the previous ancestor so, again this was probably due to survival of the fittest. Although the woolly mammoth itself came from that one emm... mutation gene its ancestors as a whole would still be with lack of hair however, that one mutation caused the woolly mammoth to be woolly. *laughs*.

INTERVIEWER: Okay... So, the peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT G: Mela, in emm... due to the pollution increase the, the tree bark that the, that the peppered moth, that the light coloured peppered moth used to live on, emm... they were becoming darker emm... so automatically, it’s not, they weren’t camouflaged anymore, now due again due to a mutation probably there was one moth which came out as the dark, a dark coloured peppered moth and this moth could blend in very well to the, to the tree bark and therefore, the, the predators would not see the darker coloured peppered moth, but would see the light, the light coloured peppered moth. Emm... therefore that mutation caused that peppered moth to survive emm... and therefore all the offspring came like began becoming, sorry, began becoming dark peppered moths. Emm... Because this was due to environmental change this was the best gene to come forward. Now since, emm... the dark coloured peppered moths were blending in well, hang on what’s the question. Ezatt since dark coloured were blending in well and light coloured moth were obviously the dark coloured moths were began, the, the, they began, they began emmm... becoming better prey because the birds could obviously see them because they weren’t being camouflaged well by the trees.

INTERVIEWER: When in the mid- 20th century clean air laws were put forward, the frequency of Melanic peppered moths was observed to decrease.

STUDENT G: Mela, okay! So, when the clean air laws were passed emm... obviously the frequency of the dark trees due to that became, the bark became dark due to pollution, obviously was began decreasing because more trees were being planted obviously and with air cleaner laws they weren’t becoming dark and pollu emm... due to pollution emm... so therefore the light coloured peppered moths began to survive even more. Now, emm... so the dark coloured, the dark peppered moths, the dark coloured peppered moth began being visible on the trees and therefore the prey began going after those.

INTERVIEWER: Okay. Do you need to add further comments?

STUDENT G: Emm... No.. No, I guess that's it.
**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

**STUDENT G:** Let me go through again quickly *ta.*

**INTERVIEWER:** It's okay, it's okay

**STUDENT G:** *Ghax,* it's a long one. *Mela* *Reading*. When you say the population of HIV, meaning the population the patients with HIV right?

**INTERVIEWER:** *Ehe,* le the population of HIV viruses inside a person.

**STUDENT G:** Eh, as in one person *igifieri?*

**INTERVIEWER:** *Ehe, ehe*

**STUDENT G:** Okay, Okay. *Thinking* Okay, *mela* emm... to be honest on this one I’m not entirely sure emm... however, what I could guess is that emm... the just it I’m thinking it’s probably just like the flu virus, that the emm... all right it doesn't make sense hang on. *Reading* eh, what I was going to say, that emm... probably its, it changes its structure so that it could continue reproducing however, in this case the structure really necessarily help it to, to reproduce again so... Okay, probably, I’m guessing, this one I can’t answer. I can’t answer this one.

**INTERVIEWER:** Okay.

**STUDENT G:** I don’t know the answer to this. I’m guessing it has something to do, that probably the, the structure that binds to the cytosine emm... would change slightly so that it can’t bind to 3TC anymore and it has to bind to, to either something else or cytosine again. But I can’t answer because I’m not sure, but I’m guessing it has something to do with like similarities to flu virus how the flu virus keeps changing so that the drugs that you take would not affect it anymore. But to be honest I am not entirely sure so I’d rather not answer because I’m not entirely sure.

**INTERVIEWER:** That’s it. I mean do you need to add further comments about anything.

**STUDENT G:** Emm... Ah also the thing you had like the, most of the situations you gave me emm... were like clear examples of survival of the fittest. Emm... so over all that’s, like the main thing I think of biological evolution like its survival of the fittest, that you get a mutation and that mutation would survive and so that would be the likely mutation to be carried to offspring. Emm...

**INTERVIEWER:** That’s it. I mean do you need to add further comments about anything.

**STUDENT G:** Emm... Ah also the thing you had like the, most of the situations you gave me emm... were like clear examples of survival of the fittest. Emm... so over all that’s, like the main thing I think of biological evolution like its survival of the fittest, that you get a mutation and that mutation would survive and so that would be the likely mutation to be carried to offspring. Emm...

**INTERVIEWER:** So it’s like you’re telling me of all evolution is always beneficial?

**STUDENT G:** No. It’s not always beneficial it would just be that in that period of time and that gene would be the likely as to survive, now if that in that period of time, yes maybe that gene was likely to survive so it was beneficial, however, in future offspring it could be unbenefficial for example, emm... there was one with emm... rice I believe it
was emm... that there was emm... one brand of rice, one section of rice, a species of rice which was, it didn’t have, it wasn’t affected by certain virus like a certain virus or something emm... and however, and so that, that brand of rice would, it found was the best one because obviously it wasn’t affected. However, it then it found out, they found out later one that it didn’t have certain emm... other characteristics which the rice need to be beneficial in the long run, so to speak. So it can be beneficial in that period of time however, later on it can be found to not be beneficial at all. Emm... but no, evolution isn’t always beneficial it just has to happen at in that maybe in that period of time it is. But it’s not always beneficial.

INTERVIEWER: Okay, that’s it?

STUDENT G: That’s it.
Student H

**INTERVIEWER:** Did you participate in credits involving either genetics or evolution?

**STUDENT H:** Ijwa emm... kelli credit ta' genetics dis-sena u credit ta' evolution, emm... u iġifieri tara qisu l- affarijiet minn żewż apsetti. Kelli t- tnejn.

**INTERVIEWER:** How much do you accept the theory of biological evolution and why?

**STUDENT H:** Emm... it-teorija tal-evoluzzjoni naċċettaha emm... ghall- fatt li qisu l-affarijiet ma' ġewx hekk waqghu mis- sena u ġew, imma nemmen li l- bniedem, l-organiżmu ikun xi jkun irid jadatta ghall-ambjenti li qed jghix fihom u jadatta u jevolvi biex, the survival of the fittest at the end of the day iġifieri tagħmel hafna sens u jekk taraha minn, minn aspett ta' kif l-evoluzzjoni f partijiet ohra tal-biology iġifieri jien naf kif l-evolution ghenet biex tifhem l-istruttura tal-qalb, l-istruttura tal-kliewi, li strutura ta' organiżmi ohra kollox qisu jillinkja wahda m' ohra.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT H:** Ara qisu 4 ghax highly knowledgeable, 4.

**INTERVIEWER:** Okay.

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT H:** Emm... ovjament kien hemm emm... organiżmi, primitive organisms li throughout the, the centuries u years, u years u years they evolved accordingly. Emm... what drive qisu which expects drive biological evolution the most emm... the most organisms fit will be selected for ovjament l-ohrajn ha jmutu imma those selected for will reproduce and eventually l-ahjar organiżmi ha jiġu evolved.

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT H:** Qisni li kont qed nghidlek li per eżempju din wahda minnhom it selects for u iġifieri nature selects for a particular trait, per eżempju jien naf qed nahseb il- giraff ghall- argument. Emm... l-għonq t- twil jiġi selected for ghaliex iltkar, ghaliex iltkar fiċli jieklu minn siġar, per eżempju ma nařtix ta li qed jiġuni f’ rasi bhalissa, minn siġar għolja mentri ta’ ghonqhom iżghar sabuha hafna iltkar diffiċli allura they died hu.

**INTERVIEWER:** Okay emm... What do you understand by the following statement: “the fittest species”?

**STUDENT H:** Emm... the fittest species iġifieri l-iltkar li kapaċi jghix u jirriproduċi fil-verita’, ghaliex qed jirriproduċi hafna iltkar offsprings biex l- ispeċi tibqa’ fl-ambjent li qed jghix fih iġifieri per eżempju din tal- giraff li kont qed nghid emm... emm... t’ ghonqhom twil kien l-iltkar emm... l-ahjar li ghex u li jkollu iltkar, iltkar offsprings.
INTERVIEWER: Emm... Explain the following statements, *dawn huma* statements *li għibt minn xi riċerka inti kemm tispjega għalxiex hekk u, billi tuża’* biological evolution, concepts of biological evolution. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT H: Issa mhux, per eżempju jista’ jkun li ġara milli jista’ jkun li l- prey li kienu qed jieklu minnhom qabel u kienu differenti minn minn tal- lum allura per eżempju il- prey qabel kien ħafna iktar slow mentri tal- lum ikunu ħafna iktar fast pero’ biex jibqa’ emm... jibqa’ jgħix kellu ikabbar il- emm... kemm jiġri iċ- cheetah.

INTERVIEWER: Daqsekk kollox?

STUDENT H: Daqsekk.

INTERVIEWER: Emm... ha nerġa’, ha nerġa’ immur lura fiha, taf tispjegali kif ġrat emm... by evolution?

STUDENT H: Emm... *heqq* most probably *iġifieri dawk li kienu jiġru iktar mill- oħrajn emm... baqghu jghixu mentri l- oħrajn spičċaw mietu ghax ma kellhomx fuqiex jgħixu u emm... ovjament* the most fit they were selected for.

INTERVIEWER: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

STUDENT H: Per eżempju, most probably, *li seta’ ġara hija illi ċertu flies saru reżistentit, evolvew b’ ta’ li mod li saru reżistenti ghal, ghal, ghal ċertu insecticides b’ hekk ma jinqatlux iġifieri jekk kien hemm fly partikolari li kellha jien naf, genetic information partikolari li setghet emm... qisu ma, tkun reżistenti ghall- , ghall- insecticides dik probabilment, produċiet l- oħrajn ovjament l- insecti, l- insecticide qatilhom u emm... kibret il- populazzjoni ta’ dawk l- insetti li huma reżistenti ghall- insecticide.

INTERVIEWER: Nista’ kemm nistaqsik mistoqsija? L- insects evolvew r- reżistenza, jew ir- reżistenza kienet fihom diża?

STUDENT H: Jien nahseb li r- reżistenza kienet fihom diża imma kienet fin- numri iġifieri per eżempju jista’ jkun li sar mutation throughout the years *fuq ammont vera żghir ta’ insetti imma dawk l- insetti li ġew, il- mutations saru fihom u ġew reżistenti permezz ta’ din il-mutation kibru fl- għadd għaliex ma kienux qed jiġu afettwati mill- insecticide.

INTERVIEWER: Okay.

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT H: Ara, North America *jghidlek huwa cold region, iġifieri dik żgur għandha x’ taqsam ma, ma temperatura while Northern parts of Eurasia m’ humiex daqsek cold. Emm...*

INTERVIEWER: *Lt- tnejn huma* cold. Both parts are cold.

STUDENT H: *Emm... vera mela dil- biċċa aqtagħha ta’ Sher. Aqtagħha minn hawn.*
INTERVIEWER: Eh, le, le, don’t worry, don’t worry mhux we’re discussing the question.

STUDENT H: Stenna ta.

INTERVIEWER: Qed tghidli biex naqtaghha mil-question jew?

STUDENT H: Le aqtaghha minn hemm.

INTERVIEWER: Eh mir-recording. U le don’t worry, we’re discussing the questions. Li qed nistaqsik huwa li the woolly mammoth gie evolved minn, minn elephants li kellhom inqas xagħar bhal dawk li nsibu l-elephants, L-African elephants u l-Asian elephants li nsibu illum il-ġurnata, minn ftit xagħar ghal hafna xagħar.

STUDENT H: Eżatt. Emm... ħeqq mela most probably dawn ġew. Imma l-ancestors tagħhom kienu jgħixu f' postijiet, fl-istess postijiet?

INTERVIEWER: Ehe, jew jista’ jkun li eżempju imbagħad marru emigraw, they migrated to colder parts jew inkella eżempju l-climate ġiet iktar cold.

STUDENT H: Ghaliex jekk l-ancestor ewwel kienu jgħix f' region mhux daqsekk cold imbagħad emigra qisu kien hemm speciation post.

INTERVIEWER: Dik ma nafhiex imma jista’ jkun li nbiddlet il-klima tal-post, ġew iktar colder.


INTERVIEWER: Okay. I can proceed?

STUDENT H: Yes.

INTERVIEWER: The peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. Now, as pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT H: Din ġara, emm... din studjajtha ta, emm... din ġara emm... biex hi tohloq ċertu emm... ha nghidlek x’ inhi l- kelma. Emm... *thinking* Biex huma ma jiġux attakkati imma stenna hemm kelma.

INTERVIEWER: Camouflage?

STUDENT H: Ehe, camouflage, sorry wehlet.
INTERVIEWER: Ma jimpurtax.

STUDENT H: Erġa’ ibdiha naqra mil- bidu din ta. Mela minnhabba li kien hemm, il, huma riedu jkunu camouflaged biex jiġu ma jidhrux fuq il- branches tas- sijar allura kif, as the pollution increased u l-lichens gew destroyed emm... hux qed nifhem sew, li u imbagħad d- dark coloured sewwa qed nghid emm.... gholew fil- population sabiex emm... iktar birds ma, ma jarawhx u jiġba’ jghix. Ovjament dawk li kienu, matul iż- żmien dak li gara, dawk li kienu light coloured kienu qed jiġu jidhrux u l- birds kienu jattakawhom ovjament il- population tal-light coloured b’ hekk tonqos mentri tad- dark coloured tiżdied according to the population allura qisu meta imbagħad qisu jonqos il- population tonqos il- pollution, tonqos il- pollution cioe jiġri.

INTERVIEWER: Okay. Now when in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths iġifieri the dark coloured ones was observed to decrease.

STUDENT H: Eżatt ghaliex meta imbagħad emm...naqset il- pollution l- lichens ovjament ma, ma kienux qed jiġu destroyed bl- istess mod ta’ meta kien hemm pollution gholja emm... u li ġara li l- light coloured peppered moth kienu, setghu jghixu f’ambjent li ma, li ghaliex l- birds xorta ma kienux jaffettwahom, xorta kienu jkunu camouflaged according to their environment they’ re living in, imma l- light, d- dark coloured moth kienu qishom conspicuous iktar u ġew detected by the birds.

INTERVIEWER: Okay. Trid iżżid xi haġa?

STUDENT H: Le

INTERVIEWER: All right mela, nista’ mmur għan- number 5.

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesise DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT H: Ara bhala virus, jekk niefqu fuq il- virus, bhala virus hu jiġi mutated very easily allura hekk few mutations jistghu jwasslu ghall- various complications. Issa emm.... u f’ dal- każ emm.... f’ dal- każ hu jghidiek il- fatt li l- ewwel ġew treated by drug 3TC ma kienx qed jaffettwaha d- DNA, l- virus cioe.

INTERVIEWER: Sewwa ghall- bidu meta bdew ituhom, beda jaffettwah hafna ghax kien hemm an exponential decrese.

STUDENT H: Eżatt beda jonqos imma imbagħad as you go a long, hu ġie resistant.

INTERVIEWER: Okay.

STUDENT H: Sewwa qed nghid?

INTERVIEWER: All right.
**STUDENT H:** Allura most probably li jkun ġara li jew il- virsu ġie mutated, ġifieri d-DNA while reproducing copies ma nafx ta’ ġifieri jista’ jkun li ġie mutated u b’dal mod kien qed, qed qisu kien reżistenti iktar ghal, ghal did- drug allura il- population imbaghad regġhet, terga’ tikber ghax ma taghmilx differenza, imma ġifieri m’ ghandix ideat oħra, qed jghid hekk, ghax hu jghidlek stenna naqra ta "reading". Eh ghax hu l- enzyme, l-enzymes ma nafx xi haġa bl- enzyme. Le le jiena nahseb li bl- enzyme stenna naqra dan kollha trid taqtagħhom Sheryl ta biex tkun ta. Ara ma nkunx naf li għamilthom hemm *laughing* emm...

**INTERVIEWER:** Trid iżżid xi haġa oħra?

**STUDENT H:** Le

**INTERVIEWER:** Forsi mill- interview kollha trid żżid xi haġa?

**STUDENT H:** Le

**INTERVIEWER:** All right.
Student I

INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT I: Yes, genetics.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT I: I accept the, the theory because I think it’s very credible and, and there are emm.. there is evidence that the theory is right.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT I: I would go for 3.

INTERVIEWER: Describe the theory of biological evolution.

STUDENT I: Emm... that there, there’s a common ancestor and all of the other, all of the other organisms have arisen from this common ancestor.

INTERVIEWER: Which mechanisms drive biological evolution?

STUDENT I: Emm... speciation, genetic drift... *Pause*

INTERVIEWER: Anymore?

STUDENT I: No.

INTERVIEWER: What do you understand by the following statement: “the fittest species”?

STUDENT I: It is the species, that, that is capable the most of reproducing, reproducing species.

INTERVIEWER: Explain the following the statements. Emm... Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT I: Through evolution the cheetahs got adapted to their prey, since their prey have... I mean... through evolution the, the, the cheetahs got adapted to catch their prey at a more efficient way. Emm... so, so they would ensure that their survival is... so that their survival is more

INTERVIEWER: if you want to speak in Maltese, you can speak in Maltese.

STUDENT I: All right, mela matul iż- żmien, iċ- cheetahs ġew developed b’mod li peress illi il- preys taghhom kien jiġu jiġru hafna emm... biex iku, mod li biex is- survival taghhom ikun jista’ jkun u jiġu jkunu more adapted ghall- environment, bdew ġrew, jiġru aktar biex, biex ikollhom l- ikel.
Student I: Ovjament, mhux minn slow għall-fast mil-ewwel, gradually il-ħaġa, iġifieri emm... jien naf, filli kienu jiġru at 20 miles per hour u imbagħad ghadda ċertu ammont ta’ żmien u ġew 40, ovjament dawk li kienu l-aktar fittest dejjem kienu jiġu selected for, u...

Interviewer: X’ jiġifieri dawk li kienu l-iktar fittest, f’dan il-każ?

Student I: Emm... jien naf iġifieri min ma kienx kapaċi li jkun, jirroproduċi speċi kien jinqered as in dawk li kienu jiġru at 20 miles per hour, imbagħad il- biċċiet li kienu kapaċi jirriproduċu baqgħu jirriproduċu u through ż-żmien, emm... bdew jiġu 40, 60 għax il-genes dejjem kienu qed jiġu selected for.

Interviewer: Imma, Kif kienu differenti dawn li bdew, kif kienu differenti dawn li they were passing on their genes, u the others that were not passing on hier genes?

Student I: Jista’ jkun illi l-ohrajn... min kien kapaċi jiġri l-iktar kien jsib il-prey, min ma kienx jiġri daqsek, ma kienx isib allura jmut.

Interviewer: All right. U dawk li imbagħad kienu jiġru iktar x’beda jiġrilhom?

Student I: Imbagħad dawk li bdew jiġru iktar ovjament peress li kienu qed isibu prey, iktar bdew isibu ikel kienu qed jghixu allura l- genes setghu jghadduhom to future generations.

Interviewer: Okay, Mela I can proceed?

Student I: Yes.

Interviewer: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

Student I: "Reading".

Student I: Emm... it could be that, that the, the system of the mosquitoes, the defence system got adapted to the pesticide and through evolution the new offspring were becoming more resistant to, to the, to the pesticide.

Interviewer: Okay... Okay.

Interviewer: Emm... The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

Student I: "Reading* Because the weather was very cold, emm... because the weather was very cold, the, the mammoth was becoming adapted to the weather in a way, that, that who had an increase in number of hair was surviving and those who did not were not surviving so who managed to have the increase number of hair was, was passing on fut, their genes to future generations and in turn they continued to increase their number of hair.

Interviewer: Okay. Number 4. The peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and
the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. Issa, as pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

**STUDENT I:** Emm... as the number of lichens on the tree was, was emm... decreasing and the trees were becoming more dark the peppered moth was becoming more emm... camouflaged to the tree and, and, and the... of course pollution helped, helped and pollution helped this fact because soot or whatever was, was emm... was covering the trees thus making them darker, the peppered moths was camouflaged, it had, it had less chance sort of, for the predators to spot it. And, it falling a prey to their, their predator.

**INTERVIEWER:** Now, when in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

**STUDENT I:** Emm... of course the, the lichen, the lichens were increasing again on the tree and... the lichens were increasing and thus contributed for *reading* .

**INTERVIEWER:** If you don’t know it just leave it.

**STUDENT I:** Ha nerja’ naqraha ta. *Reading* Dawn inti ghalik hux?

**INTERVIEWER:** Ijwa, Ijwa

**STUDENT I:** Ahjar nersqu, ma nafx.

**INTERVIEWER:** Okay, kemm forsi just kemm intik clue, clean air laws, igifieri emm... qabad ezempju bdew jadattaw biex ma jkunx hemm daqshekk pollution.

**STUDENT I:** Daqshekk pollution.

**INTERVIEWER:** Ezatti.

**STUDENT I:** Emm... ghax hi il- peppered moth bdiet tonqos u meta Ḷdiedet meta kien hemm hafna pollution le? *Pause* Ghax imbaghad regghu bdew jigu dominant il- moths li ma kinux swed li kienu bojod ghax peress li, li kien hemm il- clean air laws is- sjar ma kienux qed ikunu daqshekk swed allura biex, biex il- , il- moths ikunu camouflaged mas-sjira regghu kien qed jiziedu il- bojod popolari mas- sjira.

**INTERVIEWER:** I can proceed?

**STUDENT I:** Ehe

**INTERVIEWER:** The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.
STUDENT I: isplayi pratt kidem irrid ghalien reghet bdiet tiżdied il-population. *Thinking*

INTERVIEWER: Il-population tal-viruses.

STUDENT I: Il-population tal-virus. *Thinking* Nixtieq nghiek Sheryl imma

INTERVIEWER: Jejk ma taftixi don’t worry.

STUDENT I: Vera, I mean nixtieq noqghod vera nifhimha bil-mod *Reading*... il-madoffi din irrid noqghod nifhimha bil-mod jien.

INTERVIEWER: L-ewwel ma tghidlek li inti emm... il-virus jingħaqad mal-, mal-emm... mal-DNA tal-, tal-, tal- humans, imbaghad l-enzyme reverse transcriptase sewwa biex li jaghtina il-virus sewwa biex ibiddel il-human DNA ma RNA sewwa?

STUDENT I: Sewwa...

INTERVIEWER: Zomm, ezatti biex l-RNA tiegħu jaghmel DNA sewwa, issa l-biċċa hi meta jkun hemm drug 3TC, dan l-enzyme transcriptase sewwa minn flokk jeħel mal-RNA tal-virus ser jeħel mad-drug. So it inhibiting, it is stopping reproduction. Imma kien hemm population ta’ DNA il-virus li hemm minnflokk beda, minnflokk beda jinahaqad mad-drug 3TC beda xorta jinagħqad mal-RNA dan l-enzyme sewwa?

STUDENT I: Ehe

INTERVIEWER: Issa ghalfjejn, it stopped, it stopped reproducing in certain viruses imma others xorta kienu present fil-population, it started increasing?

STUDENT I: Kellhom xi tip ta, aw x’ tghidilhom, aw x’ tghidilhom mhux antibodies emm...

INTERVIEWER: Resistance.

STUDENT I: Ezatt resistance dik hi il-kelma li ridt, mhux antibodies, resistance.

INTERVIEWER: Min kienu resistant?

STUDENT I: Dawn li il-DNA tagħhom, are jien uff... il-viruses emm... emm... dawn ghax inti pereżempju kien hemm ċertu minnhom wehlet, wehlet id-drug meta jeħel, meta teħel id-drug ma jkunx hemm, viral reproduction, hux reproduction?

INTERVIEWER: It inhibits reproduction.


INTERVIEWER: Imbaghad x’ tahseb li ġara?

STUDENT I: Emm... *Reading*

INTERVIEWER: Jejk qed titfixkel...
STUDENT I: All right all right emm... *Reading* ġifieri stenna din l- ewwel wehlet, as in dawn kellhom ir- resistance u ma kinitx qed taffetwahom id- drug, imma imbaghad din il- biċċa ma fhintx. After a few days the population of HIV...

INTERVIEWER: Emm... meta tawhom d- drug 3TC bdew jaraw li l- population tal-viruses naqset imma wara ftit żmien reġa’ bdiet tiżdied.

STUDENT I: Ħeqq inkella r- resistance,emm... ċertu mumenti, as in, kien hemm ċertu resistance għal ċertu mumenti u everything speċi kien under control imbagħad reġghet bdiet tieħu over il- haġa.

INTERVIEWER: You need to add anything more.

STUDENT I: Le thank you very much.
INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT J: Emm...

INTERVIEWER: Le tista’ tkellimni bil- malti don’t worry.

STUDENT J: Eh ċiż ta’ dis-sena genetics imma evolution credits l- universita’ għadu ma kellniex.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT J: Emm... okay, naħseb it is very relevant speċi emm... naħseb, tagħmel sense li ċertu affarrijiet maż- żmien inbiddlu, ċertu organisms inbiddlu adattaw. Pero’ xorta hemm speċi aw dubbji fuqha, speċi hemm biżżejjed evidenza li eżistiet din il- biological evolution jew forsi emm... speċi ta leaks, links mhux leaks sorry, gaps li ma nafux bihom. Ma nafx.

INTERVIEWER: Iġifieri taċċettaha jew ma taċċettah? 

STUDENT J: Emm... naħseb at this point tiği biex tifhem l-affarrijiet naħseb ċiż naċċettaha.

INTERVIEWER: Okay.

Which mechanisms drive biological evolution?


INTERVIEWER: Okay. Which mechanisms drive biological evolution?

STUDENT J: Emm... ma nafx qed nipprova niftakar *laughs*

INTERVIEWER: Calm down, don't worry.
**STUDENT J:** Nahseb competition,

**INTERVIEWER:** Competition all right.

**STUDENT J:** Environment.

**INTERVIEWER:** Environment, all right.

**STUDENT J:** Competition nahseb l-iktar.

**INTERVIEWER:** Okay.

**STUDENT J:** Emm... forsi aw xi geographical isolation.

**INTERVIEWER:** By the way ghax insejt nghidelek fejn ma tkunx taf don't worry just ghidli ma nafx.

**STUDENT J:** All right.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT J:** L-iktar illi emm... kapaci they survive in an environment.

**INTERVIEWER:** Okay. Trid izziż xi ħaġa ohra jew hekk?

**INTERVIEWER:** Issa emm... Explain the following statements. I have a number of statements which I acquired from different reserach about evolution, and evolutionary process u emm... tipo youu need to expplain the statement why it happened and how it happened, in terms of evolutionary biology. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT J:** Emm... ġifieri irrid nispejagaha

**INTERVIEWER:** Eżatti x’ ġara u x’ ma ġarax through evolution? X’ tahseb inti li ġara.

**STUDENT J:** Li forsi kellhom jiġru iktar emm... biex emm... jaqbdhu il- prey taghhom.

**INTERVIEWER:** Ehe... Okay. Tista’ tispjegaheli naqra ohra kif ġew jiġru iktar, iktar fast.

**STUDENT J:** Li forsi il-prey naqas maż- żmien allura qisu speçi jew inkella beda bdew jieklu fuq xi prey li jiġri, jiği ġallura riedu jiġru iktar biex jaqbdhu. Ma nafx. Jew inkella forsi il-, il- emm... bhala predators huma kienu qed jikbru, forsi kien hemm competition u allura riedu jiġru iktar to catch their prey iktar fast.

**INTERVIEWER:** Imbagħad emm... emm... kif bdew jghaqqlu iktar, imma imbagħad kif tahseb li ġrat din, li bdew jiġru dejjem iktar?

**STUDENT J:** Emm... baqghu jiġru iktar.
INTERVIEWER: Iġifieri eżempju bdew jiġru eżempju il- prey iktar u bdew jiġru iktar warajohom l- ancestors sewwa? U meta bdew jiġru iktar bdew jghadduha kif imbaghad ghaddewwa lill- offspring taghhom, kif ġrat illi by time...

STUDENT J: I see, Emm... skond jekk genetic, jekk forsi inbiddlet ifhem xi ħaġa bhall-movement nahseb iktar ghandu x'jaqsam mal- physical environment speċi m' ghandhiex x' taqsam eżatt mal- genes imma... forsi ma nafx bdew jirriproduċu iktar mitochondria biex jghaġġlu iktar. Pero' as such speċi bdew tawha lil offspring, m' għandix idea.

INTERVIEWER: All right. Ma jimpurtax. Ħa immorru number 2 sewwa jew trid iżżid xi ħaga?

INTERVIEWER: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

STUDENT J: Ghaliex emm... maż- żmien jibdew, jibdew ikunu resistant ghaliha jipproduċu certu emm... genes speċi jew antibodies li kapaċi jiżżistu, jiżżistu l- insecticide allura din tghaddi iġifieri through generations nahseb.

INTERVIEWER: Ehe

STUDENT J: Dak nahseb.

INTERVIEWER: U meta tghaddi through generations imbaghad, kif bhala reżultat kif ikun?

STUDENT J: Emm... li l- anc aw, il- offsprings jibdew ikollhom l- istess genes speċi allura dejjem ikollhom, dejjem, jibqgħu, jibqgħu resistant ghall- insecticide allura din tghaddi iġifieri through generations nahseb.

INTERVIEWER: Nista' immur ghan- number 3?

STUDENT J: Ijja.

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT J: Peress li cold r- region, emm... to trap more, to trap more heat kellhom, kellu jikber il- hair to survive. U nahseb l- istess speċi li baqghet, li baqghu ikollhom long hair speċi kienet xi ħaġa genetic li, li dawn l- ancestors li kellhom little hair ġxax forsi kienu kapaċi jiżżistu il- cold regions, allura kellhom bils forsi beda jinbidel biex jibqghu shan.

INTERVIEWER: Iġifieri qed tghidli li dan l- ancestor tal- elephants ma kellhomx daqshekk hair emm... ġaralhom xi ħaġa u żiedu il- hair huma stess?

STUDENT J: Le jien nahseb li maż- żmien, dawn mietu pero' l- offsprings li bdew jipproduċu emm... ma nafx eh iġifieri pero' eh jista' jkun li forsi l- offsprings li bdew jipproduċu emm... through, through breeding forsi beda jinbidel il- genetic code.

INTERVIEWER: Okay. All right. Okay.

STUDENT J: M' għandix idea.
INTERVIEWER: Okay. Don't worry.

INTERVIEWER: Now. The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT J: *Emm... filfatt qabel kien, kien hemm iktar bojod milli suwed, pero’ għaliex il-... peress li it- tree barks kienu iktar camouflaged il- bojod, allura il- predators ma kinux jarawhom. Emm... meta bdiet il- pollution beda jkun hemm it- tree barks li huma iktar dark allura il-, iktar bdew jiġu camouflaged is- suwed allura il- predators iktar sabu il-, il- white. Pero’ ma nafx irrispondejtekx kollox.*

INTERVIEWER: When in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

STUDENT J: *Emm... għaliex peress li ma baqghux, ma baqghax ikun hemm daqsekk hmieg speċi t- tree barks forsi regghu bdew... emm... speċi their natural colour, speċi iktar bdew regghu they camouflage il- bojod mis- suwed allura ovjament regghu s suwed bdew iktar ikunu prone għall- predators.*

INTERVIEWER: I can proceed jew you need to add?

STUDENT J: Yes.

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT J: *Emm... din it- 3TC jekk minix, ma nafx inix sejra żball emm... din drug mhux xi haġa genetic. Drug li trid tehodha.*


STUDENT J: I see. *Emm... iġifieri dawn l- istess patients li l- HIV, x’hin jiehdu d- drug l- HIV jonqos.*

INTERVIEWER: *Jonqos imbagħad wara ż- żmien jerġghu jibdew jarawh jiżdied t- tobb.*

STUDENT J: *U mhux, mhux neċessarjament l- istess patients.*

INTERVIEWER: Le l- istess patients.

STUDENT J: L- istess patients.
INTERVIEWER: Jekk eżempju għandna patient A u nafu li għandha l- aids, tajniha d-drug 3TC u bdew jinnuttaw li kien hemm perjodu fejn il- virus population, the number of viruses decreased exponentially, iżifieri maδajr ħafna, imma imbagħad after a few days bdew jinnuttaw li l- virus population regghet bdiet tiżdied, regghet bdiet tiżdied.

STUDENT J: I see, emm... ma nafx. Forsi il- virus emm... speċi mhux jinduna as such. Il-3TC forsi il- virus, il- viruses qed jattakkaw il- pazjent. Emm... ma, ma jkunux jaffettwahom it- 3TC speċi qishom jiġu resistant, mhux resistant imma, jsibu metodi ohra qed... uff ma nafx. Jew forsi jindunaw li hemm it- 3TC allura emm... they use other methods ta kif xorta jirreplikaw.

INTERVIEWER: Iżifieri taħseb li hemm f’ dil- population tal- viruses hemm viruses li huma forsi differenti minn viruses ohra.

STUDENT J: Ehe

INTERVIEWER: Li ma taffettwahomx d- drug 3TC? All right.

STUDENT J: Li ma taffettwahomx t- 3TC.

INTERVIEWER: Imbagħad x’ tahseb li jiġri, x’tahseb illi, x’jiġri tipo imbagħad wara?

STUDENT J: Emm... speċi imbagħad forsi il- pazjenti reġghu speċi aw il- virus dal- viruses li ma affettwahomx it- 3TC reġghu they, ikun they infect them, aw they infect the patients u jew jieħdu over tal- viruses ta qabel speċi il- viruses li jaffettwahom it- 3TC. Emm... u... jibda jidher l- HIV.

INTERVIEWER: All right. You need to add any further comments.

STUDENT J: No.

INTERVIEWER: All right.
INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT K: Yes I did, I, għamilt evolution fis- second year, second semester u genetics din is- sena third year first semester.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT K: Mela, t- theory ta’ evolution jien naċċettaha ghax speċi daż- żmien ħafna nies saru jaccettawha u hawn ħafna evidenza illi turik illi speċi li vera sehhet li huwa hekk, li evolution hija hekk, u veru hawn ħafna nies u hemm speculations fuqha imma as such anke, anke il- bħala knisja catholic, catholics sa fejn naf jiena, aċċettawha issa le? Għad hawn naqra...

INTERVIEWER: Għad hawn min hu naqra vague.

STUDENT K: Imma nahseb bhala ammont ta’ evidenza li hawn fuq hekk, aw speċi jien naċċettaha ghall- inqas.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT K: Wara l- units li għamilna speċi nahseb li ġejt bejn 3 u 4 knowledgeable fuq evolution.

INTERVIEWER: Describe the theory of biological evolution.

STUDENT K: Mela biological evolution as such huwa me ha jkollok a change in, in an organism throughout a span of time li ha jkollok a change jew in ġhandu x’jaqsam mal-phenotype u l- genotype. Illi maż- żmien ha jkollok some kind of change illi, emm... tipi differenti ta’ changes differenti illi jistghu jsriu, li ser taffettwa l- ispeċi u l- organism li throughout a span of time li normalment, huwa bil- mod ħafna li ssir l- evoluzzjoni. Li ha jkollok change li tista’ tiffforma bih another kind of species or other subspecies.

INTERVIEWER: Which mechanisms drive biological evolution?

STUDENT K: Issa, mechanisms, sa fejn naf jien għandek, għandek jew mutation, li ha jkollok a change in the DNA sequence li tista’ tkun jew favourable ġhall- organism jew not favourable jew not, ma jkollokx l- ebda effett fuqha. Hmmm... li mutations, aw mutation mhux ha, mhux bilfors ha tirriżulta fil- awn f’ positive change illi l- organism ha jiġi, ha jkun aħjar ghal dak l- ambjent li qed jgħix fih. Imbagħad għandek mela, mutations, natural selection. Illi natural selection huwa tal- organism speċi aktar kemm hu, jekk hemm organisms differenti ta’ l- istess speċi li ġhandhom, il- genes ivarjaw naqra dak li ġhandu genes illi huma aktar adaptive ġhall- environment li jgħix fih ha jiġu favoured agianst l- oħrajn għax... issa meta tghid genes li huma aktar addattati ġhall- ambjent normalment jidhol illi genes illi jgħinu lill- organism to reproduce more. Allura, if the organisms even to reproduce more to pass on its genes to the next generation more than the otehr organism allura ha jiġu represented in the population
allura dejjem ha jibda jkollok selection against dawk li huma iktar addattati fil-popualtion, iktar adattati ghal dak l-ambjent. Emm... mechanisms ghandek mutations, natural selection, hmm... imbaghad kien hemm xi hağa... uff ma nafx.

**INTERVIEWER:** Jekk dan.

**STUDENT K:** Li meta jkollok eżempju a population u ftit numbers minn population ta’ species u ftit numbers minn dik il-, minn dawk l- ispecies jispiċċaw post iehor u aw, ikollok isolation ta’ ftit membr ta’ dawk l- ispecies u speċi allura ha jispiċċaw il- genes tagħhom, ha jkunu hafna iktar similar mit- true population allura ha jkollok evolution speċi ta’, ta’ dawk li jispiċċaw eżempju ikollok island u dil- biċċa mill- island ha tinqasam biċċa minnha, taf kif inhi, ommi ma, ma nafx kif ser naqbad nispjegaha. Insejt, insejt, imma insejt x’jghidulha eżatt.

**INTERVIEWER:** Genetic drift?

**STUDENT K:** Eħe, eħe, eżatt, eżatt. Illi aw genetic drift, ehe, eżatt genetic drift, tkun random u just ikollok, genetic drift hemm hafna tipi different jidhirli, ma nafx. Tip ta’ effett minn genetic drift hekk hu illi, meta eżempju jien ġo din l- islan jien naf biċċa minnha tinqasam u jkun hemm ftit species milli kien hemm jghixu fuqhom ġew ghalihom allura l- genes tagħhom huma ha jibdew jirripproduċu bejniethom allura mhux ha jkollhom daqsqekk variation fil- genes allura tibida tiforma qisu population ġdida, b’ genes differenti li ha jiġu differenti hafna mit- true population kif kienu qabel. Xi hağa hekk. *Laughs*.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT K:** Issa meta nghidu fittest normalment l- aktar li huwa fit-, fis- sena illi it-the more aw l- iktar li jista’ jirripproduċi. Ahna in biological terms the meaning of life tfisser illi aw kemm inti tajeb biex tirripproduċi and you pass on your genes to the next generations u, in biological terms the fittest species is, are those which are able to reproduce the more, aw l- aktar li jistghu jirripproduċu those are the most fit, aw dawk huwa biological terms x’ inhi il- meaning taghha minghalija.

**INTERVIEWER:** Trid iżżid xi hağa jew I can proceed?

**STUDENT K:** You can proceed.

**INTERVIEWER:** Okay, so now I got a number of statements which I got from different research in evolution and I’m going to tell you just a statement and you need to exlain how evolution occurred.

**STUDENT K:** Okay

**INTERVIEWER:** Okay so we’ve got Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT K:** Mela, so the ancestors ran 20 miles per hour while the modern cheetahs run at 60 miles per hour li probabl, li sehh huwa li emm... dak kien hemm iċ- cheetahs
ill kien, kellhom genes differenti u kien hemm ċertu cheetah li jistgħu jiġru naqra iktar minn oħrajn u dejjem kien qed ikkolok natural selection fuq iċ- cheetahs li jiġru iktar ghax iktar kemm kien jiġru aktar setghu jaqbdū prey allura peress li dawn jikbru u jieklu allura setghu jgħixu hafna aktar ghax setghu jgħixu hafna aktar ghax setghu jaqbdū prey allura setghu jirriproduċi iktar allura l- genes tagħhom bdew jiġu aktar transferred to the next generation allura dejjem dawk il- genes illi ġieghlu liċ- cheetahs jiġru iktar, bdew jiġru dejjem iktar, jimxu minn generation ghall- ohra spiċċajna biċ- cheetahs jiġru hafna iktar.

INTERVIEWER: I can proceed

STUDENT K: Yes you can

INTERVIEWER: Okay mela, when humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

STUDENT K: The same thing that in mosquitoes meta dejjem użaw l- insecticides forsi ma kienx hemm dak iż- zmien mosquitos illi kellhom xi genes partikolari li, illi jgħinuhom. Ehe resist.. aw genes li jgħinuhom ikunu reżistenti ghall- insecticide u imbaghad forsi kien, sehħet xi mutation f'xi mosquitos illi b’dik il- mutation kellek il- mosquitos adattati iktar resistant ghall- insecticide allura ġiet reżistenti ghall- insecticide ma mietīt sien kapaċi tirriproduċi u dik il- gene bdiet tiġi transferred minn generation ghall- ohra spiċčajna ċertu mosquitoes li they have some kind of resistance to this insecticide allura ghaddew, ma jagħmlux effett fuqhom l- insecticide.

INTERVIEWER: Okay.

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT K: *Mumbling* *Reading*

STUDENT K: Iġifieri il- woolly mammoth... that lived in the cold regions of North America, North America u Northern parts of Eurasia, was found to have evolved from ancestors that had little hair... illi ma cold regions allura no, mhux nifhimha. Il- woolly mammoth li kien jgħix fil- cold regions ta’ North America u in the Northern parts of Eurasia... imma it lives, it lived in the cold regions, allura ha jkollu aktar hair le? Le nahseb qed nimissjaha xi haża fiha din.

INTERVIEWER: L- ancestors tagħhom ma kellhomx, ma kellhomx daqsekk emm... suf bhal elephants, kienu bħall- elephants li ghandna illum ġurnata, mela you've got the woolly mammoth that lived in the colder regions, issa his ancestors resembled modern elephants because they have little hair, they had little hair.

STUDENT K: All right, minhabba a change, mela kien hemm xi change in cliamte illi l- ancestors kien jgħixu f' iktar shana probabil.

INTERVIEWER: Ehe.
STUDENT K: Nahseb hekk tiġi, u imbagħad kien hemm a change in climate illi spiċċaw aw fin-Northern, North America cold regions of North America and those of Northern Eurasia, allura l-ambjent huwa ħafna iktar hemmhekk allura spiċċcaw again, those which were, which had more hair speċi aktar setghu, they were more adapted to the cold environment allura again kellek selection against those which had more hair allura setghu izommnu lihom infushom ilktar shan u mentri l-ohraj bil-kesha probabli bdew imutu allura kellek selection against those u spiċċcaw agian they could reproduce and pass on thier genes to the next generation. *Laughs*

INTERVIEWER: You need to add further comments.

STUDENT K: No, no, no.

INTERVIEWER: The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT K: Illi, qabel mela t-trees, it-tree barks kellhom hafna lichens fuqhom li kienu jagħmluhom kulor naqra ċar allura, inti kellek two types of peppered moths li kienu... id- dark coloured u l-light coloured, allura meta kien hemm lichens fuq il-barks tat-trees il-light coloured peppered moth kien jiġi hafna iktar camouflage mid-dark coloured allura seta' jiġi inqas predate mal-, seta' jiġi inqas predate mal-, dark coloured ghax il-birds, birds, il-birds kienu jaraħom id-dark coloured kien jidher hafna iktar fuq il-bark allura il-birds kienu jaraħom iktar u jiġu iktar predate, allura hekk ha tispicča bil-light coloured, light coloured jiġi iktar, ikun hemm iktar aw... speċi il-black ha, aw d-dark coloured ha jibda jmut u ha jkun hemm hafna reproduction bejn il-light coloured allura il-light coloured ha jkun, ha jkun hemm aktar numri... eżatt more numerous. Mentri imbagħad as pollution increased kif ħawn miktabb illi pollution tends to destroy lichens that covers trees thus making the trees appear darker allura ha tiġi bil-kontra illi dawk li huma coloured li jiġu aktar camouflage dind dawk li huma coloured li jiġu aktar camouflage mimm dawk li huma light coloured allura l-birds bdew jaraż il-light coloured u bdew jieklu iktar il-light coloured milli d-dark coloured. Allura, d-dark coloured aktar bdew jiżiediu.

INTERVIEWER: Okay, mela when in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

STUDENT K: Eżatt kif spegajt illi, illi when air become more clean the lichens on the trees started to increase agian allura the bark of the trees became again light in colour therefore the light peppered moth, peppered moths were less predate then the, the darker coloured peppered moth, thereforre the birds could observe them and see more the darker colour therefore they ate more the darker coloured so the light coloured peppered moths increased in numbers again and therefore, the frequency of the melanic peppered moth was observed to decrease.

INTERVIEWER: Okay you need to add any further comments.

STUDENT K: No.
INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT K: Mela ġifieri l- HIV *reading*... Hmm... ġifieri il- population l- ewwel ha tonqos tal- HIV mentri imbajhad after a few days it seems to increase again.

INTERVIEWER: In the same person.

STUDENT K: In the same person. Maybe the HIV, aw found some sort of way to reproduce. I don't know. But the drug is given to the patient.

INTERVIEWER: Regularly

STUDENT K: Regularly xorta? So, ġifieri qatt ma waqqaf ittihielu, dejjem bqajt ittijielu regollarli u b'xi mod l- HIV sabet mod kif xorta tirriproduċi.

INTERVIEWER: Eħe hekk nassumi, ġifieri taħseb illi forsi kien hemm xi ħaga fid - drug?

STUDENT K: Jew inkella apparti mhux mid- drug illi forsi l- HIV ghax virus aw iċ- changes, it can be change slightly over time ma in a few days. Could it change that fast? Mabe the virus changed and it was in the presence of this drug, it was still able to bind to cytosine to reproduce? Or else found some way to reproduce when attached to this drug? Ma nafx ta. Hmm... The enzyme binds to the eħe, binds to the drug instead of cytosine and then the virus stops reproducing *reading*, ma nafx l- effett ta' drug mhux qed immur jekk you are giving it to the patient regularly.

INTERVIEWER: Jiena the thin g about it that I want to know is why the population of the virus increased after it decreases. ġifieri mhux ghax...

STUDENT K: Eh mhux ir- raġuni ghalfnejn.

INTERVIEWER: Ghalfnejn kif u x'fatta inbiddel, kif, kif...

STUDENT K: Illi kif l- ewwel it decreased.

INTERVIEWER: Eħe dik that's the point to explain how it first it decreased.

STUDENT K: And then it increased

INTERVIEWER: Eħe it increased.

STUDENT K: Hmm...

INTERVIEWER: Mhux ġifieri the changes that...

STUDENT K: Mhux all right, fhimt, fhimt, fhimt... Mela minuta, illi first it decreased in the presence of the drug. Imma appuntu ghax in the presence of the drug first it decreases ara sippost if you’re continuously giving the drug to the patient it will continue to decrease. Imma... le ma ġarax hekk it increased wara after a few days. That
dik illi għalfejn it increased after a few days... *Reading*. Jien naf forsi b'xi mod 1- virus sab mod kif jirriproduċi hafna iktar malajr. Ehe, hmm... ma nafx. Forsi b' xi mod fi x'hin beda jara illi qed jara, ma nafx, ma nafx. B' xi mod beda jirriproduċi hafna iktar malajr biex il- population tiegħu iktar, ma nafx, ma nafx kif naqbad nispjega. Veru ma nafx kif naqbad nispjegaha, ma nafx.

**INTERVIEWER:** Okay. You need to add any further comments about the interview.

**STUDENT K:** No, no.
Student L

INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT L: Yes the first year and the second year.

INTERVIEWER: Għamiltu evoluzione?

STUDENT L: But we didn’t go into depth in evolution only

INTERVIEWER: Ah you mentioned

STUDENT L: Just mentioned it

INTERVIEWER: Okay, just mentioned it and you had a credit about genetics?

STUDENT L: Yes, this, this year ehe.

INTERVIEWER: Just to clarify ta.

STUDENT L: All right. Okay.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT L: I highly agree with it because when I see, *whispers* nista’ nitkellem bilmalta? Meta nara eżempju l- annimali kif kienu qabel u kif inhuma issa u kif evolvew biex huma jkunu jistgħu jgħixu eżempju dik- il kwistjoni tal- ġiraff li imbagħad biż- żmien emm... l- ghonq tagħha twal biex tkun tista’ tilhaq iktar sīgar twal u tkun tista’ tiekol biex ma tmix. Emm... imbagħad għandek il-kwistjoni ukoll tal- bird’s finch ta’ Darwin, emm... biex l- ġhasfur ikun jista’ tiekol ċertu frott u ċertu seeds li jesponuh li ma jistghax tiekol u mhux huma jieklu ta’ xulxin. Jekk eżempju ma jistagħx isib frotta u jkun jista’ tiekol is- seed jista’ tiekol is- seeds biex ma jmutx.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT L: 3, nahseb.

INTERVIEWER: Describe the theory of biological evolution.

STUDENT L: Okay, emm... there are particular characteristics an organism has and if the characteristics are good enough to live comfortably in the environment, eating, surviving, reproducing, then they remain the same. But then if the environment changes the characteristics change to adapt to the new environment and be able to survive.

INTERVIEWER: Okay.

INTERVIEWER: Which mechanisms drive biological evolution?
STUDENT L: Mutations? And env, due to environmental changes?

INTERVIEWER: Mutations due to environmental changes, mhux mutations u environmental changes?

STUDENT L: Ghax mutations do not occur as frequently, as changes due to environment changes, so both but one is less frequent than the other.

INTERVIEWER: Le, ċififera irrid nghidek mhux il- mutations they are caused because of the environmental changes, qed tghidli two mechanisms.

STUDENT L: Ehe

INTERVIEWER: All right.

STUDENT L: Ehe hekk, ija

INTERVIEWER: Two mechanisms, okay.

INTERVIEWER: What do you understand by the following statement: “the fittest species’”?

STUDENT L: The fittest species are the ones which are able to survive in the environment they have due to the characteristics they have.

INTERVIEWER: Okay.

INTERVIEWER: Explain the following statements. Cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT L: Okay, so the cheetahs evolved, they, they can now run faster to catch more prey, because maybe before they could catch particular number of preys now the variety of preys they can catch is larger so they can be able to survive.

INTERVIEWER: Can you explain how it happened, tipo..

STUDENT L: The ones who could not catch prey didn’t find any food and died out maybe, so the fittest species mated and the offspring had the, the characteristics of running faster.

INTERVIEWER: Okay.

INTERVIEWER: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

STUDENT L: What happened maybe at first the mosquitoes didn’t have the necessary emm… antibodies weren’t found against this pesticide and then they got used to it, the pesticide was being used to much, the offspring they started producing had this antibody already in them and they started being generated in the new generation.
INTERVIEWER: Okay.

STUDENT L: So the pesticide didn't work.

INTERVIEWER: Okay.

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT L: Din ma fhimthiex il- question.

INTERVIEWER: Mela emm... ara hawnhekk ghandek il- woolly mammoths sewwa, issa hawnhekk ghandek modern elephants, the woolly mammoth is very woolly and it has lots of hair and the modern elephant it does not have lots of hair, the ancestor of the woolly mammoth resembled, looked like the modern elephants.

STUDENT L: Okay, so first there was the elephant with really short hair, then the woolly mammoth and then the modern elephants.

INTERVIEWER: The modern elephants. Now I’m asking how tipo the woolly mammoths that lived in the cold region show did they evolve from the, from the, from the

STUDENT L: Those with short hair

INTERVIEWER: Ehe exactly.

STUDENT L: Emm... Because of the changes in the environment, environment was colder so they wanted to protect themselves from the cold so they evolved these characteristics of having really thick and long hair.

INTERVIEWER: How do you think that it happened?

STUDENT L: Changes in the genes bilfors imma... il- mechanism eżatt ma nafx, ma nafx kif.

INTERVIEWER: Okay.

INTERVIEWER: The peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT L: Becasue since the peppered moth wasn’t camouflaged due to all the pollution, they changed their characteristics in ways to be better camouflaged themselves by, by turning into a darker colour.

INTERVIEWER: Okay.
INTERVIEWER: When in the mid-20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

STUDENT L: Now since there, there was less pollution, the peppered moths which were dark coloured weren’t camouflaged anymore, anymore, and so, anzi kienu iktar prone ghall- predators u setghu jarawhom il- predators allura ittiektlu.

INTERVIEWER: Okay. You need to add further comments, so we can proceed to number five?

STUDENT L: I think they change back to a light coloured peppered moth afterwards. That’s it.

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT L: Ha nerjaj naqraha jiena, ħu paċenzja. *Reading* Maybe there's a particular modification where it can bind to cytosine, or it cannot bind to cytosine at all costs.

INTERVIEWER: Emm... Can you please repeat it? Ara what I’m up to, emm...what I’m up to, what I need you to explain I why the population of HIV first decreased when AIDS patients were given the drug 3TC and then after a few days, why the population of viruses increased again.

STUDENT L: Okay. So first it decreases because the, the 3TC is acting as an inhibitor to the HIV virus, but then I can't understand why it increases again. *Pause* Could it be that the drug needs to be taken more frequently, it doesn’t bind to the cytosine for a long period of time?

INTERVIEWER: And what about if the drug is taken like as medicine, very frequently.

STUDENT L: Hmm... Qas idea qed nipprova nahseb. *Pause* Maybe it evolved, I don't know it’s a guess, it evolved in a way that it is able to bind to another, for example to Guanine or something else. And then it can be able to make copies of itself, it can make copies of itself without binding to cytosine maybe.

INTERVIEWER: Okay. Okay. Do you need to add further comments about this questions or any other questions in the interview.

STUDENT L: No.

INTERVIEWER: Okay.
Student M

**INTERVIEWER:** Did you participate in credits involving either genetics or evolution?

**STUDENT M:** Mela genetics kelli emm... dis- sena third year u evolution ghadna le.

**INTERVIEWER:** Okay.

**STUDENT M:** Hlief A’ level.

**INTERVIEWER:** How much do you accept the theory of biological evolution and why?

**STUDENT M:** Emm... naċċettaha ta, fis- sens ghax kieku ma ġewx emm... ma ġewx produced tipo organisms ohra differenti u ohrajn ġew extinct tipo.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT M:** Mela 3.

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT M:** Emm... mela dak naħseb ta’ Darwin, ta’ natural selection? Ta’, meta per eżempju ikollok emm... two organisms of the same species imbaghad per eżempju through mutations jew hekk ikollom different characteristics imbaghad ikun hemm per eżempju organism minnhom li jkollu, jkollu tip ta’ characteristics differnti minn ta’ l-ohrajn forsi jirenxxilu jghix ahjar fl- environment u allura jirriproduċi iktar, qisu at an advantage ghal dawk li m’ għandhomx din il- karakteristika igżifieri imbaghad ohrajn eventwallment jibdew jonasu ma jibdew jirriproduċu u jiġu extinct fl- aħħar mil- aħħar.

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT M:** Emm... mutations, boqq *Background noise* Emm... mutations, speciation jew le ma nafx, le m’ għandhiex x’ taqsam ma nafx mutations biss ghax ma nafx iktar.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT M:** Emm... dawk l- organisms li jkollhom tipo characteristics differenti minn ta’ organisms ohra tal- istess species imbaghad qishom iġieghluhom jghixu ahjar fl- environment allura jirriproduċu iktar eventwallment jikbru bla numru u hekk.

**INTERVIEWER:** Okay. Jikbru bla numru?

**STUDENT M:** Jikbru bhala numru.

**INTERVIEWER:** Jikbru bhala numru? Okay.

**STUDENT M:** Ehe.
INTERVIEWER: Issa I have a number of statements that I got from research and you need to explain what happened in evolutionary terms.

STUDENT M: All right.

INTERVIEWER: Okay. So number 1, cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

STUDENT M: Mela, emm... jien nahseb xi darba kien hemm bhal, emm... through mutations emm... kellhom ċertu karatteristiċi li tipo ġew jįgru iktar u imbagħad tipo bdew tas- 60, ġijifieri ċertu żmien kien hemm tas- 60 miles u kemm tat- 20 miles per hour, imbagħad tas- 60 miles forsi bdew jaqbdu iktar preys u bdew jirnexxilhom jghixu aktar. U eventwallment tat-20 miles forsi ma jibaghux isibu x’jieklu u hekk u bdew jonqsu bhala numbru u tas- 60 miles ovjament bdew, jirreproducing flimkien u hekk u l-mutation tipo baqghet tikber u baqghet teżisti.

INTERVIEWER: Okay. Nista’ nkompli?

STUDENT M: Ijja Ijja.

INTERVIEWER: When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

STUDENT M: Mela *pause* emm... forsi ghax imbagħad ġew adapted ghal, ghal din it-tip ta’ insecticide?

INTERVIEWER: F’ liema sens ġew adapted?

STUDENT M: Forsi kien hemm ċertu, ġisimhom forsi bdew jirriproduċu ċertu affarijiet li tipo jifqulhom lil dawn l-insecticides forsi, ma nafx. Ma nafx, m’ għandix idea.

INTERVIEWER: Okay. Nista’ inkompli?

STUDENT M: Iva, iva.

INTERVIEWER: The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.

STUDENT M: jien nahseb li din l- istess bhal taċ- cheetahs tipo dawk li kellhom... emm... ftit hair ma baqghux jghixu minnhabba il- ksieh u dawk forsi li kellhom l- aktar hair mill-ohrajn insomma rnexxihom jghixu aktar il- ksieh, dejjem l- istess teorija qed inqiblek tipo... emm... u rnexxihom jghixu iktar. Ma nafx imma ġijifieri....

INTERVIEWER: All right. U, emm... ġijifieri tista’ tispjegahieli please?

STUDENT M: Ijja mela, emm... ghax forsi dawn li kellhom ix- short hair tipo hemm little hair ma rnexxihom jghixu go dak il- ksieh u hekk imbaghad forsi bdew forsi kien imbaghad xi uhud, kien hemm xi wiehed li kellu iktar hair insomma u irnexxielu jghix iktar fil- ksieh.

INTERVIEWER: ġijifieri emm... meta ssemmi mutations...
STUDENT M: Ehe?

INTERVIEWER: Emm...x’ jiġifieri, iġifieri beda jiksaħ l- ambjent ġrat mutation?
STUDENT M: Le, mhux hekk, jien insomma mhux hekk ridt infisser per ezempju hekk bi żball just dan.

INTERVIEWER: All right, li tipo ikkawzat imbagħad variation.

STUDENT M: Eżatt forsi ehe dawk li kellhom ħafna hair insomma imbagħad irnexxielu jghix iktar jirreżisti iktar il- ksieħ.

INTERVIEWER: Iġifieri mhux għax kien hemm il- ksieħ ġrat il- mutation.

STUDENT M: Le

INTERVIEWER: Le?! All right. So nista’ nkompli?

INTERVIEWER: The peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT M: Mela ghax dak l- ewwel, mela l- ewwel kien hemm il- light coloured hux hekk?! Għax imbagħad mela light coloured sewwa imbagħad kien hemm il- xi pollution minħabba industrial, ma nafx sewwa.

INTERVIEWER: Okay.

STUDENT M: Through pollution, emm... il- light peppered moth bdew ikunu jidhru peress li huma bojod fuq it- tree barks u hekk peress li t- tree barks minnhabba pollution jiġu skuri u jew xi haga li hemm, emm.... imbagħad eventually ġew dark coloured peppered moth li ma kienux qed jiġu destroyed minnhabba li kienu jiġu camouflaged mat- tree bark. Allura imbagħad hekk naħseb kien hemm ħafna, żdiedu d- dark.

INTERVIEWER: Issa, if, sorry, light coloured peppered moths biss were observed how come illi imbagħad the dark coloured peppered moths appeared?

STUDENT M: Ghax peress li, ma nafx taqplex sens iġifieri, imma dan iġifieri qatt ma kienu jeżistu d- dark iġifieri, jew?

INTERVIEWER: Emm... ifhem hu jghidiżna li in the 18th century only the light coloured peppered moth was observed issa how come li imbagħad after some time that dark coloured was observed jekk il- light coloured peppered moth kien jidher biss?

STUDENT M: Emm... forsi xi, xi mutation forsi gie wiehed dark u imbagħad peress li kien jiġi camouflaged kien jirnexxielu jghix iktar mil- bojod imbagħad forsi naqsu.

INTERVIEWER: U l- mutation meta iġifieri meta tahseb li, li saret wara li bdiet tiżdied il- pollution jew tahseb li ġrat qabel?
STUDENT M: Emm… forsi, waqt li, waqt li kien f’dik l- era li tipo beda jiżdied il- pollution u hekk.

INTERVIEWER: Okay. All right. Emm… I can proceed to B?

STUDENT M: Ijja.

INTERVIEWER: When in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

STUDENT M: Ėżatt ghax imbaghad forsi t- tree barks u hekk fejn joqoghdhu dawn il- peppered moth emm… ma baqghetx daqṣekk tipo iswed habba l- pollutions u hekk allura dawn bdew jiġu visible il-, il- black peppered moth allura imbaghad bdew ikunu iktar prone tipo li jinqatlu mil- predators u hekk.

INTERVIEWER: Okay. Issa mmorru għan- number 6.

STUDENT M: Il- 5?

INTERVIEWER: Li jmis iġifi emm…

STUDENT M: Il- 5!

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT M: Mela, nista’ nerġa’ naqraha għax…

INTERVIEWER: Yes of course

STUDENT M: *Reading*. Emm… hmm… ma nafx ta’ mhux forsi l- enzyme tvarja fis- sens ma tkunx l- istess. Forsi form ohra ma nafx.

INTERVIEWER: Emm… jiena l- iktar li emm… l- iktar li qed nistaqsi hij ghaxliex emm… dil- population of HIV it first decreases exponentially and then after a few days the population of HIV increases again?

STUDENT M: Hmm… ma nafx ta, m’ghandix idea emm… iġifieri dan qed jghdilek ha nara fhiimtx sew, meta ghandek id- DNA meta ghandek l- HIV virus emm… it normalment tibbindja mar- reverse transcriptase.

INTERVIEWER: Mhm

STUDENT M: Imma ghandek dan t- 3TC minnflokk tibbindja mar- reverse transcriptase tibbindjaha mat- 3TC l- HIV virus.

INTERVIEWER: So it inhibits viral reproduction

STUDENT M: Mhm
INTERVIEWER: Emm... Issa I’m after li tipo why if the patients are given drug 3TC okay first the virus, the population of the viruses decreases but how come then it increases?

STUDENT M: Mhux forsi jiġi, mhux ivvintat tipo xi tip ta’ HIV virus iehor tipo kollu ikun ftit differenti allura ma jibqaghx jahdem t- 3TC.

INTERVIEWER: Eeh okay, so we tipo qed intuhom d- drug...

STUDENT M: Li tipo ma taqbilx mal- HIV virus, ma nafx.

INTERVIEWER: Ehe imma dan il- virus li ghedtli inti jiġi ivvintat, iġifieri jiġi ivvintat wara li d- drug 3TC emm... inkunu tajniha l- pazjenti taghna?

STUDENT M: Ehe.

INTERVIEWER: All right

STUDENT M: U forsi ma tipo ma jibqaghx jaqbel mat- 3TC tiġi xi haġa ohra.

INTERVIEWER: Tipo jiġi reżistenti ghaliha.

STUDENT M: Ehe reżistenti ghaliha.

INTERVIEWER: All right, all right.

STUDENT M: Imbagħad jibdew johorjū l- HIVS ohrajn.

INTERVIEWER: Okay, All right

STUDENT M: Ma nafx.

INTERVIEWER: Trid iżżid xi haġa forsi?

STUDENT M: Le

INTERVIEWER: U fuq l- interview kollha, trid forsi żżid xi haġa jew hekk.

STUDENT M: Emm... le ta’ ma nahsibx li hemm ghalfejn.

INTERVIEWER: Okay.
Student N

**INTERVIEWER:** Did you participate in credits involving either genetics or evolution?

**STUDENT N:** Emm… yes I participated in some biology credits such as evolution andemm… genetics.

**INTERVIEWER:** How much do you accept the theory of biological evolution and why?

**STUDENT N:** Emm… I, I accept the theory because emm… it's fundamentally proven with, with evidence emm… so, so I accept it fully.

**INTERVIEWER:** Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

**STUDENT N:** Emm… I think, I have a good understanding of evolution so I would say around 4.

**INTERVIEWER:** Describe the theory of biological evolution.

**STUDENT N:** Emm… so… in my view biological evolution is emm… like a consequence of how animals or, or organisms let's say organisms emm… change over time how the populations change over time to adapt to their environment and depending on the, on the limiting factors such as resources or pressures that are emm… influencing that population to adapt.

**INTERVIEWER:** Which mechanisms drive biological evolution?

**STUDENT N:** Emm… mechanisms such as natural selection emm… and mutations, genetic mutations emm… affects how, how the populations change over time so, therefore evolution.

**INTERVIEWER:** What do you understand by the following statement: “the fittest species”?

**STUDENT N:** So emm… the fittest species is emm… the species which, which can produce more offspring emm… or, or is the population which can produce more offspring over time.

**INTERVIEWER:** Okay, explain the following statement. Now I have a number of statements that I got from different research and emm you need to explain in evolutionary terms. Okay so, cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT N:** Emm… so the, the new let's say new cheetahs or modern cheetahs can run this fast because emm… over time the emm… the ancestor, ancestral cheetah had offspring with mutations that could benefit emm... faster running so the cheet, the offspring which could run faster emm... survived, survived more because they caught
more prey and therefore, therefore they got selected for and had more offspring so over time the the fastest cheetah evolved.

**INTERVIEWER:** What do you mean when you told me they had offspring which had mutations?

**STUDENT N:** Okay so, the ancestral cheetah would have offspring, offspring as any other animal would emm... but, but since emm... offspring have carry on their genes from their parents emm... there could be mutations in the genetic code emm... and these, these mutations could either be beneficial or, or, or not. Now if one of the offspring has emm... a mutation which is a random change in the genetic code which makes it faster than the cheetah would have an advantage over, over it siblings.

**INTERVIEWER:** Okay. I can proceed?

**STUDENT N:** Yes.

**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT N:** So as I see it the, the emm... in the past their ancestor were no insecticides or were not using them, at least they were natural the, there emm... there was just a normal population of flies, now over the years since you're putting insecticides and killing almost, almost all, all the flies and mosquitoes then the only, only mosquitoes and flies that emm... have a resistance u this insecticide will survive and therefore those insects will have offspring, offspring which are immune or resistant to, to these insecticides so over time the, the strong or resistant insects will, will start to dominate and the population will become resistant to, to the insecticide.

**INTERVIEWER:** Okay, emm... now you told that the insects developed resistance no to it, the flies and the mosquitoes when do you think that they will developed these resistance, when the insecticide is introduced or before the insecticide is introduced?

**STUDENT N:** Emm.. I think emm... that most insects some emm... insect populations already have like a resistance there are individuals in the population that have the resistance to the to let’s say natural insecticides certain plants, but since in, in the wild emm... they do not get exterminated completely because the insecticide is just spread around the environment emm... when humans put insecticides artificially they will emm... kill almost all the non- resistant ones and those that are already resistant will dominate the population.

**INTERVIEWER:** So there is genetic variation, if I am understating well?

**STUDENT N:** Exactly

**INTERVIEWER:** Okay, so I can proceed to the next question?

**STUDENT N:** Sure.

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.
STUDENT N: Okay emm... so since the woolly mammoth lived in cold regions emm... let’s say emm... the woolly mammoths found in cold regions had long, longer fur because if they did not have it they would not survive so evolution is like a consequence not a cause so emm... if they did not have long hair they would not found in Northern, Northern climates so the, the elephants which had emm... short hair could only live in hot regions and those that genetically evolved like they had mutations for longer hair could then move towards, towards the North.

INTERVIEWER: Okay. You need to add further comments?

STUDENT N: Emm...

INTERVIEWER: To it?

STUDENT N: No I think that’s all.

INTERVIEWER: The peppered moth *Biston betularia* lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

STUDENT N: Emm... okay. So, in this case emm... the main factor or the factor which is affecting evolution of the moth is the colouration of the wings I guess or of the animal emm... so the animal is evolving or changing the populations changing to adapt to changes in its environment.. so when the peppered moths had a light colour variation emm... and the trees were, were white emm... it could, it could not be found so it was not predated upon. However, since emm... emm... the melanic form the other one is dark and pollution darkens its environment or, or the walls on which it was found the dark one could escape from the predators and the, and the light one was visible so the light one emm...the light coloured variation got exterminated from the population and emm... 90% of the population became dark, just because they were not, they were not killed so as I see it both of them, both of the forms are, were were already present in the population and is just the change in the, in the environment which emm... affected whether one of them, one would be dominant in the, in the population, whether the population would be one form or the other.

INTERVIEWER: Okay. Now when in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

STUDENT N: Ehe so emm, since these clean air laws emm... diminished the, the effect of pollution on the environment in the, in environment emm... it does not remain black let’s say black due to, due to pollution emm... the, the dark version, the dark coloured moth was again visible on, on the walls or wherever it landed so it got removed from the population and the white coloured version emm... started to dominate again because it, it was again camouflaged, camouflaged in its environment. And there’s there’s the change in, in, in moths emm... colour version due to, to the change in the, in the environment.

INTERVIEWER: You need to add further comments.
STUDENT N: Emm... No.

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT N: Okay emm... so in this case we will, scientisits are tyring to, to control HIV by emm... by, binding the, the, the emm... binding certain molecules in, in, in the HIV however, it’s, it appaears that its the populaition is, is still growing exponentialy, and I think emm... this is happening due to, to how HIV emm... changes quickly over time emm... and since the enzyme is, is specific to binding to a certian kind of molecule and the HIV changes very rapidly emm... and it’s DNA changes very rapidly emm... which of course means that if the DNA is changing is producing different kinds of proteins so the enzyme is going to have to bind to a new specific protein or emm... molecule so if the HIV is changing rapidly these emm... drugs that we are trying to synthesise will not be effective, effective for very long. Emm... so that’s why the, the, the HIV decreases but at the start when it’s being attacked by this drug however, it will, it will quickly change and the drug will become ineffective.

INTERVIEWER: Okay, so you’re telling me that they emm... virus changes when the, because of the drug 3TC?

STUDENT N: Emm... okay, emm... no actually I think that the, the virus changes over time emm... in it’s, in it’s natural state like it changes normally over time so the drug itself emm... will induce the, the, the the drug itslef would kill all the, all the HIV which susceptible to it. However, there will be some HIV in the population which emm... change or with mutations so they become immune to the drug because they are not being affected, they are not being killed. Since these HIV are not being killed and the others are emm... the remaining survivors will reproduce they will have.

INTERVIEWER: Okay so you're telling me that there are variants strains, strains of HIV

STUDENT N: Exactly

INTERVIEWER: Okay

STUDENT N: Like in any bacteria or viruses there are, there are different variations of the same species of the same virus.

INTERVIEWER: Okay, Okay.

STUDENT N: Do you need to add further comments to this question or other questions of the interview.

INTERVIEWER: Emm... the only thing I would like to say is like, in my view evolution is, is more of a consequence then a cause so emm... what we see today in our environemts are there because emm... like if they did not have certain traits they wouldn't be there so emm... if, like for example the woolly mammoths, was found in the Northern climates
just because it had long, long, long fur or long hair if it didn’t have it wouldn’t be there so evolution is more, is more of a consequence.

**STUDENT N:** Thank you very much.
Student O

INTERVIEWER: Did you participate in credits involving either genetics or evolution?

STUDENT O: Both yes.

INTERVIEWER: How much do you accept the theory of biological evolution and why?

STUDENT O: Emm... i accept it completely emm... and why because emm.... I guess there is no other emm.. kind of explanation behind the evolution of species and the other like the only other emm.... explanations which have been proposed are related to religion and how as in minn żmien Adam it doesn't make sense. So, but obviously I’m not accepting it blindly, I accept it because I agree with the science there has been behind it.

INTERVIEWER: Rate your understanding in the theory of biological evolution; 1 being not knowledgeable and 5 being highly knowledgeable.

STUDENT O: I would say 3.

INTERVIEWER: Describe the theory of biological evolution.

STUDENT O: The process by which emm... species evolve emm... but like it is driven by how do we say in simple terms that’s what it is basically how, how species emm... evolve as in and how different species exist but emm... it isn’t like the fact that a species no longer exists is also, igifieri extinction is also evolution as in, nah qed inħawwad Emm... but like the theory of biological evolution is also related to how theories as in vanished not only how species come. Qed tifhem xi rrid nghid.

INTERVIEWER: Okay, igifieri you’re telling me emm.. that the theory of evolution also shows how species come and go extinct?

STUDENT O: Eżatt.

INTERVIEWER: Okay.

STUDENT O: Emm... And if I ask you what is evolution what would you say?

INTERVIEWER: A process of change.

STUDENT O: Okay. Okay. All right. Very good, I agree.

INTERVIEWER: Which mechanisms drive biological evolution?

STUDENT O: Which mechanisms, eh there's mutations obviously emm... we have a bottleneck for example, we have like one population you might have like an environmental disaster and then the remaining population which emm... is left emm... is forced for example, you have like one smaller population so then that drives evolution because emm... there's only a small emm... obviously a small gene pool nahseb qed inħawwad nahseb dik extinction. I need to revise to my notes before this
emmm... mutations definitely drives evolution emmm... what else emmm... bottleneck, I can't remember.

**INTERVIEWER:** Okay. It’s okay. Emm... What do you understand by the following statement: "the fittest species"?

**STUDENT O:** Emm., the species which is most adapted to that particular environment necessarily how strong it is but if for example you have an environment which is very hot and you have a specie, species which tolerates very high temperatures then that is the fittest compared to other species

**INTERVIEWER:** *Mela* explain the following statements, I’ve got a number of statements which I got from research and you need to explain them in evolutionary terms, what do you think happened emmm... to get these outcomes.

**STUDENT O:** Okay.

**INTERVIEWER:** Okay so cheetahs developed the ability to run very fast in order to catch their prey. Modern Cheetahs run faster than 60 miles per hour even though their ancestors ran at 20 miles per hour.

**STUDENT O:** So basically you’re asking how did they evolve such...

**INTERVIEWER:** Exactly, Exactly

**STUDENT O:** So probably emmm... it was favourable in the enviro, in its environment that emmm... running faster so, so running faster was adaptive in this population so emmm... every time the fastest individuals were always selected for, until eventually you get the emmm... modern one which is like the fittest and the fastest one. I assume that the modern and the ancestor are related of course...

**INTERVIEWER:** I can proceed?

**STUDENT O:** Sorry.

**INTERVIEWER:** When humans first started using insecticides to kill mosquitoes and flies, insecticides were found to be very efficient. However, it seems that after twenty years insecticides became less efficient, killing fewer mosquitoes and flies.

**STUDENT O:** *Mela*, emmm... because emmm.. this is would got to do with resistance I imagine because emmm... as, as emmm... more insecticides were being used emmm... the insecticides aw the insects were becoming more adapted to the, emmm... insecticide so the ancestors would already have like a kind of resistance inside them typo the gene to unknock it and so it was as effective because emmm... there were more insects which were adapted to, to the drug iğiği more of, less of them were emmm... killed.

**INTERVIEWER:** Okay.

**STUDENT O:** Okay.

**INTERVIEWER:** The woolly mammoth that lived in the cold regions of North America and those in the Northern parts of Eurasia, was found to have evolved from ancestors that had little hair resembling modern elephants.
STUDENT O: Hmm... *reading* Wait the question is why did it emm...

INTERVIEWER: Because the ancestors of mammoths had little hair kind of the elephants that we find today. How do you think that the ancestors of mammoths if they had little hair evolved in the mammoths as we know they have very hair, they are very hairy.

STUDENT O: Eh tipo how, how did they develop hair?

INTERVIEWER: Exactly.

STUDENT O: In Simple terms. Emm... in the cold regions. Emm... nahseb similar to the first one emm... it’s, it’s because since,emm... as in they found it more favourable eh... it was more favourable that emm... emm... since it, they are in colder regions that they develop more wool tipo emm... then emm... as in those, those individuals which had more hair were more adapted and so it was more favoured tipo, fhimt.

INTERVIEWER: The peppered moth Biston betularia lives on tree barks. There are two forms of peppered moths; the light-coloured peppered moth and the dark-coloured peppered moth. In the 18th century only the light-coloured peppered moth was observed. It was in 1848 when the melanic form that is the dark-coloured peppered moth was observed. As pollution increased, the melanic form increased in frequency such that it made up 90% of the population. Indeed, pollution tends to destroy lichens that cover trees, thus making the trees appear darker. Additionally, research held by Kettlewell in 1973 showed that peppered moths are vulnerable to bird predation.

INTERVIEWER: Now what I’m asking here is emm... how come that if only light coloured peppered moth was observed then kind of emm... melanic form, the melanic form the dark coloured peppered moth came into, came out?

STUDENT O: Stenna ħiġiferi basically, there was emm... there were two forms initially light coloured and the dark, dark coloured but then only the dark was found to be observed?

INTERVIEWER: Emm... to the contrary only the light coloured moth was observed then kind of as pollution increased the dark coloured peppered moth

STUDENT O: Ehe because it was covered more with soot probably so it wasn’t observed by and so it is less, predators, aw it can be it was less, aw sorry, emm... it’s like exposed, it exposed less for the predators to see tipo it’s kind of emm... it remained higher in abundance because it isn’t preyed upon unlike the dark one which is camouflage emm... I did not understand the question *reading*. So that’s the answer tajjeb?

INTERVIEWER: Ehe, because that's just emm... a little bit of information.

STUDENT O: Basically because you have the moth going on the trees with the soot of the industrial revolution there’s emm... it like camouflage so it is less exposed by the predator so it’s more like emm... a better prey tipo it just stays there, qed tifhem.

INTERVIEWER: And why do you think that kind of there were only the white ones and then the dark ones came tipo kif kien hemm il- bojod imbaghad wara l- bojod ġew, ġew is- suwed. Jekk kien hemm il- bojod biss qeghdin jeżistu?
STUDENT O: So initially there were only white, kif gew s-suwed ukoll?

INTERVIEWER: Yes there were only white, kif ġew is-suwed jekk kienu white biss?

STUDENT O: Hmm... stenna emm... the white ones were emm... were preyed upon more we said, right?

INTERVIEWER: Yes.

STUDENT O: Probably another form evolved which was naturally more resistant to the emm... to the aw to the other prey. Ma nafx. Iġifieri how kif why did a second moth evolved you're saying?

INTERVIEWER: Ehe kind of how come tipo għax the population only consisted of white peppered moth before pollution, increased and then as pollution started increasing, the kind of black moths came into action kind of.

STUDENT O: But maybe not because they came into action maybe emm... like it just became more abundant, forsi qabel ġa kien hemm imbagħad qisu.

INTERVIEWER: Okay.

STUDENT O: jista' jkun ma nafx.

INTERVIEWER: Okay.

INTERVIEWER: Now emm... When in the mid- 20th century clean air laws were put forward, the frequency of melanic peppered moths was observed to decrease.

STUDENT O: Peppered moth is the dark one?

INTERVIEWER: Yes exactly the melanic ehe.

STUDENT O: So when the eżatt għax imbagħad li jiġri the, the light coloured ones became again more favoured whereas the, the darker ones became more visual because imbagħad their pollution decreased again so there were no longer camouflaged.

INTERVIEWER: Okay. I can proceed jew...

STUDENT O: Yes, yes.

INTERVIEWER: Okay.

INTERVIEWER: The Human Immunodeficiency Virus (HIV) enters human cells to synthesize DNA copies of its RNA by using the enzyme reverse transcriptase. The enzyme reverse transcriptase binds to the nucleotide cytosine to transcribe the DNA copies. However, in the presence of the drug 3TC, the enzyme binds to the 3TC instead of cytosine. As a result the virus stops reproducing. It is observed that upon treating AIDS patients with drug 3TC, the population of HIV decreases exponentially. However, after few days the population of HIV seems to increase again.

STUDENT O: Mela, can I read it again becuase I mean... becasue ti was a bit fast. *Reading* So basically you're treating the patients emm... the, the, the treatment was successful but then after few days they get sick again basically.
**INTERVIEWER:** That's what I'm after not about the biochemistry of the question.

**STUDENT O:** Okay okay. Emm... this i think emm... it when you have emm... ehhe because the virus emm.. it is able to emm.. it change it’s RNA emm it has like a short, a very fast turn over so emm... if you're using an enzyme which is specific to the reverse transcripase it is specific RNA and the RNA is changing it wont be active anymore so it won't be able to emm... kill the HIV *ghalhekk ghax toqghod tinbidel kull darba.*

**INTERVIEWER:** Okay, you need to add further comments to this or other questions.

**STUDENT O:** No.