AMERICAN MUSLIM UNDERGRADUATES' VIEWS ON EVOLUTION

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Bismillah religious emblem from the Boy Scouts of America for Cub Scouts and Webelos Scouts. The Arabic text on the emblem states, “With the name of God, the Most Merciful, the Ever Merciful. All praise is due to God, the Master, Planner, Creator, Cherisher, and Sustainer of the worlds.”

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A qualitative investigation into American Muslim undergraduates' views on evolution revealed three main positions on evolution: theistic evolution, a belief in special creation of all species, and a belief in special creation of humans with evolution for all non-human species. One can conceive of the manner in which respondents chose their respective positions on evolution as a means of reconciling their religious beliefs with scientific evidence in support of current evolutionary theory.

Of 19 theistic evolutionists, 18 affirmed that revelation is a source of knowledge. 74% were convinced by the scientific evidence that evolution happens and did not see evidence in the Quran that contradicts this. 37% state that it is consistent with God's attributes that He would have created organisms to evolve. That seeking knowledge in Islam is important was mentioned by 21%.

All 19 participants with a belief in special creation of humans affirmed the idea that revelation is a source of knowledge and considered scientific evidence a source of knowledge as well. Their positions on evolution can be seen as a means of reconciling their religious beliefs with scientific evidence. They found scientific evidence convincing for all non-human species. They thought that humans could not have evolved because the creation of humans is treated with more detail in the Quran than is the creation of other species. Most accepted microevolution, but not macroevolution for humans.

Those with a belief in the special creation of all species found the evidence in the Quran and hadith more convincing than scientific evidence. They interpreted the Quran and hadith as

indicating special creation of all species. They accommodated scientific evidence by accepting microevolution for all species.

Because most respondents accepted microevolution for all species, teaching microevolution before macroevolution might be beneficial for Muslim students. Teachers helped some students navigate the relationship between science and religion to allow them to accept evolution without negating their religious beliefs. Providing role models who reconcile science and religion, Muslim evolutionary biologists, and examples of Muslim scientists from history can help accommodate acceptance of evolution by Muslims.

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Chapter 1 – Introduction

"Nothing in biology makes sense except in the light of evolution," Theodosius Dobzhansky famously titled his seminal 1973 paper. What is less well known is that he staked out his position as a theistic evolutionist in that same paper by declaring, "It is wrong to hold creation and evolution as mutually exclusive alternatives. I am a creationist *and* an evolutionist. Evolution is God's or Nature's method of creation" (Dobzhansky, 1973, p. 127). Yet, many people have difficulty accepting biological evolution because they believe that this acceptance would run counter to their religious faith. They are somehow unable to reconcile the two as Dobzhansky did.

This study explores the relationships among American Muslim college students' religious beliefs and their ideas about biological evolution. Evolution is an important part of national science standards in the United States (NGSS Lead States, 2013). Yet, unlike most other areas of the science curriculum, learning about evolution is impacted by students' personal religious beliefs and the manner in which they negotiate the relation between religion and science. In the American context, the relationships between mainstream students' religious beliefs and their acceptance of evolution have been studied and addressed in recommendations for teaching evolution. There has been no similar treatment of American Muslims' religious beliefs.

Cultural Border Crossings

Many argue that science should be for all, but the fact is that science education has not been historically available to all, nor is it equally accessible to all currently (Lee & Luykx, 2007). There are gaps between mainstream and non-mainstream students due to the opportunities available to students as well as their ability to take full advantage of them. Although these gaps are closing, this change has been slow.

Gaps exist because the educational system is structured to benefit those who are already in power (Lee & Luykx, 2007). This power structure is supported by the myth of the meritocracy, that student achievement is linked only to ability and effort. A first step towards addressing gaps is to expose this myth so that students' learning needs can be uncovered and addressed.

Teacher practices, such as dysconscious racism, where teachers ignore differences in race, class, and culture of students, rather than addressing these, helps to perpetuate gaps, rather than close them (Bryan & Atwater, 2002). Teachers who lack the skills to deal with the diverse students in their classrooms or who hold a deficit view of students also contribute to the problem.

The disconnect between students' home lives and their lives at school is another source of gaps (Lee & Luykx, 2007; McKinley, 2007). If there is no congruence between school science and students' home experiences or cultural norms, this can make it difficult for non-mainstream students from different linguistic and cultural backgrounds to learn science.

Although further research is needed, a number of methods have been proposed to close achievement gaps. A number of pedagogical strategies, such as creating constructivist classrooms and inquiry teaching, which help both mainstream and non-mainstream students achieve, have been shown effective in closing achievement gaps (Guo, 2007; Oliver, 2007). Some strategies, such as bringing an inclusive history of science which depicts non-mainstream scientists along with their mainstream counterparts, helps to counter the development of hegemonic attitudes among mainstream students while, at the same time, encouraging non-mainstream students to achieve in science (McKinley, 2007; Bianchini, Johnston, Oram, & Cavazos, 2003). For effective teaching of both mainstream and non-mainstream students,

teacher education programs and professional development must address and teach these specific pedagogies.

To address achievement gaps, the science curriculum should be amended. It can be expanded to include mention of all groups' contributions to science, rather than concentrating on mainstream scientists. Science materials can be created which include cultural and linguistic references which reflect the diversity of the students in the classroom (Lee & Luykx, 2007). To better suit the needs of indigenous students, western modern science should not be presented as the only way to understand the world. Indigenous ways of knowing should be included and valued as well (McKinley, 2007).

To address the disconnect between students' home lives and school science, the metaphor of "border crossing" has been employed to describe strategies which seek to bridge this gap. In this construct, teachers serve as "culture brokers" who help students make repeated "border crossings" between their experiences inside and outside of school by making the contrasts and crossings explicit and by creating a cross-cultural curriculum (McKinley, 2007). Making connections between school science and students' lived experiences and interests can help to facilitate border crossings (Barton, 2007; Guo, 2007; McKinley, 2007; Oliver, 2007).

There are a number of ways these issues relate to Muslim students in the United States. Muslims are members of a minority religion, and are often sidelined by mainstream practices that assume all religious people follow the Christian model. This is a form of dysconscious racism.

In her critical ethnography of Canadian Islamic schools, Jasmine Zine (2008) discusses these issues. Presumably, many of the same issues that she raises in the Canadian context would apply in the American context, as the two are neighboring countries and share many cultural

similarities. Muslim students experienced racialized encounters where their lifestyle, clothing, and food were devalued by their peers in public schools. For example, Nusaybah, a 16-year old 11th grader reported, "But in public school, if you bring a sandwich and if it's like even slightly the weirdest thing they'll be like, 'Oooh…why are you doing?! Why are you eating that?' So you pretty much have to stick to peanut butter in the public school" (Zine, 2008, p. 98). In her analysis of this quote, Zine (2008) explained, "Having to 'stick to peanut butter in public school' is a powerful metaphor for the dominance of Eurocentric practices in the culture of mainstream public schools, where any deviation from socially enforced norms results in being labelled 'weird'" (p. 98).

Students and parents in Zine's (2008) study reported that "public schools often failed to accommodate Muslim religious practices and holidays" (p. 102) Zarqa, another 16-year old 11th grade student, reported, "Like in public school, you'd be like so whitewashed! You'd be like paying attention more to other cultures, you wouldn't really care about your own religion. Like it's Ramadan, and you'd be like, 'Oh, yeah' (Zine, 2008, p. 102). These practices caused a disconnect between the students' religious identities and their public school experiences. "From a critical faith-centred perspective, the exclusion of specific faith-based knowledges and experiences from the secular Eurocentric framework of public schools delegitimates the religious identity of students from outside that framework and forces them to deny this critical aspect of their identity" (Zine, 2008, p. 105).

To remedy this situation, Zine (2008) recommends that, "More inclusive practices are required in order to create a more multicentred curriculum in public schools, one that will validate religiously and spiritually based realities" (p. 105). In the context of the science

classroom, teachers should not make the assumption that the interaction between science and Islam would be the same as the interaction between science and Christianity.

There are important differences in the ways that Muslims and Christians see the world through their respective religious lenses. For example, in his study of Sunni Muslim and Christian evangelical high schools in New York, Jeffrey Guhin (2013) found that although both Christian and Muslim respondents did not accept evolution, they approached this rejection differently. The Christians saw acceptance of evolution as a kind of dividing line between faith and unbelief, while the Muslims did not regard their rejection of evolution as having such importance. Guhin (2013) stated that the theory of evolution was dissonant to the boundaries and religious practices of the Christians, but non-resonant for the Muslims.

The current study will hopefully provide a fuller picture of the ways in which American Muslims actually view evolution, so that these actual views can be taken into account by their teachers, rather than have them rely on the mistaken belief that Muslims' beliefs are similar to those of Christians. This should help teachers of Muslims become more effective in facilitating cultural border crossings for their Muslim students.

One assumption that is often made is that Muslim majority countries are "backward" due to their religion, and that the more religious the people, the more "backward" the country. For example, Riaz Hassan (2007) mentions the "technological and economic stagnation" in Muslim majority countries that "co-exist with a high degree of religious commitment in the Muslim world" to pose the question, "Is religion a drag on the economic and technological development of the Muslim world?" (p. 472). These deficit model attitudes can be projected onto Muslim students in American classrooms where teachers may assume that they will not be good at doing science.

This prevalent attitude ignores the fact that the huge opportunity gaps present in Muslim majority countries are the legacy of colonialist practices that systematically degraded the educational institutions present in those countries to make their populations better suited to serve the colonizers (McKinley, 2007; Zine, 2008). There is every reason to believe that when these opportunity gaps are closed and Muslim students are exposed to a high quality education, they can achieve at levels similar to other students in those educational systems (Guo, 2007; Oliver, 2007).

Inclusion of contributions to science from the Muslim world would facilitate border crossings for Muslim students in those classrooms by including and valuing the historical contributions of people from their cultural traditions. This should be fairly easy to accomplish, because modern Western science is based on the legacy of science from the Muslim world that it appropriated and adapted for its own uses. It was the influx of ideas from the Muslim world that spurred Western scientific advancement in the first place. Unfortunately, this legacy is often ignored in the science classroom, even though the very science that is taught in that classroom is based on it, so this opportunity to facilitate border crossings for Muslim students is often missed.

Rationale for and Purpose of the Study

Because the relationships between mainstream students' religious beliefs and their acceptance of evolution have been studied and addressed in recommendations for teaching evolution in the American context, but these relationships have not been studied for American Muslims, this study explores the relationships among American Muslim college students' religious beliefs and their ideas about biological evolution to address this gap. This information can be used by teachers of Muslim students in lesson planning and implementation. By specifically addressing concerns Muslims have about biological evolution, teachers can avoid the

dysconscious racism caused by assuming that Muslims think like Christians. This will help them in facilitating cultural border crossings for their Muslim students in the science classroom.

Although the relationships between religious beliefs and acceptance of evolution have been explored for Muslims in other countries, there is some reason to believe that the American context might differ from that in other countries. Although Muslims worldwide have a 53% acceptance rate for biological evolution, American Muslims' 45% acceptance rate mirrors that of their compatriots rather than that of their co-religionists in other countries. Qualitative research on American Muslims is currently lacking. Filling in this gap could illuminate the reasons for this low acceptance rate among American Muslims. Additionally, it could elucidate whether and how their religious beliefs interact with their views on evolution. Quantitative research on Muslims world-wide has shown a negative correlation between religiosity and acceptance of evolution. However, those Muslims who are highly religious, but still accept evolution could hold the key to understanding how to help students integrate both their religious beliefs and acceptance of evolution into their schema. By using a quantitative methodology, this study can elucidate the traits that highly religious accepters of evolution hold with a view towards designing lessons to accommodate acceptance among highly religious Muslims. From a teaching and learning perspective, it is important to take students' conceptions into account when investigating a topic, so that they can be addressed during the lesson (Etkina *et al.*, 2005). Armed with a better understanding of factors associated with Muslim students' acceptance or rejection of evolution, teachers would be better prepared to anticipate possible alternative conceptions their students might have and address these during lesson planning. To address these concerns this study will be a qualitative investigation conducted using structured and semi-

structured interviews with American Muslim undergraduates about their views on evolution and the factors that shape these views.

To explore the relationships among American Muslim undergraduates' religious beliefs and their ideas about biological evolution, this study addresses the following specific research questions:

1. How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?
2. What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?
3. What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?

A Brief Introduction to Islam

The following discussion of Islamic religious thought is included to provide a context for readers who may not be familiar with Islam and to situate Muslims' views of evolution within the broader context of Islamic thought. Islamic religious texts and ideas from scholars representing the major groups of Muslims in the United States are explored, as these are likely sources for respondents' views on evolution in the context of their religious faith.

The context of the study is described using a detailed demographic portrait of Muslims in the United States set against a brief historical overview of how these various groups of Muslims arose and came to live in this country. Different groups of Muslims vary in their interpretations of religious scriptures, so it is important to examine them separately because these differing interpretations might have affected the interactions between respondents' views of evolution and their religious beliefs.

Evolution in Islamic thought. Muslims may hold differing interpretations of evolution, and this is true in part because of their different interpretations of religious texts, and how they see these texts as viewing various aspects of the theory of evolution. In Islam, there are two main textual sources (Aslan, 2006). One is the Quran, which Muslims hold to be the word of God as revealed to the Prophet Muhammad, and the other is the hadith, which are traditions attributed to Prophet Muhammad. All Muslims, regardless of sect, follow the Quran. However, there is disagreement over which of the traditions are considered authentic, and thus appropriate for deducing religious rulings, among the different groups of Muslims (Aslan, 2006). For example, Sunni Muslims use traditions that were collected from the Prophet's companions and retold by later generations. Shi'a Muslims use traditions transmitted by the imams, descendants of Prophet Muhammad who they believe to be his pious successors.

Relevant verses of the Quran. According to the Quran, God created the universe with a purpose in mind as mentioned in the following verse. "And We have not created the heavens and the earth and whatever is between both of them as one who indulges in idle play"[1] (21:16). Creation is teleological in its essence, as everything has been created for a set purpose determined by God.

Not only did God create the universe, but He is responsible for maintaining it, and encompasses it with His knowledge, as described in the following verse:

> God – there is nothing worthy of worship but He, the Living, the Self-subsisting, Eternal. Neither drowsiness nor sleep can seize Him. For Him is whatever is in the heavens and whatever is in the earth. Who is there who can intercede with Him except with His permission? He knows whatever is in front of them and whatever is behind them, and they will not encompass anything from His knowledge except what He wills. His authority extends over the heavens and the earth, and He does not weary of guarding and preserving them both, for He is the Most High, the Always Most Magnificent. (2:255)

[1] All translations of the Quran from the Arabic are my own.

Notice from this that God is depicted in the Quran as being continually necessary for the perpetuation of the creation. If He were to shift His attention from it for only a moment, it would cease to exist. However, He is constantly awake and alert, preserving the universe and everything in it.

Muslims do not have any problem accepting an old age for the Earth. Although creation is described in the Quran as taking place in six days (سِتَّةِ أَيَّامٍ), "days" is generally understood to mean periods of time, and not necessarily 24-hour "days." For example, "God is He Who created the heavens and the Earth and whatever is between both of them in six eons" (32:4).

Noah's flood is mentioned in the Quran, but it engulfs only Noah's people, and not the entire Earth, for example, the following verse.

> And We helped him against the nation who belied Our miraculous signs. Indeed they were an evil nation, so We drowned them all together (21:77).

This verse does not pose any problem to Muslims who wish to believe in evolution, as verses in the Bible concerning the flood do for some Christians. Christians who accept a literal interpretation of the Biblical version of the flood must somehow explain the evolutionary bottleneck that would have occurred on the Ark. Muslims, on the other hand, believe that only Noah's people were flooded, so plants and animals could have easily survived outside of the flood zone. Even a literal interpretation of the version in the Quran would not be incompatible with acceptance of evolution.

Many Muslims have no problem accepting evolution as it relates to any other living thing besides human beings, but do not believe that human beings evolved from a common ancestor of another animal. One reason for this is that the Quran does not specify how these other living things were created, but it does specify how Adam was created.

One example of a verse mentioning the creation of plants and animals is the following:

> He created the heavens without any visible pillars and He cast in the Earth anchors (firm mountains) lest it shake with you, and He spread on it every living, crawling creature, and We sent down water from the sky and germinated on it every noble pair. (31:10)

Verses such as this one do not specify exactly how animals and plants were created, and therefore leave open the possibility that they could have evolved as part of the creative process.

Evolution of human beings is problematic for some Muslims because of verses that could be interpreted to specify how human beings were created. The following is one such verse.

> Indeed the example of Jesus with God is like the example of Adam. He created him from dust, then He said to him, "Be!" so, he became. (3:59)

The issue is not so much in the verse itself, but in an interpretation of the verse using traditions attributed to the Prophet. According to the interpretation, a delegation of Christians came to Prophet Muhammad in Medina and claimed divinity for Jesus because he was born without a father. The verse was revealed to dispute these claims. Although Jesus was born without a father, Adam was born without a father or a mother, so if Adam has no claim to divinity because he was born without parents at all, then Jesus would not have a claim to divinity by being born from only one parent.

Another verse that describes the creation of Adam is the following.

> And when your Sustainer said to the angels, "Indeed, I am One Who creates a human being from clay dried from stinking dark mud. So, when I have proportioned him and I have breathed into him from My Spirit, then all of you fall down in prostration to him." 15:28-15:29.

Many Muslims interpret this verse to signify that God created Adam at a specific point in time and in a specific manner. From this, they infer that Adam was specially created, and that therefore he could not have evolved.

There are some Muslims who not only accept evolution, but claim that verses in the Quran are consistent with the idea that human beings evolved, such as the following verses.

> And when your Sustainer said to the angels, "Indeed I am One Who Makes a *khalifah* (خَلِيفَةً) on the Earth." They said, "Will you make on it one who will cause corruption in it and shed blood, while we glorify with Your praise and purify for You?" He said, "Indeed I am the most knowledgeable of whatever you all do not know." And He taught Adam the names, all of them. Then, He presented him to the angels. So, He said, "Inform Me of these names if you are truthful." They said, "Your glory! We have no knowledge, except whatever You taught us. Indeed, You are the Always All-Knowing, the Always All-Wise." (2:30-2:32)

The term "*khalifah*" can be translated as "successor." The question then becomes successor to whom? If Adam is the first human being, who would he be succeeding? The angels say that human beings will cause corruption and shed blood on Earth, yet it is clear from the succeeding passages that their knowledge is limited. How would they know what human beings would do if they do not possess any knowledge of the future? From this, these Muslims conclude that there must have been people on Earth before Adam. God called Adam a *khalifah*, because he was to succeed these people. The angels had observed these people, and this is why they knew what people would do.

In general, Muslims would not have any problem with an old age for the Earth based on the Quran, as it does not specify an age. Nor would the story of Noah's flood pose a problem for Muslims who want to accept evolution, because in the Quranic version only Noah's people were flooded and not the entire Earth. Some verses concerning the creation of human beings can be problematic for Muslims in accepting evolution for humans, particularly if they are interpreted literally and according to traditions attributed to Prophet Muhammad.

Popular scholars' ideas about evolution. There are a number of Islamic scholars whose speeches are readily available online. As these scholars are popular and persuasive, it is likely that their views have impacted the way that American Muslim students view evolution. Also, Asghar (2013) found that scholars were influential in shaping Canadian Muslim teachers' views.

Since the American context is similar to the Canadian one in many ways, it is not surprising that scholars are an influence on American Muslims' ideas of evolution as well.

Yusuf Estes. One such scholar popular on the internet is Dr. Yusuf Estes. He is a former evangelical Christian preacher with a doctorate in theology. He identifies himself as "just a Muslim." He was a long time Muslim prison chaplain, and currently works both online and by giving lecture tours to propagate Islam. He takes a strictly creationist stance. He claims that the theory of evolution "lacks any real, testable evidence. The most we can come up with is not even a possibility, more or less like a dream that they're trying to use evidences, mix them together, stack the deck, as we say, to come up with something" (Estes, 2009). He raises some issues that he feels disprove the idea of evolution, such as, "If we evolved from monkeys, how come we still have monkeys?" (Estes, 2009). Another problem for him with the idea that humans evolved from monkeys is that we cannot use organ donations from other primates. Since they can get organs from pigs, would that mean we are descended from pigs? These arguments are quite similar to those raised by Christian creationists. Perhaps Yusuf Estes finds them attractive in part because of his background as an evangelical Christian. Estes sees evolution as part of a strategy used by atheistic scientists to turn believers away from God. Estes (2006) even goes on to suggest that since evolution is so nonsensical, scientists must have some sort of ulterior motive for promoting it. He suggests their desires to publish papers in academic journals and to obtain academic appointments as possible ulterior motives.

Yusuf Estes cites Harun Yahya as one source of his ideas on evolution. Harun Yahya is "a pseudonym that has become the brand name for the best known form of Islamic creationism" (Edis, 2009). The arguments are based on those used by American creationists to produce a form of old earth creationism. An example of a typical argument from the Harun Yahya corpus is, "A

450-million-year-old fossil horseshoe crab, no different from those crabs of our day" (Yahya, 2008, p. 32).

Yasir Qadhi. Sheikh Yasir Qadhi is another theologian popular among American Muslims. He was formerly affiliated with the Salafi movement, but currently identifies as Sunni. The American-born son of Pakistani immigrants, he has a doctorate in religious studies from Yale University, a B.S. in chemical engineering from the University of Houston, and another bachelor's and also a master's degree from the Islamic University of Madinah in Saudi Arabia. He teaches at Rhodes College in Memphis, TN, and is Dean of Academic Affairs and instructor for the Maghrib Institute, which offers seminars in Islamic studies using weekend classes in various locations in the US, Canada and UK.

In a video posted on You Tube, Qadhi (2013) presents a view that integrates his understandings of both the Islamic faith and the science behind the theory of evolution. First, he begins by clarifying the role of a theory in scientific thought, by likening the theory of evolution to the theory of gravity. He then goes on to mention some evidence for evolution, particularly microevolution. For example, he discusses microevolution occurring in flies that are kept in the laboratory, and fossil bones, including those of hominid species. "So, what the theory of evolution does, it takes these facts – these are undeniable facts – and then proposes a system that takes into account all these facts… To say that the theory of evolution is only a theory ignores the whole point… The theory of evolution from a purely scientific standpoint, in my humble opinion, makes a lot of sense." (Qadhi, 2013).

Given that, Qadhi (2013) discusses how Muslims could reconcile what is contained in the Quran with the theory of evolution. He discusses the Western view of religion and science, because, "There's a very big difference in how the West views science and religion and scripture

and how the East, or the Muslims in particular, view science and religion and scripture" (Qadhi, 2013). He then goes on to discuss tensions between religion and science in the history of Western thought, including Martin Luther's translation of the Bible into the German language which common people could read, Galileo's persecution and house arrest for his belief in a heliocentric solar system, and the Dark Ages in Europe, which he attributed to the church being in charge in Europe at that time.

He then contrasts European history with that of the Islamic civilization. Under the Islamic caliphate, "Muslims ruled the scientific world" and "were the pinnacle of human civilization" (Qadhi, 2013). Arabic was the *lingua franca* of science during the height of Islamic civilization. At that time people traveled from distant lands to study science in the Islamic world, including Europeans who studied medicine in Islamic Spain. This is because, "When we were faithful to our tradition, when we were faithful to our book, we were the ones who Allah blessed with every blessing, worldly, political, scientific" (Qadhi, 2013). In contrast to the picture in the Islamic world, in Europe, the church ruling the state was a "dismal failure" (Qadhi, 2013). Because of this Qadhi (2013) believes it is inappropriate to transfer lessons learned from European history on to the Islamic world.

He goes on to contrast views of the Bible and the Quran by their respective adherents.

> So, by and large, the Christian world, the Jewish world, simply evolved beyond the literalism of their scripture. Now, they know from their experience that scriptural literalism is stagnancy. It's backwardness. It causes problems. (Qadhi, 2013)

In contrast, scriptural literalism is not a problem for Muslims because "the Quran is the divine, uncorrupted speech of Allah; it is the literal word of Allah" (Qadhi, 2013).

Qadhi (2013) reconciles his understanding of the Quranic teachings with the theory of evolution by making an exception for human beings.

What I lean towards is that it is possible for us to affirm the theory of evolution in the broad principles, that life as we know it came from one common ancestor, that all animals are linked together in some great, grand tree, but we, as Muslims, have to say there was one exception to the rule. That's where we draw the line. We say there was one exception, and this exception, of course, is Adam, *'alayhi salaam* [peace be upon him], and *Banu Adam* [Adam's descendants], and the max that can be said, and I'm not saying this, because I'm not a scientist, but the max that we can say is to imagine if you like, a series of dominoes tumbling, and they're all going, as we've seen on You Tube clips and what not, going in different directions, having been caused by one beginning domino, and eventually, if these dominoes continue, one line of that domino will lead to that domino which is a final domino known as man, because we know that nothing has been evolved *from* us. We are the final domino. What we can say is the maximum that any believing Muslim can say is as follows: that all of these dominoes did indeed come from that one domino, that Allah, *'azza wa jal* [God, Mighty and Majestic]- Now, here's of course, another difference. We don't believe in randomness. We believe Allah caused this. This is only the way that Allah did it, right? But we don't believe in randomness. We believe Allah did it. All of these dominoes came about, all of these species came about, and right when it was our turn, right when the next domino should have been our domino, Allah, *subḥanahu wa ta'ala* [God, Glorified and Most High], inserted that domino directly, and that's *Banu Adam*. And, of course, that domino, which is us, fits in perfectly with all the other dominoes, because, why would it not fit in perfectly? Allah is perfect in His creation, and all of the other species are evolving the way that they are supposed to, and when it was the right time at the right place, Allah, *subḥanahu wa ta'ala*, placed us where we were supposed to be such that a neutral observer, who doesn't believe in Allah quote unquote a *kāfir* [non-believing] observer, would automatically say, "Obviously, this domino comes from the one before it," and he has every right to make that claim.

But because we have something that we consider to be a fact, which is the Quran, which is just as much of a fact, in fact, more of a fact than any scientific fact, we have to say our scientific model has to take into account one more fact, and that is Allah, *'azza wa jal*, shaped Adam, created Adam, blew the *ruḥ* [spirit] into Adam, sent Adam down, the whole Quranic story. And we don't have any problem affirming other creatures, other species, hominids, dinosaurs. We don't have any problem stretching the human chain to beyond 6,000 years. We don't believe in 6,000 years, by the way. It's not an Islamic figure. It's a Christian figure. God created the world in six days and then these days are 6,000 years. We don't have that calendar. That's the Jewish calendar. We don't have that calendar. We have nothing un-Islamic to say, there is nothing un-Islamic to say man has been around for 30,000, 40,000, 50,000 years. We don't have a problem with it. Our shari'ah doesn't tell us we have been here for 6,000 years.

The only thing that we have to draw the line, that's Adam, and the children of Adam are a unique creation, and frankly, many things in science prove this point, right? Many things in science prove this point. Of them is language. We are the only creation that has language, and this fits in perfectly, *ar rahmana khalaqa insaana allamahul bayyan, wa allama Adama asmaa' kullahaa* [The Most Merciful created the human being. He

> taught him clear speech. (55:1-4) And He taught Adam the names, all of them. (2:31)] This fits in perfectly. That Noam Chomsky, of course, he's known for his political views, but he's a linguist by profession, as you know. Noam Chomsky and others they all believe that languages, as we know them, they all come from one language. All languages go back to one language. Well, this fits in perfectly with our own understanding. All languages go back to the language of Adam, the Adamic language, right?
>
> Also, the concept of '*aql* and knowledge, no other creature has '*aql* the way we have '*aql*. No other creature. We, our '*aql* is so powerful we understand our '*aql* and limitations of our '*aql*. In other words, we have something. The fancy term for it is metacognition, which means that we know what we know and why we know it and how we know it. Animals *know*…, but they cannot know why they know and how they know. They cannot study their knowledge. This is metacognition. We can study our knowledge. We have history. We have arts. We have civilization. We have poetry. The animals don't have this, and there is no biological reason for us to have these characteristics that no other species has... All of this fits in perfectly. So, the bottom line, we as Muslims cannot accept the theory of evolution's premise that man himself is a part of this chain. We can accept all other premises, and that's the point. (Qadhi, 2013).

Qadhi cautions his audience that Muslims should not consider scientists as part of some conspiracy. Rather, they are operating under a different paradigm. When Muslims say they don't believe in evolution, they appear ignorant, because people confuse them with fundamentalist Christians.

> Many Muslims when they say they don't believe in evolution, they sound very ignorant and very foolish, and they don't even intend it. . . . You need to understand when you say to a Western audience, "I don't believe in evolution," you are becoming, basically, a fundamentalist Christian. No, we're not.
>
> We should never say we don't believe in evolution. We don't, we don't deny everything evolution. Rather, we *can* say that we affirm the broad principles of evolution. We have no problem with pretty much everything evolution says. There's simply one, one issue where we have to draw the line, and we draw it with respect . . . .
>
> Look, my brothers and sisters in Islam, put yourself in the shoes of those people who don't believe in the Quran, and their history and church and science, and the tension between them. Then they see it happening to us. What do you expect them to do, other than to mock us and make fun of us? What do expect them to do, other than to say, "You guys are backwards. You need to get with the program. Leave your book and go with science." That's their world. (Qadhi, 2013)

In Qadhi's view all of evolution can be accepted, except human evolution. In this manner, he can accept all of the scientific evidence without any reservations. Also, by claiming that even though human beings are an exception to evolution, but that they were created as if they evolved, he does not have any conflict with evidence for human evolution, either. He has sophisticated understandings of both nature of science and nature of religion, so he is able to formulate his position without compromising his beliefs in either sphere.

Hassanain Rajabali. Hajj Hassanain Rajabali is a popular speaker among Shi'a Muslims (Qul, 2014). He migrated to the United States from Tanzania in 1975 and obtained a master's degree in molecular biology and a degree in psychology from the University of Colorado. After having run Netsite Corporation, an e-business service provider, and served as principal of the Tawheed Institute, a weekend Islamic school, he is currently the director of Camp Taha, located in Columbiaville, Michigan.

Rajabali (2008) does not think that acceptance of evolution is necessarily contradictory to having a belief in God. He explains, "There is no verse in the Quran where Allah forbids it, and therefore, we have to be silent about it and say maybe it's possible." According to him, "Evolution is a process; it's a methodology; it's a system." Although the Quran categorically states that God created everything, it does not explicitly state the method of creation. It is possible that evolution was one of the methodologies He used.

There are three possible positions that one could take, "to say this is categorically a no-no, or this is categorically possible, or it is absolutely possible." However, there are problems with all three positions, not the least of which is that the dichotomy between acceptance of evolution and belief in God is a false one. This false notion arises because, "there is a

misunderstanding in the concepts which has brought about this segregation of ideas." In reality, these realms are overlapping, not separate.

First, Rajabali (2008) stakes out the Islamic position.

> From the Islamic perspective, it's very clear that the Absolute Creator, God, is the Fashioner and the Creator of everything. Because we understand rationally, from nothing comes nothing. We are something. OK. And we were nothing before, and therefore we have to establish somehow, where did we come from? Where did all this start from? That's very important to understand. OK? Now, there are different arguments about this. One says, well, we came through, ah, probabilities, and it was just a chance that we were born, and we were created. There's another that says, no, it's impossible. From nothing comes nothing. There has to be an Intelligent Designer to have put us together. Otherwise, it's impossible. The system is just too complex, and too structured, and too well-formulated, and too universal for it to have simply randomly appeared from nowhere, from thin air, from this primordial soup. Even this primordial soup that we talk about, where did it come from? At the end of the day, we have to think about that reality of something existing when it was nothing before. Unless we can prove that whatever has been existing here has always existed, OK, then it's a different matter. But, there's no evidence whatsoever to prove, to show that – none, whatsoever. First of all, there's no evidence to show that. We know that there was the beginning. Particularly when you speak about the Big Bang theory, it's very clear. Even Steven Hawking speaks about this issue, that prior to Planck's moment, $1x10^{-43}$ seconds, we cannot talk scientifically, because all laws of sciences fall apart, and we understand that. So we have to start with that moment and not discuss anything further. If you want to be philosophical about it, you can, but scientifically speaking all the instruments of science cease to exist. Thus, there's nothing one can use unless one wants to be speculative. So, having established this particular position, that from an Islamic point of view God is the Creator of everything, He is the One who brings everything into existence. He is the One who is Eternal, who has no beginning, no end. (Rajabali, 2008)

Because empirical science is impossible before Planck's moment, the theory-laden nature of science becomes more evident when discussing any events preceding it. However, all science is necessarily theory-laden.

> And that, I'd like to establish very clearly, that at the end of the day, as scientific as we may want to be, one has to put some kind of a philosophical spin to it, otherwise it's impossible to understand anything in science. For example, in science we understand that science, really, if you go into pure science, we're looking at empirical observations, and empiricists observe everything systematically. They lay things down very carefully, they monitor it, and they even question the integrity of the observation. Sometimes the observation could be skewed on the basis of some biases that we may have placed. As a result, it's very important to make the process as pure and as clean as possible, so that the

> results are corroborated, or at least as valid as possible. And that's logical. So, scientifically speaking, we have a systematic approach and a scientific system. But that's just empirical observation. So, if I observe the expansion of the universe, and I have made a notation of it, correct? And I've shown the red shift, and I'm showing that the universe is expanding. OK. That's nice and dandy. What do you do after that? Well, I'm going to tie in this with this and with that. OK. At the end of the day, I can make all the observations in the world. I can observe atoms, I can go subatomically to observe. I can observe superstructures. Then, what? Do I stop? He says, well, now you're a scientist. You've made total observations. OK. Then what do I do with all of this observation? Do I tie it in with something? Do I make sense out of it? Oh, make sense out of it. Hmm. What does it mean, make sense? Oh, I'm going to now describe what's happening, but am I being very scientific here? Maybe my description is very experiential, which may be biased, and I may be putting a spin on it to see it the way I want on the basis of how I see the world. Now what happens? Suddenly you start treading into the philosophical realm and now you start spinning ideas based on what you've just seen. (Rajabali, 2008)

Science and religion take different approaches. Science is basically a tool that people can use to advance knowledge. Religion presupposes belief in God, but there is no reason that a person who believes in God cannot use the tool of science.

> [P]eople have a problem in the belief in God is because one has to take a certain leap of faith, because we're talking about a Being that cannot be measured in the realm of science. One has to take a leap of faith. This is where science has a problem. And I don't blame it. I don't expect science to take a leap of faith, and say, there is a God. Science is a tool. It's a mechanism of observations, and it's got a system. Leave it there. No one has asked it to become a believer. We must use it as means by which, as a tool, to reach our own objectives as human beings. At the end of the day, science is a methodology that we came forth to use in this spectacular system. (Rajabali, 2008)

Because "You and I exist in the relative realm where time, matter, space, time-space continuum, are parts of our superstructure that give us who we are and makes us who we are… [w]e realize that whatever started it must not have been relative, must not have been bound in time, nor matter, nor space, nor time-space continuum." (Rajabali, 2008). Since the laws of the universe suddenly came into being at Planck's moment, there must have been something that caused that. At the very least, one can posit that a deistic or Arisotelian God could have been the

First Cause. He mentions scientists, such as Einstein and Darwin, who thought there was a deistic First Cause.

Rajabali (2008) continues the argument to a theistic God. He cites Behe's idea that DNA is irreducibly complex, so "[i]t's impossible for this thing to have simply come out of pure chance…[w]hich then brings forth the idea of intelligent design" (2008). The reason that people who posit a deistic First Cause cannot accept a theistic personal God as First Cause is because they cannot reconcile the idea of evil with a theistic God.

> Which, once again, is a misconception in their point, because evil, in reality, is not a bad thing. If you take evil as a physical entity, then, it's absurd, because there's no such thing as an entity existing in any physical state that one can call evil. That doesn't exist. Evil is a reaction to a choice once makes through volition to reject the good. Wow! This is a whole different aspect of the existence of evil! Otherwise, an explosion, an implosion, blood seeping out, a bullet entering somebody's skull, a person falling, a person dying, whatever, no, none of these entities can be called evil. These are just processes of movement from point A to point B. It's got nothing else to do with evil or good. So, this establishes this basic idea from the Islamic perspective that all of this can be reconciled. (Rajabali, 2008)

Rajabali (2008) reiterates that science and religion are indeed compatible. "From an Islamic perspective, and this is very important for us to understand, we must not think that science [is a bad thing]. No, science is one of the greatest gifts God has given us. It's one of the greatest tools we have been given, and in my opinion, thank God for science!" (Rajabali, 2008).

The idea of falsifiability developed by Carl Popper means that in order for something to make sense and be useful in a scientific sense, it must be falsifiable. Even miracles can be viewed in this light. Miracles are not outside the methods of science. Basically, they are things that were not understandable to the people at the time that they occurred, but they are not outside of the natural laws, and it is possible for them to be understood from a scientific perspective. For example, a wireless communication device would seem like a miracle to people in the past, but today, it is commonplace. "We would call this a supernatural event, wouldn't we? But in

reality, it's a scientific event. It's just that our knowledge was limited, and we didn't understand it" (Rajabali, 2008).

For Rajabali (2008), the creation of Adam is a sticking point. "The Quran is very clear on this issue, that Adam was created and placed on Earth" (Rajabali, 2008). However, a scientist would argue that everything has to be within the system, and must have come from some branch of some tree, from some predecessor. "I said that is *a* system, but it is not the *only* system," counters Rajabali (2008). One cannot take evolution back to infinity. It must have started at some point. If species were created at some point in the distant past, then it is not a stretch to say that God created Adam without a predecessor.

To reject God outright is to be dogmatic. There is no evidence that God does not exist, at the most, one could be agnostic without going beyond the bounds of reason. On the other hand, rejecting the scientific viewpoint outright without examining the arguments in its favor, on the basis of religion is also being too dogmatic.

> So, those who work very hard in using the Darwinian theories, for example, to try to establish the non-existence of God have pushed the envelope too far, in my opinion. And, of course, from the religious point of view, from those who believe in a God, to bring in these ideological concepts of certain kinds of miracles and events which contradict empirical science are also pushing the envelope a little too far, in my opinion. There has to be a balancing point between these two where an individual can say, OK, both sides have a rational position, rather than simply coming in and manipulating things on the basis of something that we have a belief in. (Rajabali, 2008)

Both the religious and scientific arguments should be scrutinized to see if they stand up to the light of reason. "[A]ll these realities have to be met with a clear understanding of a holistic human being who lives within the spectrum of science, ethics, ideologies, etc., etc., which brings about the completion of who we are....[I]n reality, it's not us vs. them, or this vs. that. I think at the end of the day, they both have a position, and we need to reconcile them" (Rajabali, 2008).

Mirza Tahir Ahmad. His Holiness Mirza Tahir Ahmad (1928-2003) was the fourth *khalifat ul-messiḥ,* or successor to the Promised Messiah. He was the grandson of the founder of the Ahmadiyya Movement in Islam (AMI), Mirza Ghulam Ahmad (1835-1908). He graduated from the Ahmadiyya Theological Academy in Rabwa, Pakistan. Later, he studied briefly in England. After graduating, he practiced homeopathy and served in various capacities for the AMI until he was elected khalifa in 1982. As the khalifa he provided spiritual guidance for his followers and served as administrator of the AMI. He moved the seat of administration of the community from Rabwa to London in 1984 due to religious persecution he faced in Pakistan. Among the accomplishments of his administration was the launch of the first Muslim satellite TV network in 1992.

Ahmad (1998) accepted the theory of evolution and conceived of it as compatible with the creation of human beings as described in the Quran. He believed that evolution, like all other aspects of the natural world, was under the control of God and that He purposefully directed it. He began his discussion with the following verses of the Quran:

> Blessed is He in Whose hand is the kingdom, and He has power over all things;
> *It is He* Who has created death and life that He might try you - which of you is best in deeds; and He is the Mighty, the Most Forgiving, *The Same* Who has created seven heavens in stages (Tibaqan). No incongruity can you see in the creation of the Gracious God. Then look again: Do you see any flaw? Aye, look again, and yet again, your sight will *only* return to you tired and fatigued. (67:2-4 of Mawlawi Sher Ali translation)

These verses demonstrate that there is no contradiction in creation, and also that God creates things via stage by stage development. Another verse makes it clear that this stage by stage development applies to humans as well. That you shall assuredly pass on from one stage [Tibaqan] to another (84:20). The ultimate aim of creation is the creation of the human being. To explain this point he used an analogy.

> By way of example, we may consider the construction of an aeroplane for which many thousands of stages and processes are required. The designer while planning its production treats every component nuts, bolts, wings, seats and all – as the building of the aeroplane itself, which is the real object of this exercise. Nuts and bolts also have an independent purpose to serve other than just being the components of the plane. As such all the earlier stages are treated as merely preparatory to the consummation of the ultimate purpose. This aspect is highly essential to note because it is here that the Quran parts company with the biologists who believe in a haphazard evolution without a pre-set design. To these biologists the origin and evolution of life appear to have neither purpose nor design, nor a well-calculated plan of execution. (Ahmad, 1998, p. 342)

The selection processes that went into the creation of human beings were by the choice and design of the All-Knowing and All-Powerful Creator, and not by random chance or blind necessity.

Although the Quran was revealed more than 1400 years ago, it contains verses that could not be properly interpreted until the modern age. Among these are verses that describe the origins of life and the creation of human beings. The earliest forms of life were probably archaebacteria that were capable of drawing energy from heat. This is probably the meaning of the Quranic verses describing the creation of the *Jinn*, or hidden organisms, from smokeless fire.

Human kind is described in the Quran as having been created from dust, clay, pottery clay, and dark, fermenting mud. The creation of primordial organic molecules on Earth by inorganic processes, such as lightning, would have been reversible in the oceans, due to hydrolysis of the resulting molecules.

> There is a growing consensus among the scientific community that somehow a dry stage has to be envisioned, whereby the elementary unstable organic chemicals in the primordial soup could be given a chance to develop into more advanced irreversible organic compounds. Moreover the formation of proteins and nucleic acids from the elementary amino acids, inevitably requires the elimination of a molecule of water from every couple of amino acid molecules and nucleotides. This is called polymerisation. But the problem is that despite the fact that it occurred in sea water, the presence of water should certainly have reversed this reaction. Hence all this polymerisation would be depolymerised. (Ahmad, 1998, pp. 371-372)

In the laboratory, these types of condensation reactions work better if the mixture is allowed to dry.

> This suggests that the evaporation of primitive solutions must have taken place after it was splashed on rocks, mud and beaches. This may well have been an essential stage between the rudimentary compounds created in water and the more highly evolved ones which would no longer remain reversible to their elementary forms. (Ahmad, 1998, p. 372)

Although some scientists propose a wet beginning with dry intermediate stages and others propose that the initial stages must have been dry, clay has been proposed as a surface that would be amenable for

> an initial or intermediary dry stage. This stage was reached when the oceanic prebiotic soup was concentrated and dried in the form of laminated micro-thin layers of clay. The Quran is evidently on the side of those who support a wet beginning with an intermediary stage of dryness where concentrated primordial soup was moulded into plates like dry ringing clay, such as broken pieces of earthenware. (Ahmad, 1998, p. 373)

The idea from literalist readings of the scripture that Adam's creation from clay signifies that God molded him out of clay and then suddenly created a human being from that is as absurd as the idea scientists hold that human beings were created from a process that proceeds by blind chance. Rather, it was a slow and deliberate process, under God's direction, guidance, and care. "The scenario of natural selection as against the scenario of purposeful design, would require hundreds of thousands of variant atmospheres, accidentally created by the interplay of billions of chances over millions of earths, of which only one could be rightly proportioned to support life on earth….There are many … verses in the Quran to the … effect that life has to be protected by God, every moment of its existence, or it will cease to be" (Ahmad, 1998, pp. 400-402).

According to Ahmad (1998) living things were certainly created by a process of evolution, but that process had to be one that was under the guidance of God. An unguided,

random process could not possibly produce such a variety of organisms, each so well-suited to its environment, from the structures inside each individual cell to the organism as a whole.

> To return to the main subject of discussion, let us emphasize once again that mutative changes could go far more often wrong than right, leaving little room, if any, for natural selection to choose from, for the betterment of life. But this is not all we observe in the grand panorama of evolution at play on the stage of life. (Ahmad, 1998, p. 434)

> If, on the other hand the viewer is an unbiased observer of what he sees and permits his vision to be led to whichever direction the scheme of creation leads him, then of course the same drama will take on a completely different complexion. At each replication of life into more complex and more organized entities of higher order and at each step forward on the evolutionary journey, he will perceive the guiding hand of the Supreme Creator. If the former scenario can be likened to a game of roulette, the latter perhaps would be more aptly described as a game of chess where every pawn, king, queen, bishop, castle etc., is moved by the hand of a Prime Mover. Evidently the perplexities and the problems that we are discussing can only be resolved if the invisible hand of a Conscious All-Wise Operator is contemplated to be at play. (Ahmad, 1998, p. 470)

Interestingly, Ahmad (1998) uses creationist arguments in support of evolution. In his conception, God is the Creator, but uses the process of evolution to bring living things into existence. He is involved in every step; nothing proceeds by blind chance. This is evident in the fine-tuning of such structures as transport proteins in cell membranes and also of the universe as a whole, configured precisely so that it could produce a planet that would support life.

Nation of Islam (NOI). Timothy Muhammad (2013), writing for the Nation of Islam Research Group, begins by criticizing the current educational paradigm because it is rooted in white supremacy. He notes that even Black people educated under this system take on the values that it espouses. For example, "renowned Black astrophysicist Neil deGrasse Tyson…stated, 'I want to put on the table, not why 85% of the members of the National Academy of Sciences

reject God, I want to know why 15% of the National Academy doesn't.'" In that context, Muhammad (2013) wonders

> Does the belief in Darwin's theory of evolution produce an inferiority complex in Black students and a superiority complex in White students, and does it engender in a student the belief that there is no God Who created the heavens and Earth?
>
> How does a young Black 20-year-old student feel about himself if that student believes that his Black ancestors evolved from an ape-like creature?
>
> The damaging psychological effect of this belief on Black professionals who are trained in America's colleges and universities foments in this particular class of Black individuals a desire to be assimilated into white America, conformed to the ideas and expectations of their ex-slave master and their children rather than connected and united with the suffering masses of their people.

For Muhammad (2013), the critical question is how science has been co-opted to support the white supremacist system by engendering a sense of inferiority in Black professionals so that they abandon their communities to identify themselves with Whites. According to Muhammad (2013) identifying with Whites is not productive, because the actual facts support the idea that Black people had noble origins, and it is they who brought civilization to White people, and not the other way around. The Africans sold as slaves in the United States were skilled, and not savages who swung from trees in the jungle back in Africa. "[E]arly America's white auctioneers were selling 'valuable negroes' that included carpenters, millwrights, coopers, mill hands, blacksmiths, boat hands and engineers!" Blacks, such as dark-skinned Egyptians, were the actual builders of civilization. The actual savages were the Caucasian people of Europe, people who are much more likely to be related to Neanderthals than the people of Africa and Asia. These savages were first civilized by Blacks under the guidance of Prophet Moses, and later "the African Moors' presence in early Europe inspired the European Renaissance."

Muahmmad (2013) goes on to quote the NOI leadership on evolution.

> Minister Farrakhan in a speech stated, "We [Black people] did not come from apes." The Honorable Elijah Muhammad in 1974 wrote in *Our Savior Has Arrived*: "Many claim that there is no such one (God) and that the Creation of the Universe came by chance. Man's creation, they say, took place from some lower form of animal life of the sea. But they were never able to prove such theories."

Muhammad (2013) debunks the theory of evolution by stating, "Charles Darwin's theory of biological evolution is exactly that—a supposition, or a set of assumptions and opinions intended to explain something." He then goes on to explain the origin of White people from the pre-Adamites, "The Aboriginal People of the Earth; the Dark People of the Earth—The Black Man and Woman of the Earth from which every species of human being has come." It is these pre-Adamites that are referred to as "Us" in the Bible when it says, "Let Us make man in our image and after our likeness." That White people were derived from the pre-Adamites is supported by recent scientific evidence that the White race was born when "a major genetic alteration occurred exactly 6,600 years ago…. [T]he white race is a young race—a 'new man' who, as the Honorable Elijah Muhammad has said, 'came from us, but he is different from us.'" The pre-Adamites had civilization and advanced scientific knowledge long before the White race came on the scene.

Next, Muhammad (2013) grapples with the topic of why the White race would concoct such a lie as Darwin's theory of biological evolution. He describes the famous exchange in an early debate over evolution thus.

> Responding to the Bishop of Oxford Samuel Wilberforce's question about whether he traced his descent from an ape on his mother's or his father's side, Sir Francis Galton, a contributing father of the doctrine of eugenics (a racist concept that entails improving the genetic quality of the human population) and a cousin of Darwin, declared:
> "If then, said I, the question is put to me would I rather have a miserable ape for a grandfather or a man highly endowed by nature and possessing great means and influence and yet who employs those faculties for the mere purpose of introducing ridicule into a grave scientific discussion—I unhesitatingly affirm my preference for the ape."
> The man highly endowed by nature and possessing great means and influence is none other than the original man. From this statement made by Galton one can surmise that he

> and his ilk are too proud to publicly admit that they (Caucasian people) ultimately came from Black parents.

Darwin's theory of evolution, then, was devised to cover up the fact that the White race was "selectively bred into existence" and to place "doubt in the minds of the Black professional class … about the true reality of the Original Man, Who is God." Muhammad concludes that, "the theory of evolution is not an empirical science, but a "false knowledge," made up of racist doctrines whose aim and purpose is to deny and cover up the reality of the original people, who are God." He then goes on to question the logic of believing "a people who called 'Us' three fifths of a human being. We cannot and should not believe and follow the white supremacist model of education that our former slave masters and their children have foisted upon us."

In Timothy Muhammad's conception, Darwin's theory of biological evolution is antithetical to belief in God and does not tell the true story of the history of human beings, but is instead being taught to cover it up. Black people were not descended from apes, but, rather, had noble origins. White people, on the other hand, had ignoble origins, as they were selectively bred into existence, and had to be taught and civilized by Black people before they could make any advancements or achievements or develop a civilization.

Muslims in America. "And when it comes to America and Islam, there is no us and them – there is only us, because millions of Muslim Americans are part of the fabric of our country" – President Barack Obama (2014).

Muslims have lived in America since before the inception of the United States. During colonial times up until the middle of the 19th century most Muslim immigrants came involuntarily to these shores as part of the slave trade, although some free Muslims came to work in other capacities during this time as well. Changes in immigration laws in the 1960s have resulted in an influx of Muslims from places around the world, including Africa, Asia, and the

Middle East. In addition, indigenous forms of Islam not found elsewhere, such as the Nation of Islam, have arisen in the United States due to our own peculiar historical and cultural contexts.

Demographics. Muslims in America form a diverse population with ancestry from all over the world (Pew, 2007). As shown in table 1, nearly two-thirds of American Muslims were born in foreign countries. Of those born in the United States, four-sevenths are African-American, and nearly four-sevenths are converts to Islam. Most of the foreign-born Muslims hail from either the Arab region or South Asia.

Table 1

Muslim Americans: Who Are They?

Proportion who are…	Total %
Foreign-born Muslims	**65**
Arab region	24
Pakistan	8
Other South Asia	10
Iran	8
Europe	5
Other Africa	4
Other	6
Native-born Muslims	**35**
African American	20
Other	15
	100
Foreign-born Muslims	**65**
Year immigrated:	
2000-2007	18
1990-1999	21
1980-1989	15
Before 1980	11
Native-born Muslims	**35**
Percent who are…	
Converts to Islam	21
Born Muslim	14

Pew, 2007

Muslim groups in America. Half of American Muslims are Sunni, and 16% Shi‘a as shown on table 2 (Pew, 2007). Fully 22% of American Muslims identify as “just a Muslim” without any other affiliation. The remaining 12% includes members of the Muslim American Society, the Nation of Islam, and the Ahmadiyya Movement in Islam.

Table 2

Muslim Religious Affiliation

	Sunni %	Shia %	Non-specific (Vol.) %	Other/ DK/Ref %
All U.S. Muslims	50	16	22	12=100
Native-born	50	7	30	13=100
African American	48	2	34	16=100
Foreign-born	53	21	18	8=100
Self/Parent from...				
Arab region	56	19	23	2=100
Pakistan	72	6	10	12=100
Other South Asia	82	4	7	7=100
Iran	6	91	3	0=100

Question: Are you Shia, Sunni, or another tradition?

Pew, 2007

A brief history of Islam. The religion of Islam was founded in the seventh century when Muhammad Ibn Abdullah began having experiences that he interpreted as divine revelations, starting around 610 CE and continuing until his death in 632 (Armstrong, 2006; Aslan, 2006). These revelations were collected to form the Quran, or the Recitation, the Scripture of the Muslims. At first, in Mecca, the early Muslim community was subject to harsh persecution. Thirteen years after receiving the first revelation Muhammad and many of his followers migrated to Medina to join converts there who invited them to seek refuge. The Islamic calendar is dated from this event, which occurred in 622. In Medina Muhammad became a political as well as a spiritual leader. After his death his followers passed on many of his sayings and actions by oral tradition. These were collected in later centuries and written down to become known as the hadith collections. After Muhammad's death there was disagreement among his companions as

to who should succeed him. One party supported his longtime friend and father-in-law Abu Bakr, while others supported his cousin and son-in-law, ‘Ali.

The main teaching of Islam is that God is One and He alone is worthy of worship (Aslan, 2006). Muslims believe Muhammad is in the line of previous prophets, such as Adam, Abraham, Noah, Moses, and Jesus, and that the Quran is the final revelation to humankind. Developing a moral character and performing righteous deeds are encouraged, as the Quran urges Muslims to vie with one another in performing good deeds, as if they were in a race. Muslims believe that there will be a judgment day where God will hold people accountable for their actions, after which they will be sent to either heaven or hell. Muslims engage in various practices to attain nearness to God, such as prayer, charity, fasting, and performing the pilgrimage to Mecca.

Sunni Islam. After the death of Prophet Muhammad in 632, the Muslims split into two groups, Sunni and Shi’a (Aslan, 2006). Sunni Muslims hold that leadership of the Muslim community could rest in any pious, knowledgeable man, and they were the party that initially supported Abu Bakr is the first successor to the Prophet. Sunnis use four schools of religious jurisprudence dating to the 8th/9th century, Maliki, Shafi’i, Hanafi, and Hanbali. Their sources of jurisprudence are the Quran and six hadith collections from the 9th century, including those of Bukhari and Muslim, consensus, and analogy. Currently in the United States Sunnis have a diffuse, decentralized leadership, although umbrella organizations, such as the Islamic Society of North America, provide cohesion and structure for Islamic activities (GhaneaBassiri, 2010).

Shi’i Islam. The Shi‘a hold that leadership of the Muslims should be by divine appointment only, and that this divine office of leadership in Islam was bestowed on descendants of Prophet Muhammad through his daughter, Fatimah, and Ali ibn abu Talib, his son-in-law and

cousin (Tabataba'i, 1971). This is because they believe these people to be wiser and more pious than others. They call these pious spiritual leaders the Ahlul Bait, or the People of the House, referring to the Prophet's household. They believe these leaders should be in charge of government, jurisprudence, and spiritual development of their followers. The most numerous group of Shi'a Muslims are the Ithana 'Ashari or Twelvers, who believe that there were twelve of these pious successors, called Imams, including 'Ali, his sons Hassan and Hussain, and nine of Hussain's descendants. A distinctive feature of Shi'a Islam is the ceremonies they hold at the beginning of each Islamic year to mourn the death of Hussain, son of 'Ali, grandson of the Prophet, who was killed by the army of the sitting caliph to prevent him from assuming the leadership of the Muslims. They use the Quran and hadith collections as sources for jurisprudence, but use different hadith collections than the Sunnis do, and do not allow the use of analogy as Sunnis do. To these sources, they add the sayings and actions of the People of the House. Rather than following scholars of the past, Shi'a Muslims believe that the door to ijtihad, or independent reasoning by a religious scholar, remains open, and that people should obtain jurisprudence from living scholars. Currently Shi'a Muslims in the United States have religious scholars who provide them with guidance and leadership, as well as umbrella organizations, such as the Muslim Students' Association – Persian Speaking Group (GhaneaBassiri, 2010).

Just Muslim. Those American Muslims who say they are "just Muslim," without claiming membership in any specific group, are a diverse group, and have different approaches to Islam. Some rely on the Quran alone for religious guidance, while others may rely on the hadith traditions as well. Among the reasons that they identify as just a Muslim are that they do not identify with ancient animosities or foreign cultural traditions that they view as intrinsic parts

of Muslim groups, or they may have a desire to avoid sectarian arguments. In practice, many of these Muslims attend Sunni, Shi'a, or other mosques.

Nation of Islam. The Nation of Islam was founded by a door-to-door salesman of obscure origin named WD Fard, Wallace Fard, or Fard Muhammad (GhaneaBassiri, 2010). He used his position to gain entry into people's homes in order to proselytize. He taught a Black nationalist ideology using some Islamic terminology and spiritual practices as a context in the early part of the 20th century at a time when Black nationalism was popular among African-Americans. He taught that African-Americans descended from the tribe of Shabazz, and that they could restore their original divine nature through Islam. He told his followers to avoid the "tricknology" of the Caucasian devils by abstaining from alcohol and poison animals, such as the hog.

Fard was succeeded by one of his students, Elijah Muhammad, in 1934 (GhaneaBassiri, 2010). He built the Nation of Islam into an organization of national renown, attracting adherents such as the boxer Muhammad Ali, and also Malcolm X, who was one of many who accepted Islam in prison. Elijah Muhammad taught that Fard Muhammad was Allah and that he, Elijah Muhammad, was the Prophet Muhammad. He said that African-Americans were from the lost-found Nation of Islam, and that Islam, their original religion, was taken away from them by the slave masters. His exhortations to hard work, sobriety, and entrepreneurship lifted many people out of lives of poverty and addiction and into the middle class.

Muslim American Society. When Elijah Muhammad died in 1976, his son, Warith Deen Muhammad, took over leadership of the organization (GhaneaBassiri, 2010). He renamed the organization, and it became the Muslim American Society (MAS). He led his followers to a version of Islam rooted in the Quran and mainstream Islamic practices. He aimed to develop a

distinctly American Islam. For example, I once heard him say that we should not look like Arabs or Pakistanis, but we should develop our own, distinctly American version of the Islamic dress. Gradually he decentralized leadership of the organization, although he continued working for Islam until his death in 2008.

A couple of years after Imam Warith Deen Muhammad took over the leadership of the Nation of Islam, Louis Farrakhan formed a splinter group that broke off from the main body of the organization and retained the original name, Nation of Islam (GhaneaBassiri, 2010). He resisted Imam Muhammad's guidance toward a more mainstream version of Islam and instead retained the beliefs and practices promulgated by Elijah Muhammad.

Ahmadiyya Movement in Islam. The Ahmadiyya Movement in Islam was founded in 1889 by Mirza Ghulam Ahmad of Qadian, India (GhaneaBassiri, 2010). He maintained that Islam was in need of reform, and that he was that reformer. He claimed to be the Imam Mahdi, the long-awaited reformer of the Muslims, and the Promised Messiah and metaphorical second coming of Jesus anticipated by Christians and Muslims alike, as well as the reincarnation of Krishna that the Hindus expected. He taught that Jesus did not die on the cross, but migrated to India, where he later died a natural death and was buried. The movement split into two branches after Ahmad's death in 1908. The main branch claim spiritual leadership of Muslims is divinely appointed. Although their Khalifah, or spiritual leader, is elected, they believe that God guides that election. They also claim that Ahmad was a prophet, although he was subordinate to Prophet Muhammad and did not bring any new scripture after the Quran. The Lahori branch maintain that Ahmad was only a reformer and not a prophet, making them more acceptable to other Muslims, who generally consider the main branch of Ahmadiyya to be outside Islam. Currently the Ahmadiyya Movement in Islam has leaders chosen on a local level under regional

and national leadership. There are separate organizations for women and men, and these report directly to the Khalifah (Saliha Malik, personal communication, 2010).

History of Islam in America. Although many Muslims immigrated to the United States before the 20th century (mostly involuntarily), their descendants did not retain the Islamic faith (GhaneaBassiri, 2010). It was not until the 20th century that Islam was passed from one generation to the next to gain a foothold in North America. The Ahmadiyya Movement sent missionaries to the United States in the 1920s and 1930s, successfully winning a number of converts. For this reason, they claim to be the oldest Muslim organization in the United States. Like the Nation of Islam, they appealed to Black Nationalists, so many of the original converts were African-American, including a number of jazz musicians. The First Cleveland Mosque split off from Ahamdiyya Movement in Islam in 1936, and the Muslims who built the First Muslim Mosque of Pittsburg split off in late 1930s, later to found the Mosque itself in 1945. The Nation of Islam was founded in the 1930s. Incidentally, the Lahori branch of the Ahmadis had a relationship with Elijah Muhammad of the Nation of Islam during the 1940s. They tried to encourage him to institute mainstream Islamic practices among his followers, but he demurred, saying that it would be too hard on them, so he had to bring them to Islam gradually. It is the Ahmadiyya Movement in Islam and the Nation of Islam that have produced families with as many as three generations of American Muslims.

Changes in immigration laws in 1965 led to an influx of Muslim immigrants (GhaneaBassiri, 2010). Here in the United States to stay, they began building infrastructure to support the spread and continuation of Islam in America, including student groups, mosques, and schools. The Muslim Students Association was founded in 1963, and separate chapters formed and united under an umbrella organization, the Islamic Society of North America, in 1981. The

Muslim Students Association – Persian Speaking Group was founded around 1970 to meet the needs of Shi‘a students. These immigrants and their American born children currently comprise the majority of Muslims in the United States (Pew, 2007).

Theoretical Frameworks

Because this study examines the relationship between American Muslim undergraduates' religious beliefs and their ideas about biological evolution, it requires theoretical frameworks that will take these factors into account. Jasmine Zine (2008) developed a faith-centered epistemology in order to analyze data she collected on Islamic schools in Toronto. Because one aim of the current study is to examine the range of religious beliefs towards evolution that are held by people from various American Islamic groups, this critical framework is useful. It allows for examination of the students' religious beliefs in a respectful, yet critical manner. Ian Barbour's (2000) four-fold typology of ways people relate science and religion provides a classification scheme for the ways in which people view science and religion in relation to one another. Because the study of biological evolution is one area of science that looks at issues that are also dealt with by religion, this typology is useful in categorizing the ways in which the respondents relate these two ways of looking at origins of species in general and of human beings in particular. To understand these relationships in depth, qualitative research methods were employed to collect and analyze data. Michael Patton (1990) provides a framework for the use of qualitative methods. This combination of theoretical frameworks will allow collection and in depth analysis of data on the relationships between respondents' ideas about religion and science and how these relate to the concept of biological evolution.

Jasmine Zine's critical faith-centred epistemology. Traditionally in academic discourse, religious viewpoints have been dismissed. Jasmine Zine (2008) challenges the idea

that the secular viewpoint should be seen as the standard and proposes that religious viewpoints be given a hearing as well. In order to supply this missing voice to the discourse, she developed a critical faith-centered epistemology to analyze ethnographic data from her study on Canadian Islamic schools. She developed this critical faith-centered epistemology by elaborating seven key principles.

The first principle is "A philosophy of holism, or connections among the physical, intellectual, and spiritual aspects of identity and identification" (p. 53). According to this philosophy, the sacred and secular aspects of people's lives interact and intertwine, rather than existing as separate entities. There are no boundaries between the secular and the sacred in actuality, but rather the world exists as a unified whole, so that people view its aspects holistically. "[T]he notion that we are 'spiritual beings on a human path' rather than 'human beings on a spiritual path' informs the idea that "[a]t the core of this conception of Islamic ontology is the primacy of the spirit as it actualized and manifested in the physical realm (p. 53). Even mundane acts can become a form of worship for the Muslim if they are performed with the intent of pleasing Allah.

The second principle is, "Historically and culturally situated analyses of religion and spirituality are an integral component of understanding human social, historical, and personal development" (p. 54). Historically, religion and spirituality have been central aspects of the lives of human beings. Therefore, one cannot fully understand their historical development without attending to these aspects of their lives. Rituals surrounding events such as birth, death, and marriage arise from people's religious and spiritual understandings, so a full understanding of a people's culture is not possible if these aspects are ignored. The rituals surrounding these events are infused with sources of meaning including "oral traditions, prophetic knowledge, and

religious doctrines, such as those that refer to the 'word of God' or that offer guidance from the Creator" (p. 54). Therefore, "[a] critical faith-centred analysis allows this level of metaphysical engagement so that we can understand how faith and spirituality constantly inform daily social life and personal development" (p. 54).

Muslims structure their lives and living spaces around certain religious practices. For example, the five daily ritual prayers, or *salah*, form a framework around which Muslims schedule their time. During these times, they set aside worldly matters to concentrate on worship. Muslims make arrangements in their homes so that they are more conducive to prayers. Some invest in clocks that make the call to prayer, and most would have prayer spaces in their homes ranging from a prayer rug that could be spread out at the time of prayer, to specific rooms dedicated to worship. I would add that nowadays, it is common for Muslims to have a smart phone app to remind them of the times for prayer. Practices, such as organizing one's time and space around *salah*, "provide an 'anchor' and an 'oasis of tranquility' during" times of transition and stress, and connect the individual Muslim to the wider worldwide Muslim community or *ummah* (p. 55). "The critical faith-centred perspective attends to the saliency of faith and spirituality in framing the world views, beliefs, and practices of faith-centred people, and accepts this as a valid way of negotiating an understanding of community, selfhood, environment, and experience of trans-nationalism" (p. 55).

The third principle is "Religious and spiritual world views and/or contestations of those world views continue to shape human social, cultural, and political development" (p. 55). This extends the analysis from individuals to societies to illuminate how they are shaped by religious perspectives. This view "recognizes the pervasiveness of religious and spiritual ideologies in many societies and the impact those ideologies have on everyday life as well as on social and

political practices" (p. 56). For example, current laws in many Muslim majority countries are based on scholarly interpretations of the Qur'an and Sunnah dating back to the formation of the four major schools of Sunni thought or the development of the 12-er and Ismā'īli Shi'a sects in the 9th century.

The formation of new groups among Muslims and reactions of Muslims to modern-day realities continue to shape social, cultural, and political developments in Muslim societies. The relatively recent Wahabi and Salafi movements, which adopt a literalist interpretation of the scriptures, have shaped culture and politics in predominantly Muslim countries, such as Saudi Arabia. Gender segregation has its roots early in Islamic practice when men and women were separated for the performance of the congregational ritual prayers in order to avoid distractions and facilitate concentration during *salah*. In the modern era in Saudi society it has been extended to include many sectors of public and private life. Muslim feminists have pushed back against the resulting "gendered apartheid" by providing their own counter-narrative rooted in Islamic history. They point out that the Prophet's female contemporaries were active in running businesses, practicing medicine and participating in military campaigns. They ask for a reexamination of social norms and a rearrangement of public space to challenge the "male-dominated status quo" from the viewpoint of a feminist epistemology that is entirely Islamic as well. "Through these confrontations with existing static world views, social development and change move forward through dialectical shifts, which are initiated through the integration of material, ideological, as well as spiritual catalysts" (p. 57).

The fourth principle is "Religion and spirituality occupy a central place in the understanding of various academic disciplines and subjects such as economics, politics, philosophy, gender, culture, education, and anthropology and are valid and legitimate sites for

the analysis of social, existential phenomena" (p. 57). This moves religion from the margins of academic discourse so that it can be used in academic analyses. "A critical faith-centred epistemology challenges [the marginalization and objectification of religion and spirituality] by maintaining that faith-centred knowledges and understandings can be valid ways of knowing and engaging in academic knowledge production" (p. 57).

Indigenous understandings and ways of knowing, rooted in spiritual world views, with a holistic view of nature and a concern for preservation of natural resources, can no longer be viewed as "quaint," but instead provide much-needed perspectives. Islamic viewpoints should be given a voice in academic discourse as well. This does not mean that they should be uncritically accepted, but rather that they become a part of academic engagement. They can inform the discourse through inquiry and dialog, both to challenge accepted paradigms, and to form intellectual alliances to work for common goals.

The fifth principle is "Religious and spiritual identities represent sites of oppression and are connected to broader sites and systems of discrimination based on race, class, gender, ethnicity, sexuality, and colonialism. However, religion has at times been misused and become complicit in oppression. This part of the theoretical framework uses religion as a form of social difference, and analyzes the ways in which it intersects with oppression" (p. 59).

In support of this principle Zine (2009) discusses examples of oppression of Muslims spanning the history of Islam. At Islam's founding, Muslims were ostracized, tortured, and boycotted. They fled persecution in Mecca by migrating to Medina to practice their faith more freely. She mentions also the Crusades, the Spanish Inquisition, and the genocide against Balkan Muslims in the 20th century as historic forms of oppression. She views the current manifestation of Islamophobia in Canada, resulting in "verbal abuse, physical threats, assaults, … destruction

of property…, racial profiling and fingerprinting at airports and train and bus stations" (p. 60), and refusal of landlords to rent to Muslims as stemming from this history.

Religion itself can be complicit in oppression. For example, "[e]xtremist and fundamentalist views based on literal, puritanical, and patriarchal readings of religious texts can lead to forms of gendered oppression" (p. 61). However, it is important to exercise caution when analyzing the role of religion in oppression, because "[p]overty, cultural politics, and imperialism can all be linked as part of a complex etiology of gendered oppression" (p. 62). All of these factors must be taken into account in order to fully understand this oppression.

The sixth principle is "Religion and spirituality can be sites of resistance to injustice and oppression, providing a space for critical contestation and political engagement" (p. 62). According to the sixth principle, the religious viewpoint can be used as a framework for work against injustice and oppression and for liberation and political expression. She gives as an example the anti-colonialist struggles in Latin America fueled in part by the liberation theology of the Catholic Church. Another example she gives concerns Muslim feminists operating within the Islamic viewpoint to reform practices based on their own interpretations of religious scriptures. Islam's legitimacy as a "liberatory theology" has been questioned post-9/11 by those who essentialize Islamic extremism, thus ignoring the vast majority of moderate Muslims. Using this critical faith-based epistemology, one should continue to ask "how this representation serves the interests of the forces of political imperialism and economic globalization" (p. 65).

The seventh principle states, "Not all knowledge is socially constructed, but knowledge can emanate from divine revelation and can have a spiritual or incorporeal origin. Beliefs in prophets, revelation, messengers, angels, spirits, jinn, and so on must be incorporated into research and knowledge production as part of the way faith-centred people read and make sense

of the world and their place in it" (p. 65). Indigenous people value traditional knowledge, observations, and revelation. In the Islamic worldview, traditional knowledge is passed on both orally from parents to children and in weekend Islamic schools, and via written texts, such as the hadith collections. The Qur'an has been passed on both as a written text and as an oral tradition going back to its revelation to the Prophet Muhammad. Observation is important in the Islamic context as a means of transmitting religious practices, such as *salah*, from generation to generation. Observations of nature serve as important sources of spiritual insights, as observations of creation can lead one to contemplate the Creator. Revelation is central to Islamic thought and practice. In Islamic thought, one form of revelation is from God through angels to prophets. The source of this type of knowledge is often validated through accompanying miracles. This is exemplified by the revelation of the Qur'an by the archangel Gabriel to the prophet Muhammad. Another type of revelation, accessible even to people who are not prophets, comes in the form of spiritual visions and dreams. Although "spiritual knowledge cannot be fully comprehended by rational means[, t]his does not necessarily mean that such knowledge is 'irrational'; it only means that it is beyond the limits of rational, scientific exploration" (p. 68).

Zine's (2008) critical faith-centered epistemology was chosen as part of the theoretical framework for the current study because this study focuses on how American Muslims negotiate between their faith-based conceptions and Western modern science to make sense of biological evolution. Delegitimizing the religious voice while legitimizing the scientific voice would lead to a lop-sided interpretation of data that is rich in beliefs derived from religious knowledge and ways of knowing.

Ian G. Barbour's four-fold typology of ways people relate science and religion. Ian Barbour (2000) developed a classification system to describe the ways in which people relate science and religion. He places these interactions into four categories that he labels conflict, independence, dialogue, and integration. Some critics of his scheme argue that these classifications do not universally hold, but rather are peculiar to the modern era and to the West. Another criticism is that these classifications work best for monotheistic religions. Because the present study examines the beliefs of monotheistic people in the modern West, the scheme has been useful in classifying the ways in which they understand science and religion.

People who believe that religion and science are in conflict occupy the two opposing sides of the same coin. For example, a biblical literalist might argue that evolution is inconsistent with the biblical account of creation, and therefore must be rejected. An atheistic scientist might argue that the scientific evidence is incompatible with a theistic explanation, and therefore the biblical account should be rejected. "The scientific materialists have promoted a particular philosophical commitment as if it were a scientific conclusion, and the biblical literalists have promoted a prescientific cosmology as if it were an essential part of religious faith" (Barbour, 2000, p. 36). In this case both would agree that science and religion are incompatible but disagree over which one should be accepted.

People who hold the view that science and religion are independent think of them as occupying different realms. Science deals with empirical evidence and explanations for nature based on that evidence, while religion deals with questions of ultimate meaning and morality. Some people holding the independence view separate religion and science into watertight compartments, while others do not consider the categories to be mutually exclusive.

People who conceive of science and religion as being in dialogue may compare them or use analogies from one to explain the other. Or dialogue may arise "when science raises at its boundaries limit questions that it cannot itself answer" (Barbour, 2000, p. 3). While engaging in dialogue both scientists and theologians respect "the integrity of each other's fields" (Barbour, 2000, p. 3).

With integration both science and religion are used together to formulate a more complete picture of the phenomenon being considered. For example, nature could be seen as providing evidence for the existence of God. Physicists studying the Big Bang may wonder at the narrow constraints necessary to produce the universe as we know it, and consider a theistic explanation to be plausible for this. However Barbour (2000) cautions, "We distort [the rich diversity of our experience] if we cut it up into separate realms or watertight compartments, but we also distort it if we force it into a neat intellectual system" (pp. 37-38).

Chapter 2 – Literature review

Much of the literature on evolution deals with alternative conceptions held by Christians. However, there are important differences in the ways that Muslims view evolution that should be taken into account when teaching Muslim students. The studies included here are those that focus on or include Muslim students and teachers' views on evolution. These provide a picture of Muslims' views on evolution and the possible impact of these views in the classroom. In addition, a few articles on teaching and learning evolution in general are included to put the studies including Muslims in the larger context of teaching and learning evolution.

Best Practices for Pedagogy of Evolution

When planning lessons, it is important to take into account students' initial conceptions in order to ensure that the lesson addresses alternative conceptions the students hold (Posner *et al*., 1982). This is particularly important for teaching evolution, when misconceptions concerning the nature of science itself can interfere with learning (Clough, 1994). To remedy this, Clough (1994) recommends, nature of science (NOS) should be taught throughout the biology course, but especially during consideration of evolution, and especially concerning the use of the word "theory" in a scientific context.

Due to the often controversial nature of teaching and learning evolution in the American context, best practices for teaching evolution take into account societal factors as well as the academic content of evolution itself (Clough, 1994). Evolution should be taught, despite its controversial nature, because it has great explanatory power and is one of the unifying theories in biology. Also, not teaching evolution sends a subtle message to students that there is something wrong with the theory of evolution. Scientific creationism should not be taught, because it is not considered as "good science" by the scientific community.

Clough (1994) also gives a number of strategies to diminish resistance to evolution from students and their parents. It is important to distinguish evolution, which explains the diversity of life on Earth, from the origin of life, which is another, more speculative topic. The teacher should stress the utility of the theory of evolution and its implications for medicine and other fields, because it is the fruitfulness of theories that is important to scientists rather than whether they believe that these theories actually represent reality. It is important also to point out that supernatural explanations are not useful as scientific explanations and that is why they are not considered in scientific discussions. Again, utility is what matters, and not whether an individual considers them to be truer than scientific explanations. Anomalies should be included so that students understand that a theory does not have to explain everything to be useful, or erroneously think that one contradictory piece of evidence will necessitate abandonment of the whole theory. For example, punctuated equilibrium was proposed as an explanation of the incomplete fossil record. On the interpersonal level, he recommends the teacher introduce evolution later in the year after developing a rapport with students and their parents, and showing respect for students' ideas.

Philosophical issues related to evolution teaching and learning impact relationships between students' understanding of evolution, acceptance of evolution, and their beliefs (Smith, 2010a). The directionality of these relationships varies depending on context, and may also be related to how these are defined and measured.

Acceptance of evolution for some is not an all or nothing proposition (Smith, 2010a). Some people accept evolution for some species, but not others. The greater the taxonomic distance from humans, the more likely it is that people will accept that those organisms evolved. Also, it is more likely that evolution will be accepted for organisms with life cycles involving

metamorphosis. Perhaps this is because these organisms can undergo dramatic changes from one form to another in a single lifetime, and this serves as an example of how changes in a species could occur over time. Some people reinterpret evolution to make it fit within existing schema, even though this may distort evolution so that it differs from the version generally accepted by scientists. Others hold neutral views, neither accepting nor rejecting evolution.

Naïve NOS views can interfere with understanding evolution (Smith, 2010a). Particularly pertinent are misunderstandings of what constitutes scientific evidence, the difference between scientific and non-scientific claims, the function of a theory in science, and tentative NOS.

Proper attention to the type of epistemology underlying teachers' lesson design can influence students' reaction to evolution instruction (Smith, 2010a). Science is based on empirical knowledge, and scientific explanations are naturalistic or materialistic, excluding the supernatural as a source of explanation. However, religious people hold that revelation can be a source of knowledge as well. Smith (2010a) recommends that in the science classroom it is best to distinguish between philosophical materialism and methodological materialism to avoid having religious people reject scientific explanations in order to retain their religious beliefs.

Smith (2010b) identified stumbling blocks to effective teaching and learning of evolution, and reviewed the effectiveness of instructional strategies used in teaching evolution. Most people hold misconceptions about evolution, and these are often resistant to change even after instruction. One issue is conflating the origin of life with the origin of species. It is the latter that Darwin addressed in developing his theory of evolution, while it is the former that most often causes conflicts between people's personal religious beliefs and their acceptance of

evolution. Another issue is people's tendency to view natural selection as a direct process instead of an emergent one resulting from the interactions between many factors.

In the United States many biology teachers themselves do not accept evolution (Smith, 2010b). About a quarter teach creationism, another quarter omit evolution altogether, and many of the rest give it a quick or superficial treatment. Reasons for this include lack of content knowledge on the part of the teachers, a lack of knowledge of resources for teaching evolution, perceived or real pressures from administrators, school boards, and parents, and students' lack of acceptance and conflicting religious beliefs. Also, many teachers think that belief in evolution will have negative consequences on one's sense of purpose and morality.

Students may be "hard-wired" to think in terms of teleological explanations, to think that things are purposefully caused by an intelligent agent, and to think of kinds as being fixed (Smith, 2010b). These innate tendencies may explain why it is so difficult for students to attain adequate understandings of evolution. Other cognitive factors influencing students' acceptance and understanding of evolution include whether they are dualist, relativist, or committed thinkers, and whether they are dogmatic or open-minded in their thinking.

People holding fundamentalist Christian beliefs think that belief in evolution involves rejection of their faith, and consequently eternal damnation. These beliefs override other factors, making it difficult for fundamentalist Christians to accept evolution. Students can hold a range of views on evolution including non-theistic evolution, theistic evolution, and both old Earth and young Earth creationism.

Students' experiences in the elementary years can impact their learning about evolution later on (Hermann, 2011). Hermann (2011) recommends that attention be paid to understanding evolutionary theory in preparation of pre-service elementary teachers. His survey of the

literature demonstrates that students' conceptions of evolution are formed before they enter college and that one-shot interventions do not have a lasting impact on students' conceptions. Therefore, Hermann (2011) recommends "that a sequential, systemic approach to teaching evolution is needed beginning in elementary school and middle school" (p. 270). Foundational concepts, such as fossils, taxonomy, and NOS, could be taught at the elementary level to better prepare students to understand evolutionary theory in high school and college.

Muslim Students' and Teachers' Views of Evolution

Much of the literature on evolution deals with alternative conceptions held by Christians. However, there are important differences in the ways that Muslims view evolution that should be taken into account when teaching these students. The literature on Muslims' views toward evolution contains both opinion surveys on evolution acceptance in general and qualitative studies elucidating individual viewpoints on evolution and how these interact with religious views to impact teaching and learning of evolution. Here, both types of studies are examined to gain a fuller picture of Muslims' views on evolution and the possible impact of these views in the classroom.

Polling data. According to polling conducted in Muslim countries from 1996 and 2003, acceptance of evolution ranges from a low of 8% in Egypt to a high of 40% in Kazakhstan (Hameed, 2008). Although only 28% of Kazakhs responded that they thought evolution is false, around 60 or 70% of Turks, Indonesians, Pakistanis, Malaysians, and Egyptians thought it was false. Interestingly, a sizeable minority from around 7 to 15% in each country reported they never thought about evolution. According to Hameed (2008), there has not been much discussion in the Muslim world over whether evolution is compatible with religion, so the opposition that exists tends to center "on the social and cultural threat that the theory poses for

Muslims" (p. 1637). Young earth creationism is absent, as Muslims have no religious objection to an earth that is billions of years old. However, human evolution is more likely to be controversial than evolution of other organisms.

The Pew Forum on Religion and Public Life (2013) conducted surveys of Muslims around the world. (See Figure 1) They also conducted surveys of American Muslims (Pew, 2007), which they compared with surveys of Americans in general (Pew, 2008). (See table 3) They found American Muslims closer to Americans in general than to Muslims worldwide in rejecting evolution (Pew, 2013) with 51% of American Muslims disagreeing with the statement "Evolution is the best explanation for the origins of human life on earth" (Pew, 2007, p. 95) and 45% agreeing, compared with disagreement from 45% of Americans generally and agreement from 48%. This is lower than Muslims worldwide, who have a global median acceptance rate of 53% (Pew, 2013). However, caution should be used when comparing the two studies, because the questions were slightly different. Because the worldwide poll asked about evolution of humans and other living things, it is possible that some respondents disagreed with human evolution, but agreed with evolution of all other living things, and so analysis of their answers to this question is not as straightforward as analysis of the question asked of American Muslims, which mentioned only evolution of humans.

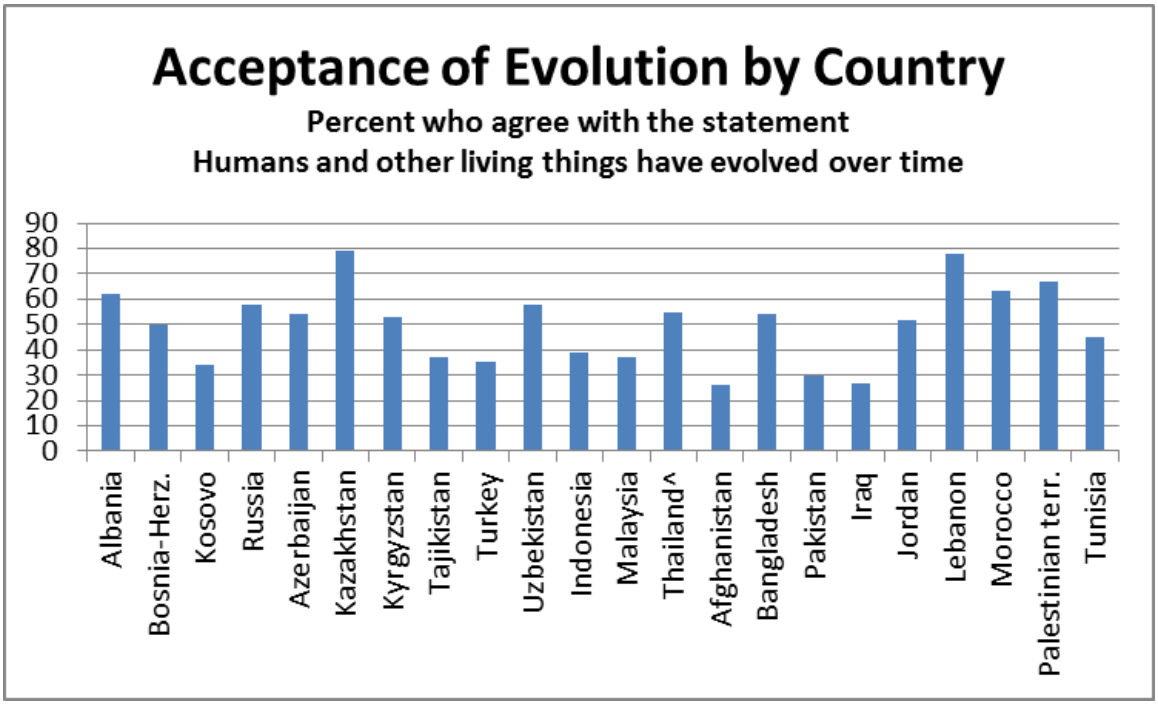
Table 3

American Context

Evolution is the best explanation for the origins of human life on earth

	Completely agree	Mostly agree	Mostly disagree	Completely disagree	Don't know/ Refused	Total
Total	20	28	16	29	7	100
Muslim	16	29	14	37	3	100

Figure 1.



Acceptance of the statement "Humans and other living things have evolved over time" (Pew, 2013, p. 34) ranged from a low of 30% in South Asia to a high of 58% in the Middle East and North Africa. When considering data by country, the lowest acceptance of evolution is found in Afghanistan, Iraq, and Pakistan at 26%, 27%, and 30%, respectively, while the highest rates of acceptance are 67%, 78%, and 79% in the Palestinian territories, Lebanon, and Kazakhstan, respectively.

A smaller poll sheds some light on Muslims' thinking on evolution as well. Guessom (2011) conducted a poll at Sharjah University in the UAE on 100, or about a third, of the faculty and 100 students on their evolution views in 2007. All of the student respondents were Muslim, but there were both Muslim and non-Muslim faculty, allowing for comparisons between religions for that group. Although most of the Muslim respondents and more than a third of the non-Muslim professors stated that they did not know the age of the earth, 39% of the students thought it was millions, billions or tens of billions of years old, and 7% of students thought it was

hundreds of thousands of years old or younger. None of the Muslim professors thought it was younger and 47% thought it was millions or billions of years old, in contrast to 4% of non-Muslim professors who ventured to say that it was younger, while 53% agreed that it was millions or billions of years old. When asked directly about evolution, 62% of Muslims rejected it, compared to 10% of the non-Muslims. Of the acceptors, 28% of the students, 22% of the Muslim professors, and 16% of the non-Muslim professors rejected it for humans, while accepting it otherwise. 74% of non-Muslim professors thought evolution is strongly confirmed by evidence, but only 11% and 14% of Muslim students and professors, respectively, thought so.

These data give some indication of opinions of highly educated Muslims in the predominantly Muslim, though cosmopolitan, society of the UAE. Most did not know the age of the Earth, but of those who ventured an opinion most posited that it was ancient. Muslims generally accepted evolution, but difficulties arose only concerning human evolution. There was also a wide-spread misunderstanding of the amount of evidence for evolution on the part of the Muslim respondents in this study.

Quantitative studies. Deniz and colleagues (2008) examined the relationship between acceptance of evolution and understanding of evolution, epistemological beliefs, thinking dispositions, and parents' educational level for 132 Turkish preservice biology teachers. In the Turkish context, 99% of the population is Muslim. Creationism in Turkey is based on the Qur'an, which states that God is responsible for creation. Noah's flood, while mentioned in the Qur'an, is not considered by Turkish Muslims to be global in nature. The concept of time in the Qur'an is relative, so that a day need not be interpreted as literally 24 hours. Therefore, Turkish Muslims could be "old Earth" creationists, accommodating an old age for the Earth with their religious beliefs. Although the Qur'an does not mention specifically what process brought living

things into being, it does state that God created the universe for a purpose. This leads to a clash between teleological concepts of the creation of living things with a Darwinian concept that sets neither purpose nor direction for evolution. For these reasons, adopting the stance of theistic evolution can cause conflicts for some people, who perceive evolution as necessarily atheistic and incompatible with a belief in God. Deniz and colleagues (2008) argue that the implications of this social and cultural context must be taken into account when considering people's acceptance of evolution.

There was a significant correlation between understanding and acceptance of evolution ($r = 0.20$, $p < 0.05$), indicating that the better the participants understood evolution the more likely they were to accept it (Deniz *et al*., 2008). Thinking dispositions were also significantly correlated ($r = 0.27$, $p < 0.01$), meaning that participants "with cognitive flexibility and openness to belief change are more likely to accept evolutionary theory" (Deniz *et al*., 2008, p. 432). This was similar to previous findings in the American context. There was a significant correlation between parents' educational level and acceptance of evolution ($r = 0.19$, $p < 0.05$) meaning that the higher the educational level of the parents, the more likely the respondent was to accept evolution. These three factors together explained 10.5% of the variance in the regression model, $F (3, 129) = 6.1$, $p < 0.01$. The data on epistemological beliefs was not internally consistent enough to use in the regression analysis, and so was not considered in the data analysis. Deniz and colleagues (2008) hypothesized that other factors of teachers' cognitive ecology that they had identified, but that were not amenable to quantitative analysis, such as religious views and views of nature of science, were likely responsible for the remainder of the variance.

As a result of this study Deniz and colleagues (2008) concluded that learning about evolution includes not just cognitive learning, but also students' affective domains and cultural

contexts. For these reasons, students' conceptual ecologies should be taken into account when designing evolution education. They recommended that exposing students to alternate explanations for data and explicit, reflective nature of science instruction during evolution instruction could improve acceptance. In order to address the problem of the perceived incompatibility between science and religion, they "advocate a constructivist teaching strategy emphasizing the constructed nature of knowledge as opposed to the notion that knowledge of evolution is a direct representation of reality" (Deniz *et al*., 2008, p. 439).

A subsequent study was conducted to address some gaps in the original study by examining religiosity as a factor in acceptance of evolution of 147 Turkish preservice biology teachers (Deniz *et al*., 2011). In this study there was a significant negative correlation between acceptance of evolution and religiosity ($r = -.57$, $\rho < .01$).

Peker and colleagues (2010) conducted a survey of undergraduates in Turkey in the context of a long-standing creationist campaign in that country. Creationism has been a part of the biology curriculum there since the 1980s, so the students polled in the study would all have been educated under that system. Most students do not have evolution in high school, because it is offered only in upper level science electives, and because even the students enrolled in those courses are often preparing for university entrance exams during the part of the year when it is normally taught. This has resulted in an acceptance rate that is only about 30% nationwide.

Peker and colleagues' (2010) study examined the relationship between 1098 freshmen and senior Turkish undergraduates' understanding and acceptance of evolution along with socio-economic factors. The students were enrolled in biology, biology education, or elementary science education programs. Overall, 27.9% of the students accepted evolution, 20.7 rejected it, and 51.4 were undecided. Seniors were more likely to accept evolution than freshmen. Internet

access had a positive effect on both acceptance and understanding of evolution, in contrast to having books in the home, which had no effect. The family's income and educational levels of fathers had no effect, but those with educated mothers were more likely to accept evolution, though understanding of evolution was not affected. Gender was not related to understanding of evolution, but females were more likely to accept it than males. Seniors attending universities in major cities were more likely to both understand and accept evolution than their counterparts studying in smaller cities. Students who were interested in learning more about evolution were more likely to both understand and accept evolution than those were not interested in learning more.

Peker and colleagues (2010) recommend an improvement in evolution education for Turkish students, because they attributed the high numbers of undecided students to a lack of information on their part. Due to the low acceptance rates among pre-service teachers, they did not hold out much hope that the situation in Turkey would change any time soon, however.

Akol and colleagues (2012) studied the interactions between 415 junior and senior Turkish preservice science teachers' acceptance and understanding of evolution, views of nature of science, and their self-efficacy beliefs for teaching evolution. They used path analysis to understand both direct and indirect effects and the ability of the data to explain the overall model. They found that views of the nature of science along with understanding of evolution accounted for 17% of the variance in acceptance of evolution and 26% of the variance for self-efficacy in teaching evolution. Their major finding was that, "Overall, these findings suggested that, for pre-service science teachers, higher levels of both understanding and acceptance of the theory and naïve views on NOS were associated with stronger self-efficacy beliefs for teaching evolution effectively" (Akol et al., 2012, p. 949). Preservice teachers with greater understanding

and acceptance of evolution felt more confident in teaching it. Although nature of science views were negatively correlated with self-efficacy in teaching when examined directly, more sophisticated nature of science views were positively correlated with both understanding and acceptance of evolution, and therefore indirectly related to self-efficacy in teaching evolution, which correlated positively with both understanding and acceptance of evolution. They recommend teaching nature of science along with evolution content to foster better understanding and acceptance of evolution.

Qualitative studies. Dagher and BouJaoude (1997) examined the views of college biology majors on evolution and how their religious beliefs impacted these views using a survey of biology majors followed by in-depth questions for 15 of the respondents. The students were Christian, including Maronite, Eastern Orthodox, Catholic, and Protestant, or Muslim, including Sunni, Shi‘a, and Druze.

They found students’ responses fell into four categories, “for evolution, against evolution, compromise, and neutral” (p. 429) Those who accepted evolution did so by arguing from evidence for evolution, or from a perspective reconciling religion with evolution. Those who rejected evolution argued using evidence against evolution or from religious arguments. A third group forged a compromise between evolution and religion. The fourth group consisted of people who did not commit one way or the other, or whose responses were confused and did not articulate a clear position. None of the Christian students rejected evolution, while 47% of the Muslim respondents did. In Dagher and BouJaoude’s (1997) interpretation, this was because the Christian accepters were not using literal interpretations of scripture, while the Muslim rejecters were. They classified the objections students raised to evolution under four themes, “conceptual

difficulties; alternative interpretations; nature of science; and nature of religion" (Dagher & Boujaoude, 1997, p. 436).

One student reported that learning evolution with a professor who took a neutral stance made the students indifferent toward evolution so that they learned it only because it was required. Dagher and BouJaoude (1997) did not agree with this approach because it led to students compartmentalizing their knowledge rather than integrating it so that it could be fully used. They recommended teaching nature of science, especially the functions of hypotheses, theories, and laws, with all science topics to address misconceptions both from those who reject evolution because it's "only a theory" and from those who accept it because it's a "fact." Because evolution has metaphysical implications for students, they also recommend allowing students to air their views in a non-judgmental forum "to clarify concepts, beliefs, and conflicts without pressures to convert any party to any one belief about either science or religion" (Dagher & Boujaoude, 1997, p. 441).

Hokayem and BouJaoude (2008) examined beliefs of 11 college students who completed a course on evolution and their instructor using surveys and semi-structured interviews. The respondents included Sunni, Shi'a, and Druze Muslims as well as Christians. Students fell into three categories, acceptance of evolution, rejection of evolution, or uncertain (uncertain was similar to the neutral category in Dagher and BouJaoude's (1997) study. The students placed a high value on scientific explanations of nature, but showed differing views when it came to evolution, with some accepting scientific explanations, and one rejecting them for this aspect. The students reported that taking the course did not change their stances on evolution. What they did instead was to "restructure those arguments in such a way that fit within their worldview in light of new acquired knowledge" (Dagher & Boujaoude, 1997, p. 411)

BouJaoude and colleagues (2011) conducted a study using semi-structured interviews to elucidate the views on evolution of Lebanese biology professors and teachers. As Lebanon is a multi-religious society, consisting of Orthodox and other Christians, and Sunni, Shi‘a, and Druze Muslims, this provided an opportunity to examine the relationship between religious affiliation and views on evolution. They found that religious affiliation did correlate with views on evolution, with one Shi‘a, two Christian, and one agnostic professor accepting evolution and two Sunni and one Druze professors only selectively accepting it. One Sunni professor accepted evolution of all living things, except humans. With the secondary biology teachers, the affiliations shifted somewhat. Five Druze and four Christians accepted evolution, three Shi‘a, two Sunni, and one Christian rejected evolution, two Shi‘a and one Sunni selectively accepted evolution, and two Sunni and one Christian were non-committed or confused. As the sample sizes were small, some caution in generalizing the numerical results is warranted.

BouJaoude and colleagues (2011) elaborated on the teachers’ and professors’ positions on evolution. Some accepted evolution based on the scientific evidence. Others, who held a reconciliation position, based their acceptance on integration between the scientific evidence and their religious beliefs in which the scientific evidence was found to be compatible with a non-literalistic interpretation of scripture. Of those who rejected evolution, some held a creationist stance in which they perceived evolution as incompatible with a literal interpretation of scripture, while others rejected it using objections to the theory itself based on ideas that were problematic from the standpoint of nature of science. Some held a selective acceptance, in which they accepted some parts and rejected others to make evolution more compatible with their religion in response to what they perceived as a conflict between the two, but in so doing, they made “scientifically untenable” assertions (BouJaoude *et al*., 2011, p. 986). Some respondents did not

commit to a particular position, and others were designated as confused due to their "inability to articulate a defined position" (BouJaoude *et al*., 2011, p. 986).

In the Tunisian context Aroua and colleagues (2009) used information from previous studies to design a unit to effectively teach evolution to high school seniors. Previous studies showed that Tunisians held a variety of opinions, ranging from rejection of evolution to acceptance. Those who rejected evolution based their rejection on theological beliefs, while those who accepted evolution based their acceptance on a mixture of both scientific and theological reasoning. This is in Tunisia's concordant socio-cultural context in which scientific and theological knowledge are seen as conceptually and logically continuous, albeit with a lack of understandings of scientific methodologies. Aroua and colleagues (2009) designed their lessons to address the problems of misunderstanding the differences between scientific and theological reasoning, and misconceptions about the science of biology, specifically the role of historical evidence. They used pre- and post-tests consisting of semi-structured interviews, and recordings of student discussions in small groups during the intervention. During the pre-test interviews some students used mixed explanations where God created living things and then biological mechanisms, such as mutations and environmental factors, produced diversity. After the intervention students were able to distinguish between creationist and scientific arguments, and to use scientific arguments to explain evolution. The key to this change was "development of epistemological reflection among the students, assisted by the teacher's interventions, a construction of knowledge about methods of validation in evolution, a characterization of the scientific basis of evolution, and especially a separation between evolutionary and creationist ideas" (Aroua *et al*., 2009,p. 478). By situating their lesson in the "pedagogical, intellectual, and

… social context" of Tunisia they were able to move their students forward by targeting the specific misconceptions prevalent in Tunisian society (Aroua *et al*., 2009, p. 478).

Mansour (2008) examined Egyptian Muslim science teachers' personal religious beliefs in the context of how they taught topics such as evolution in their classroom. He contrasted these with more sophisticated interpretations of Islam based on its sources that would not lead to a perception of a conflict between science and religion. Mansour (2010b) examined Egyptian Muslim science teachers' attitudes toward teaching controversial topics, including evolution, in the Egyptian context. Teachers were issued science textbooks containing verses of the Qur'an pertinent to particular science topics, but did not receive any guidance in how to integrate these verses into their science lessons. Mansour (2010b) used Barbour's model of the relationship between science and religion to place respondents in categories of conflict, independence, dialogue, or integration. He found evolution was involved in some instances in which the teachers found a conflict between religion and science, because it was viewed as a part of Eurocentric science, or because it was believed to conflict with verses of the Qur'an concerning creation, or because it was associated with atheism. In another study, Mansour (2010a) again found conflict associated with teaching of evolution. He also found dialog. For example, one teacher reported teaching evolution, even though he did not agree with it, by contrasting it with verses from the Qur'an. Another teacher was classified in the independence category for teaching evolution "to clarify the right and the wrong aspects" (p. 132) and then reviewing verses of the Qur'an with students.

Asghar and colleagues (2007) examined Muslim high school students' and teachers' and university faculty's and their families' views of evolution in Canada, Indonesia, and Pakistan. In this article they reflect on their experiences in conducting this research using qualitative analysis

of their field notes, team meetings, and observations. In conducting their study they faced many challenges. In translating terms such as “ancestor” into other languages, they had to negotiate between terms with purely biological connotations, and others which included spiritual content as well. They wanted to use the MATE (Measure of Acceptance of the Theory of Evolution) as a measure of respondents’ acceptance of evolution to be able to make comparisons across studies. However, this measure is geared toward Christians, and so some items had to be reworked. They substituted “the Holy Book of your religion” for “Bible” both to include non-Muslims in their survey samples, but also to avoid the suspicion from Pakistani Muslim respondents that the surveys had an anti-Islamic agenda. One item was dropped, rather than reworked, because even the suggestion by using a Likert scale that the Quran might not be scientifically accurate was seen as highly offensive by some Canadian and Pakistani Muslims. Although the majority of respondents reacted favorably to the research, some respondents and potential respondents expressed skepticism about the intentions of the researchers. That they had Canadian institutional affiliations was helpful in the Canadian context, but worked against them in the overseas context.

Asghar (2013) contrasted Muslim teachers from Pakistan and Canada on their views of evolution and of teaching evolution and examined how their religious beliefs affected their views using semi-structured interviews and focus groups. The Canadian teachers were mostly immigrants from south Asian and Arabian countries teaching in Islamic schools. The teaching environment in Canada, which is a secular country, differed from that in Pakistan, which is an Islamic republic with a population that is 95% Muslim.

None of the seven Canadian teachers accepted human evolution, because they viewed this as conflicting with their religious beliefs, although three accepted evolution of other

organisms. While evolution was taught in biology classes at the Canadian schools, six of the seven teachers thought that the religious perspective on the origin of life should be taught alongside biological evolution, and two teachers taught the viewpoints of an Islamic creationist alongside Darwin's theory.

Only 4 of the 18 Pakistani teachers rejected evolution completely with one of those accepting a Lamarckian version instead. The remaining teachers accepted evolution of non-human organisms based on the scientific evidence. They saw human evolution as conflicting with their religious beliefs, but accepting evolution of all other organisms as compatible with their faith. All but one of the Pakistani teachers taught the religious viewpoint along with the scientific one, a practice that was supported by the inclusion of verses of the Qur'an in the biology textbooks. Interestingly, despite their skepticism toward evolution in general or human evolution specifically, none of the teachers in either country considered that there was a conflict between science and Islam.

Analysis of the data showed that the teachers in the study were more influenced by religious scholars than by scientific evidence when it comes to human evolution. In addition, they held serious misconceptions about evolution and the nature of science that hindered their understandings. Many of them taught creationist views alongside evolution and many told students that human evolution was wrong according to their faith, thus contradicting the content that was in the provincial or national standards. Asghar (2013) considered it likely that these deficiencies hindered the teaching of evolution in these teachers' classrooms, and therefore impeded the learning of evolution by their students. She suggested that professional development of in-service Muslim teachers aimed at improving evolution content understanding, as well as understanding of nature of science, could remedy these deficiencies.

Summary of findings. There is adequate quantitative data to determine general acceptance rates for evolution among Muslims worldwide and in specific countries. Although interesting quantitative studies have been conducted in the Turkish context, it is not known whether the same results would hold in other cultural contexts. What is lacking from the literature are qualitative studies that could elucidate the specific factors leading Muslims to accept or reject evolution. In some of the qualitative studies mentioned here Muslims are included in the study population, but there is no effort made to distinguish between Muslims and non-Muslims in presenting the results. It is possible that differences between Muslims and non-Muslims are obscured by lumping them together for data analysis. In some of the studies the numbers of Muslims are small, and so it is likely that some Muslim viewpoints have been missed. There are only a few qualitative studies that adequately address these issues, including the studies in the Egyptian and Tunisian contexts mentioned here. The sample size of Egyptian science teachers was large enough to uncover a variety of viewpoints from the teachers, although the main focus of these studies was controversial issues in general, rather than evolution specifically. The Tunisian study, by focusing on Muslims in a particular cultural context, was able to address important factors impacting Tunisian students' acceptance of evolution.

Implications and recommendations. Important characteristics of Muslim students are that they may reject human evolution while fully accepting evolution for all other living things, and that both Muslim accepters and rejecters of evolution may not perceive any conflict between science and religion, nor have any difficulties with an old age for the Earth. There is a great deal of diversity among Muslims both in their views on evolution and in the manner in which they do or do not reconcile their religious beliefs with their views on evolution. Some Muslims are comfortable with non-literal interpretations of religious texts, and can use these to construct a

position in which acceptance of evolution is compatible with their religious beliefs, while others insist on a literal interpretation of religious texts that may be at odds with acceptance of evolutionary theory. Still others hold intermediate positions that compromise the scientific understanding in order to make it compatible with their religious convictions.

Recommendations made by Clough (1994), including teaching nature of science so that students understand the importance of theories in science and do not succumb to a naïve realism concerning the explanatory power of scientific ideas, were echoed by Dagher and BouJaoude (1997) and by Asghar (2013). Although Clough (1994) stressed the importance of the role of the teacher in setting the tone for lessons on evolution, Dagher and BouJaoude (1997) go farther by recommending a dialog where students can air and clarify their viewpoints in a non-judgmental setting. Aroua and colleagues (2009) emphasize the importance of designing lessons to take into account the socio-cultural setting. In a context in which students' perception that there is compatibility between religion and science can lead to misconceptions about the methods particular to each and the boundaries between them, helping students reflect on these distinctions can address these misconceptions. As Aghar and colleagues (2007) noted, it is important to consider the socio-cultural context when conducting research on Muslims' ideas about evolution, so that questions should be worded to avoid cultural misunderstandings which could interfere with obtaining valid data from respondents. Asghar (2013) noted that secondary teachers themselves may lack adequate understandings of evolution and of nature of science. She recommended that professional development to address these issues was warranted so that these inadequate understandings would not be passed on to students and so impede their learning. Peker and colleagues (2010) noted that lack of understanding was common among preservice

science teachers as well, and made similar recommendations to improve the teaching of evolution during teacher training.

Chapter 3 – Methods

The literature review on Muslim students' and teachers' views on evolution reveals an important gap in this research. Although quantitative studies have explored their views, qualitative studies that could elaborate on Muslims' views on evolution are lacking. The qualitative studies that exist either include Muslims without focusing on them specifically or include evolution with socio-scientific issues, rather than focusing specifically on evolution.

None of the qualitative studies of Muslim students and teachers takes place in the American context. There are reasons to believe that American Muslims may differ from their co-religionists worldwide. Their acceptance rates for evolution mirror that of Americans in general, rather than that of Muslims worldwide. There are forms of Islam in America not found elsewhere, such as the Nation of Islam. For these reasons, it is possible that American Muslims view evolution differently than Muslims in other countries.

The current study used qualitative methodologies to study American Muslims' views on evolution in greater depth than would have been possible with quantitative methodologies. The specific research questions addressed in this study were as follows:

1. How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?
2. What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?
3. What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?

To address these questions I employed a variety of instruments directed at the different constructs inherent in these questions.

Theoretical Framework for Qualitative Research

Qualitative research uses the researcher herself as the instrument of study, and therefore hinges on her ability to conduct the inquiry (Patton, 1990). Qualitative research can give a depth of insight that is lacking in quantitative research, but it is not generalizable from the population under study to the population as a whole. In contrast, well-designed quantitative research is generalizable to the population as a whole, but it lacks important details that could shed light on participants' views. Because quantitative research deals with evened out means, the richness of the experiences and their importance to participants is missed. People who do not fit the general pattern are subsumed in the averages in qualitative research, but their ideas can be explored in detail using a qualitative approach.

Quantitative studies employ questionnaires that present respondents with a narrow range of responses, while qualitative studies allow respondents to provide answers that were unanticipated by the researcher (Patton, 1990). For example, Deniz and colleagues (2008) were only able to account for 10.5% of the regression with the questions they asked in their initial study, and needed another study to elucidate further the factors important in acceptance of evolution by Turkish preservice biology teachers. They were limited by the questions they asked in their survey, and had to conduct their follow-up study to examine another factor, religiosity, that turned out to account for more than half of the regression found in their model. Although this quantitative data is generalizable to the population of Turkish preservice biology teachers as a whole, it missed important considerations in their thinking because their responses were constrained by the questionnaire they received from the researchers. In contrast, qualitative research allows the discovery of patterns and factors that are generated by the respondents rather

than by the researcher. In this way, the two types of research complement each other to construct a fuller view of the phenomenon under examination.

According to Patton (1990), "Qualitative methods are particularly oriented toward exploration, discovery, and inductive logic" (p. 44). Rather than imposing categories on the data a priori, the qualitative researcher allows patterns to emerge from analysis of naturalistic data consisting of open-ended observations. In contrast,

> Inductive analysis with the hypothetical-deductive approach of experimental designs … requires the specification of main variables and the statement of specific research hypotheses *before* data collection begins. A specification of research hypotheses based on an explicit theoretical framework means that general constructs provide the framework for understanding specific observations or cases. The evaluator must then decide in advance what variables are important and what relationships among those variables can be expected. (Patton, 1990, p. 44)

Using an inductive research design allows

> the important analysis dimensions to emerge from patterns found in the cases under study without presupposing in advance what the important dimensions will be. The qualitative methodologist attempts to understand the multiple interrelationships among dimensions that emerge from the data without making prior assumptions or specifying hypotheses about the linear or correlative relationships among narrowly defined, operationalized variables….Theories about what is happening in a setting are grounded in direct program experience rather than imposed on the setting a priori through hypotheses or deductive constructions" (Patton, 1990, p. 44).

In the context of the present study, it is not clear that we understand all of the factors that go into the ways in which American Muslim undergraduates construct meaning of evolutionary theory in light of their religious beliefs and their understandings of nature of science. Qualitative research will allow new factors to emerge from the data that the researcher had not thought to consider before conducting the interviews. Although quantitative research has shown the relationships among evolution acceptance and understanding, understandings of nature of science, and religiosity, it cannot show the specific ways in which these constructs are negotiated by individuals, nor how they are integrated or not into their personal belief systems. By using

qualitative methods, this study will be able to compliment previous quantitative research by elucidating these relationships.

The Researcher as the Instrument of Study

As an American Muslim, I am a part of the community that I have studied for this research. I have at various times been either a member of or affiliated with the groups of Muslims examined here. Studying members of the group "American Muslims" when I myself am an American Muslim presented opportunities as well as challenges. My familiarity with various Islamic groups and organizations, as well as numerous personal contacts within these groups, afforded me access to venues where I could recruit respondents. My familiarity with Islamic norms and customs has made it more likely that I would be able to establish a rapport with my respondents and understand what they were telling me as I interviewed them. My respondents likely trusted me, as a Muslim myself, to more accurately represent their views, and to avoid casting their ideas in a negative light simply because I did not understand Islam and Muslims. A possible downside of this familiarity is that I might have missed reporting on cues and information that was invisible to both myself and the respondent due to shared parts of our cultural perspectives. I might also have assumed that there is more similarity in perspective between myself and a respondent than actually existed. This might have caused me to fail to ask follow-up questions that I should have asked in order to gain a better insight into a respondent's thinking.

My presentation as a White, middle-aged woman wearing Islamic modest dress who converted to Islam and is currently pursuing a Ph.D. evoked certain responses in my respondents. My presence in an interaction with my respondents as I interviewed them inevitably influenced

the manner in which they answered my questions in ways that may or may not have become apparent during the interview.

People tend to project various conceptions onto me, based on the modest dress. For example, they may assume that I am conservative and traditional, rather than progressive and open-minded. They may assume that I share their understanding of what Islam is or should be, rather than understanding that people construct complex religious identities based on their own unique backgrounds and experiences, and that my construction may differ in significant ways from theirs. People who are less conservative or less religious might have been reluctant to participate in the study, because they may have believed that I would judge their ideas in a negative light.

Due to my age, respondents may have thought of me as a respected auntie. Age is often highly respected among Muslims, and this would result in the perception of an unequal power balance. Respondents may have answered questions in ways that they perceived would please me, rather than share their actual ideas. As education is often highly respected among Muslims as well, my position as a Ph.D. student might have evoked similar responses. It also caused respondents to worry about whether they gave me "right" answers, particularly when answering questions about natural selection or nature of science.

My whiteness likely interacted in various ways, depending on the race and background of the respondents. African-American respondents may have projected onto me negative experiences they have had with other Whites, and may have been suspicious of my motives. This might have colored the manner in which they answered questions and might have affected their willingness to share their responses or to participate in the study. Conversely, they may have found it interesting or unusual that a White person has accepted Islam, and this may have

caused them to be more willing to participate and share information. Respondents with backgrounds in countries that suffered from colonialism, such as Pakistan or India, may have viewed my whiteness both positively and negatively at the same time. They may have harbored resentment against Whites as Westerners, while still considering the West as developed and therefore having positive attributes at the same time. Although living in the West, they may have felt that they were still outsiders and not completely American, and this may have negatively affected their views of Whites as well. Consequently, they might have harbored resentment against me because I am White. Alternatively, they might have viewed the conversion of a White, Western woman to Islam as a sort of "prize" that validated their world view. This could have caused them to be more willing to participate, or it might have caused them to try and give answers that would please me, rather than share their honest opinions.

My status as a convert could have evoked different reactions from respondents. They may have felt that my conversion validates Islam in some way. They may believe that converts are "better" Muslims than people born into Muslim households. This may have caused respondents to be reticent about admitting that they are not very religious. Conversely, they may have viewed converts as not "real" Muslims and may not have accepted me as fully Muslim. This would have given me an outsider status, and they may have been less willing to trust me with their genuine ideas.

Regardless of power relations that respondents may or may not have projected onto me, there was a power imbalance inherent in my position as a researcher. It is I who chose the research questions and the instruments that were used, and it is I who chose the methods of analysis.

It was, in reality, not possible to avoid the various biases that I hold due to my background and experiences from influencing the manner in which I formulated questions and collected and analyzed data. As Helen Longino (1990) put it, "The myth of scientific value neutrality that is a consequence of the more general view that scientific inquiry is independent of its social context is, thus, a social myth" (pp. 224-225). My situatedness in a particular social context at a particular time in history as a particular minority in a particular society studying particular subjects at a particular university was inevitably reflected in the manner in which I interacted with my respondents and the data they generated for me. However, knowledge, by its very nature, is situated in a social context. As Helen Longino (1990) explained,

> Scientific knowledge is social knowledge, that is, that it is constructed through interactions among individuals. Those interactions are themselves shaped by social relations existing among those individuals. The account I have defended is antireductionist in two related respects. Scientific knowledge cannot be reduced to the knowledge of an individual and cannot be understood in terms of processes in principle individualistic, such as the simple additive accumulation of individuals' knowledges. Secondly, an individual's scientific knowledge is made possible by that individual's social and cultural context, that is, it rests on the work of others as well as on the social conventions of interpretation and it requires participation in practices of transformative criticism. A consequence of embracing the social character of knowledge is the abandonment of the ideals of certainty and of the permanence of knowledge. (pp. 231-232).

The idea of a neutral analysis free of biases of any kind is an impossible ideal. By adding my viewpoint to the discussion on students' views on evolution, which already contains numerous varying viewpoints, methodologies, and theoretical approaches, this serves to illuminate another aspect of the phenomenon.

Because biases cannot be eliminated from inquiry, I have made my approaches to this problem clear in the section on theoretical frameworks. A basic assumption of this study is that a person's ideas about science and religion can interact in various ways, and this, in turn, can influence their views on a particular scientific idea, in this case biological evolution. Barbour's

(2000) theoretical framework on the ways in which science and religion can interact provides a lens through which to examine this in my respondents. Because I am a Muslim researcher examining the views of Muslim respondents, I need a theoretical framework that will enable me to understand and respect their viewpoints, while at the same time subject them to a critical analysis. Zine's (2008) faith-centred epistemology provides a theoretical lens to scaffold my efforts to do this.

I address the issue of validity using several approaches. First, I have used instruments that have been validated in the field by previous researchers whenever possible. I analyzed data collected from these instruments using the methods recommended by their developers. Secondly, I used multiple sources for data. For example, if NOS issues were mentioned when the person discussed natural selection, for example, then this information was compared with the data from the VNOS-C. Finally, I used multiple theoretical frameworks to examine my data. I used both Zine's (2008) and Barbour's (2000) theoretical frameworks, as mentioned above, in addition to the separate analyses of data recommended by the developers of the various instruments I used.

Sampling

American Muslims are a diverse population, consisting of people with ancestry from countries all over the globe, different racial and ethnic groups, and a variety of schools of thought within Islam. According to a Pew (2007) survey, 38% of American Muslims are white, 26% are Black, 20% are Asian, and the remainder other than that or mixed. The "white" category includes both Arabs and people of European descent. Thirty-five percent of Muslims in America were born in the United States, 24% in the Arab region (Middle East and North Africa), 18% in South Asia, 8% in Iran, 5% in Europe, 4% in sub-Saharan Africa, and 6% elsewhere.

Half of American Muslims identify as Sunni, 30% as just Muslim, 16% as Shia, and 5% with another school of thought, such as Nation of Islam or Ahmadi. The rest refused to answer or did not know.

Previous researchers working in Lebanon, a diverse society including Muslims from several different schools of thought, have suggested that views on evolution may differ by school of thought (BouJaoude et al., 2011; Dagher and BouJaoude, 1997). Therefore, it is desirable to include Muslims from the different schools of thought represented in the United States in order to obtain a comprehensive picture of American Muslims' views on evolution. Acceptance of evolution by Muslims worldwide varies by country, ranging from a low of 26% in Afghanistan to a high of 79% in Khazakhstan (Pew, 2013). For these reasons, it was important to take both the country of ancestry and the school of thought of the respondents into account when collecting data in order to make it more likely that the sample included the whole range of views that American Muslims may hold on evolution.

To sample Muslim college students, I attended several Islamic conferences and two academic conferences and made cold contacts with college students or their parents attending these conferences. These were the Islamic Society of North America (ISNA), The Muslim Students Association – Persian Speaking Group (MSA-PSG) Conference, The Midwest Ijtema, Jalsa Salana U. S., the Midwest Association for Middle East and Islamic Studies Conference (MAMEIS) and the ISNA Education Forum. I attended sessions that were attended by students, engaged people nearby in conversation to find out if they were undergraduates or if they knew any attendees who were undergraduates, and then asked those who were if they would be willing to participate in the research. I also made contacts with undergraduates during meal breaks at the conferences. The organizers of the ISNA Education Forum allowed me to make an

announcement at a breakfast meeting to recruit participants. I used personal and professional contacts to identify Muslim college students. Then, I contacted these students by phone or e-mail and asked if they were willing to participate in the research. I obtained additional respondents by using snowball sampling of respondents recruited from conferences and personal and professional contacts. In order to obtain Muslims from a variety of schools of thought, I attended conferences and used contacts from people from Sunni, Shia, and Ahmadi Muslim groups. The conferences were attended by American Muslims from a variety of backgrounds, so respondents recruited from the conferences were diverse in terms of their ancestry. Respondents recruited from personal contacts were diverse as well.

I asked people I know who are members of various Muslim groups if they could identify college students for me who might be willing to participate. I contacted these students by phone or e-mail and asked them if they were willing to participate. I used snowball sampling of these respondents to find more participants. I used contacts from Muslim student organizations in one Midwestern city, one Southern city, and one Midwestern college town to help me find respondents. I found respondents by contacting Muslim students from the following national and regional conferences serving students from different Muslim groups. Mainly Sunni Muslims were recruited from the ISNA and academic conferences, and from the Muslim student organizations chapters. The Muslim Students Association – Persian Speaking Group Conference, despite its name, was conducted in English and attracted Shia students of various backgrounds. The Midwest Ijtema and Jalsa Salana U. S. were attended by women from the Ahmadiyya Movement in Islam. As the Ahmadi conferences were gender-segregated, I used snowball sampling and personal contacts to obtain Ahmadi male respondents. Students who

identified as “just a Muslim” were recruited using personal contacts and from conference attendees.

I interviewed 60 students. These included people with a range of reactions and people who represented a spectrum of views on evolution and a spectrum of integrating their views on evolution with their religious beliefs. The data were analyzed to find different categories of interactions between students’ understandings of biological evolution, their religious beliefs, and their nature of science understandings. Because I was interested in finding the range of possible interactions between students’ views on evolution and their religious beliefs within different groups of Muslims present in the United States, Sunni, Shi‘a, just Muslim, and Ahmadiyya Movement in Islam, this sample represents maximal variation sampling (Merriam, 2009). Because I was looking for the range of views within each group, it was not necessary to make the groups representative of their proportions in the US Muslim population. Since the goal of qualitative research is to obtain in depth information about a particular context, purposive sampling, and not random sampling, is usually employed for this type of research (Gay, *et al*., 2009). If I sampled by making the group sizes proportional, less common viewpoints from the smaller groups would likely be missed. Alternatively, I could waste time interviewing more Sunnis long after data saturation for that sample had been reached, even though they would not provide any additional information.

Sampling limitations. By using Islamic conferences and Muslim student groups to find respondents, the sample was skewed toward more religious Muslims. Also, these respondents are likely to have been skewed toward more conservative views. Some of the male respondents may have been uncomfortable being interviewed by a female researcher. Some respondents may have assumed that I am conservative because I wear the Islamic modest dress, and may therefore

have been reluctant to express views that they do not consider to be conservative. Other respondents may have assumed that I was less conservative and may have been reluctant or apologetic about sharing more conservative viewpoints.

Due to the scientific nature of most of the topics of the interviews, the sample was skewed towards people who are interested in evolution in particular and science in general. I was able to recruit some people who were not particularly interested in these topics using snowball sampling of personal contacts.

I addressed some of these concerns by reassuring respondents that I was interested in their views, no matter what they were. I assured them that I needed a range of views, and that it was important to have people who were more informed and less informed as well as more knowledgeable and less knowledgeable about these topics. I explained to them that this research will be used to help teachers of Muslim students to design better lessons for them, and that this would not be possible unless they told me what they really thought. I explained to more reluctant respondents that I would not have a complete picture of American Muslims' views without their participation in the study. By not participating, their voices would be excluded from the discourse. This would result in a study that lacks the views of important segments of the American Muslim population.

Participant characteristics

The participants included 58% Sunnis, 12% Shias, 8% non-specific Muslims, 18% Ahmadis, 2% Salafi, and 2% Spritual (no longer Muslim). The majority, 80% were born Muslims, with the remaining 20% having converted to Islam. Traditional undergraduate students aged 18-25 comprised 82% of participants and the remaining 18% spanned a range of 27 to 45 years old. One quarter of the students were freshmen, another quarter were sophomores, 22%

were juniors and 28% seniors. Those born in the US comprised 77% of the sample, with the remaining 23% having immigrated to the US. Half or 53% of the participants were White. White participants of Arab or North African backgrounds comprised 35% of the sample. The remainder of the Whites were of European (7%), European and Arab (3%), or European and Native American descent (5%). African-Americans made up 12% of the sample. Of these, 7% of the total participants had ancestors who immigrated involuntarily as a result of the slave trade, 3% as a result of more recent voluntary immigration, and 2% with both. Asians comprised 26% of the sample, with 25% of the total sample being South Asian and only 2% from the Far East. People with ancestors from more than one continent, classified as mixed, comprised 12% of the sample.

Instrumentation

I used a combination of structured and semi-structured interviews and written survey instruments. Semi-structured interviews were used to elicit a variety of answers from people. As I did not already know all of the possible viewpoints, or all of the possible interactions between aspects of respondents' thinking, using only structured interviews would have missed important data. Also, by using an interview, rather than a written format, respondents were able to make comments even on the structured questions to provide more information. Demographic information was collected in a structured interview in order to compare categories. I used questions from Pew (2007, 2013) for demographic information because they have already been field tested and validated with many respondents. The instruments themselves are in the appendices.

I used pre-made instruments when they were available, so that I could use items that have been used successfully before and have been validated. I endeavored to interview respondents

face-to-face wherever possible, because this would have made it harder for them to misrepresent their ages, genders, or ethnicity, as they might have using an anonymous online method. All respondents that I interviewed by distance over Skype or on the phone were people that I knew or had met in person prior to the interview, or who were known to personal contacts or to other respondents, or who had been recruited from a Muslim student organization listserv.

GAENE. In order to determine whether and to what extent the respondents accept evolution, I used the GAENE (Generalized Acceptance of EvolutioN Evaluation), developed by Mike U. Smith (2011). Previous studies on Muslims' acceptance of evolution, such as those by Deniz and colleagues (2008, 2011), used a modified version of the MATE. However, this instrument does not measure a single construct, as it includes religious beliefs and understanding of evolution as well as acceptance of evolution. Because the current study aims to elucidate the interactions between respondents' acceptance of evolution, religious beliefs, and understanding of evolution, having separate instruments to measure each construct would make these relationships more apparent. If several constructs are conflated in one instrument, it would be difficult to determine which of these is actually interacting with the factor or factors under consideration. Therefore, I used the GAENE, which measures the single construct of acceptance of evolution.

For the GAENE, acceptance of evolution is defined as follows, "Evolution acceptance is the mental act or policy of deeming, positing, or postulating that the current theory of evolution is the best current available scientific explanation of the origin of new species from preexisting species" (M. U. Smith, personal communication, February 27, 2014). The measure was subjected to three rounds of pretesting on both high school and undergraduate biology students and two rounds of validation by experts in evolution (Smith, 2011; M. U. Smith, personal

communication, February 27, 2014). The measure was revised after each round in response to the comments of the pre-testers and experts to improve clarity and validity. Each item from the resulting version was subjected to an analysis of content validity. Any item with a Lawshe content validity ratio below the cutoff of 0.51 was dropped, resulting in a Lawshe content validity index of 0.72 for the remaining items. The resulting 16 items were administered to more than 650 high school and university students. The internal consistency was high, with a Cronback alpha of 0.940, as was the internal reliability, with a Cronback alpha of 0.948. Because the GAENE was validated using undergraduate students, it is appropriate for my sample, which consists of undergraduates.

ACORNS. It was important to elicit respondents' understandings of evolution in order to understand exactly what each respondent meant when he or she referred to evolution during the interviews. In order to measure respondents' understandings of evolution, I employed an interview protocol. Previous researchers have used an instrument including multiple choice and essay items that looks much like a test that might be administered for a biology class. I preferred to use an interview protocol so that the answers would be in the respondents' own words. Using multiple choice items forces a response that may or may not have exactly corresponded with the respondents' conceptions. Alternative conceptions may have been held by respondents that would not have been represented by the distractors on the forced response portion of the measure. The essay items on the measure do allow for respondents to give fuller answers and may have elicited conceptions that the multiple choice items would not have. However, if the respondents did not respond well to the prompts, there would have been no way to change the prompts in this measure. During an interview, the interviewer could use other prompts or follow-up questions if the respondents did not respond well to a particular item.

I selected items from the ACORNS (Assessing COntextual Reasoning about Natural Selection) instrument for the interview (Nehm *et al.*, 2012). This instrument was designed to measure "students' use of the core concepts of natural selection when explaining evolutionary change" (Nehm *et al.*, 2012, p. 745). It was validated using undergraduates, so it was suited for my research participants, who were undergraduates. On this assessment Cronbach's alpha for the key concepts was 0.77 and for the naïve ideas, 0.67, so it is more internally consistent for key concepts than for naïve ideas. It is designed so that respondents discuss how natural selection accounts for variation both within and between species and both gain and loss of traits in plants and animals and in familiar and unfamiliar species. This is important because people often reason differently for plants than for animals or for gain of a trait than for loss of a trait. The inclusion of unfamiliar organisms and traits served to elucidate whether respondents could generalize to apply natural selection to unfamiliar situations, and this could theoretically distinguish people who reason as experts from those who reason as novices.

VNOS-C. To understand the interactions between respondents' views of science and religion, it was important to elucidate the respondents' understandings of both of these constructs. The VNOS-C (Views of Nature of Science, form C) (Lederman, *et al*., 2002) was used mainly to provide a picture of respondents' understanding of nature of science. The first question asked respondents to explain how science is different from religion, so this shed some light on both aspects. Although both constructs were included in the same measure, the qualitative nature of the VNOS-C allowed for disaggregation of the different constructs when coding the responses. In addition, the VNOS-C targets aspects of nature of science that are important for understanding evolution, such as the nature of theories and laws and whether experimentation is necessary for the development of scientific knowledge. For example, some

people reject evolution because it is “only a theory” or because they do not understand the importance of observational studies in advancing scientific knowledge (Clough, 1994). Other questions on species and mass extinction relate directly to concepts that are necessary to an adequate understanding of evolution.

The developers of the VNOS-C recommend that validity be established for each administration of the instrument by interviewing 15-20% of the participants as a follow-up to paper and pencil administration of the instrument (Lederman *et al*., 2002). In addition, responses should be coded by more than one researcher and inter-rater reliability assessed for each administration. In this study all of the respondents were interviewed and none took a written survey. Only one researcher coded the responses.

Measures of religiosity. In order to determine the religiosity of the respondents, I used questions from the Pew (2008) survey of American Muslims. These included a question about religiosity, but they also included several questions on traditional Islamic religious practices. These questions included demographic data as well. Using multiple questions to measure religiosity gave better data than asking a single question would have. Religiosity among Muslims is a complicated, multi-dimensional phenomenon (Hassan, 2007), so using a single question as some previous researchers have done would have given only a superficial look at this complex phenomenon. Whether the different aspects of religiosity interacted differently with respondents’ views on evolution would have been missed by treating religiosity as a unitary phenomenon.

Hassan (2007) developed a multi-dimensional measure of religiosity for his study on piety in Muslim societies. His measure included the ideological, the ritualistic, the experiential,

the intellectual, and the consequential dimensions of religiosity. He described these dimensions as follows.

> The ideological dimension is constituted by the fundamental beliefs to which a religious person is expected, and often required, to adhere. The ritualistic dimension encompasses the specific acts of worship and devotion which people perform to express their religious commitment. Often it comprises public or communal, as well as private or personal, acts of worship. All religions have certain expectations, however imprecisely they may be stated, that a religious person will at some time or other achieve direct knowledge of the ultimate reality, or will experience a religious emotion. This includes all those feelings, perceptions and sensations, whether felt by an individual or a religious group, that involve some type of communication with God or a transcendental Being. Stark and Glock label this as the experiential dimension. The intellectual dimension refers to the expectation that religious persons will possess some knowledge of the basic tenets of their faith and its sacred scriptures. The intellectual dimension is clearly related to the ideological dimension, since knowledge of a belief is a necessary condition for its acceptance. However, belief need not follow from knowledge, nor does all religious knowledge bear on belief. The consequential dimension encompasses the secular effects of religious belief, practice, experience and knowledge on the individual. It includes all those religious prescriptions that specify what people ought to do and the attitudes they ought to hold as a consequence of their religion. (Hassan, 2007, pp. 439-440)

While Hassan's (2007) classifications are a useful way to think about the multi-dimensionality of religiosity, some of the items he used would have been problematic for this study, as explained below. Therefore, I used these categories when analyzing the data from the Pew questions. I used some of his questions, but edited them, and included some of my own questions.

For example, when asking about belief in miracles, two of his responses are "I believe that miracles happened the way the *Qur'an* says they did" and "I believe that miracles can be explained by natural causes." This is problematic because some Muslims would not consider those two responses to be different. For example, Mirza Tahrir Ahamd (1998) wrote, "When studied in the light of the Quranic account, miracles and signs never violate the laws of nature" (pp. 246-247).

Hassan (2007) asked his respondents if they had a sense of being afraid of Allah as part of his questioning on the experiential dimension of religiosity. Different people experience God in different ways. For example, Muslims refer to God as *al-Raḥmān* and *al-Raḥīm* frequently during their ritual prayers. These names refer to God's loving kindness in a manner that might remind a person of the loving kindness of a mother, as they are derived from the word "*raḥm*" which means "womb." For this reason, I added some questions referring to different ways that people might experience God in addition to fearing Him so that I would be more likely to include respondents who felt that they experienced God in other ways besides fear.

Hassan (2007) asked about belief in evolution as a part of his measure of the consequential dimension of religiosity. He conflated acceptance of evolution with rejection of the idea of God as the Creator, so acceptance of evolution for him was a measure of unbelief. This was problematic because it ignored the possibility that theistic evolutionists could be pious. To remedy this, I included people with medium and low consequential dimensions of religiosity according to Hassan's (2007) measure as highly religious if they had high scores in other dimensions of religiosity. Although I found some of Hassan's (2007) questions problematic, I used others to give a fuller picture of the respondents' religiosity. I also used his categories when coding all questions about religiosity.

I also used questions, such as those posed by Dagher and BouJaoude (1997) to understand interactions between college students' religious views and their understanding of biological evolution. These questions specifically targeted the manner in which the respondents viewed evolution in light of their religious beliefs.

Correspondence between instruments, interview questions, and surveys. Questions from the literature and from the survey instruments mentioned above have been used to construct

the interview protocol and the survey instruments to administer to the respondents. From the Interview Questions in Appendix A, Question 1 was designed to determine the type of belief the respondent has about evolution. "These categories broadly correspond, respectively, to theistic evolution, naturalistic evolution, the special creation of humans, and the special creation of all species." (Everhart & Hameed, 2013, p. 4). Question 1e was added after it became apparent that some respondents thought differently about microevolution and macroevolution when choosing their responses to the prompt in 1a. Questions 2 and 3 were designed to elucidate the relationship between respondents' religious beliefs and their understanding of science (Dagher & BouJaoude,1997, p. 433). Question 4 is from the ACORNS instrument and includes questions on gaining a trait (4a), losing a trait (4b), evolution of a species (4a, 4b, 4d, 4e), variation within a population (4c), plant evolution (4d, 4e), animal evolution (4a, 4b, 4c), and evolution of an unfamiliar trait in an unfamiliar organism (4e) (Nehm *et al*., 2012). Using this variety of questions will help to distinguish the level of sophistication of the respondents' understandings of evolution and determine their ability to abstract concepts and generalize them to new situations. Question 6 from Everhart and Hameed (2013) was designed to discover possible influences on respondents' ideas on evolution and religion. I wrote question 5 as a follow-up to further elucidate possible influences. Questions 7 and 8 elicited respondents' thoughts on the compatibility between science and religion and are from the World's Muslims Pew Survey (2013).

The Religious Beliefs and Practices Survey in Appendix B was taken largely from Hassan (2007) and from the Pew surveys (2007, 2013). Questions were used to determine the ideological, ritualistic, experiential, intellectual, and consequential dimensions of respondents' religiosity. Question 1 from Pew (2013) relates to the intellectual dimension of religiosity.

Questions 15-21 relate to the ideological dimension, and all but 16 and 18 are from Hassan (2007). I wrote question 16 in a similar fashion to question 15, because the Islamic testimony of faith traditionally mentions both belief in one God and belief in Muhammad's prophethood, so I thought it important to include questions on both aspects of the testimony for this dimension. I included question 18 because belief in angels is mentioned in the Quran as an article of faith (for example 2:177), but belief in Satan is not, although Hassan (2007) includes belief in Satan in the ideological dimension. Questions 21 and 22 were written as one question by Hassan (2007), but when I pilot tested these questions, it became apparent to me that they were not mutually exclusive, even though that was the intent of the original question. Therefore, I made two questions from this one question. Questions 2-14 reflected the ritualistic dimension. Question 2a uses wording from Pew (2007), but the first response is from Hassan (2007). Questions 2b and 2c are from Hassan (2007). Questions 3 and 4 are from Pew (2007), and 5 and 6 are from Hassan (2007). Questions 7-14 are from Pew and add some depth to the ritualistic dimension by elucidating the importance of ritual in the lives of the respondents. Most Muslims use the hadith and sunnah, as well as the Quran, and consider them to be secondary only to the Quran itself, so this is reflected question 8. Questions 23-28 address the experiential dimension. Questions 23 and 26-28 are from Hassan (2007). I wrote questions 24 and 25 to include some positive experiences for this dimension. Hassan (2007) wrote question 29 to investigate the consequential dimension.

The questions from the Demographic Information survey in Appendix D are mainly from Pew (2007). I added question 3 to obtain more information about how recently the family immigrated to the United States, questions 6 and 7 in case the respondents had chosen a different tradition than the one they were raised in, questions 8, 9, and 10 about their schooling, and

question18 to confirm that the respondent fit the definition of "American" I set for this research project.

Data collection and analysis

Preliminary analyses of the data were conducted shortly after it was collected so that data was being collected and analyzed at the same time. The preliminary analyses consisted of coding the data for stances on evolution, stances on the relationship between religion and science, understanding of evolution, religiosity levels, NOS views, and GAENE scores. Once all of the data had been collected I conducted the final analyses by looking for patterns in the qualitative data using the constant comparative method and by searching for relationships between different aspects of the data.

Data collection. Data was collected using both structured and semi-structured interview questions. Respondents were first identified by face-to-face contacts at conferences or Muslim Students' Association meetings or by personal and professional contacts of the researcher or from listservs of Muslim student orgnaizations. Respondents were interviewed either in person or on the phone or on Skype, depending on whether they were in the same city as the researcher and on the preference of the respondent. Both interview and survey questions were administered orally. The interviews were recorded, and then transcribed for later coding and analysis. An overview of data collection is depicted in Table 4.

Table 4.

Methods of Data Collection and Analysis

Research Question	Data Collection	Data Analysis
How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?	(1) Interview question 1 (2) GAENE (3) ACORNS (4) Interview questions 2, 3, 4f, 4g, 5, 6, 7 and 8 (5) Religious Beliefs and Practices survey	(1) Everhart & Hameed's categories (2) Mean of responses (3) Determining number of key concepts and cognitive biases in answers. (4) Barbour's 4 categories (5) Scored using Hassan's categories
What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?	(1) Interview question 1 (2) GAENE (3) ACORNS (4) Interview questions 2, 3, 4f, 4g, 5, 6, 7 and 8	(1) Everhart & Hameed's categories (2) Mean of responses (3) Determining number of key concepts and cognitive biases in answers. (4) Barbour's 4 categories
What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?	(1) Interview question 1 (2) GAENE (3) ACORNS (4) VNOS-C (5) Religious Beliefs and Practices survey (6) Demographic Information survey (7) Interview questions 2, 3, 4f, 4g, 5, 6, 7 and 8	(1) Everhart & Hameed's categories (2) Mean of responses (3) Determining number of key concepts and cognitive biases in answers. (4) Scored as more naïve or more informed views (5) Scored using Hassan's categories (6) Presence or absence of traits (7) Barbour's 4 categories

Question 1. How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?

This question can be broken down into related constructs. One is acceptance or rejection of biological evolution, and this was elucidated by administering the GAENE. Question 1 on the interview protocol was designed to elucidate specifically what type of beliefs the respondents held towards evolution, theistic evolution, naturalistic evolution, the special creation of humans, or the special creation of all species (Everhart & Hameed, 2013). This question was expanded to further break the construct of evolution down into macroevolution and microevolution once it became clear that respondents had different reactions to these aspects of evolutionary theory. Respondents then explained whether their choices for question 1 were affected when they took the difference between macroevolution and microevolution into account. Another construct is the idea of biological evolution itself. To understand the respondents' ideas about this, the ACORNS instrument was administered. This corresponded with question 4 from the interview protocol. Questions 2 and 3 from the interview protocol specifically relate to the relationship between respondents' religious beliefs and their acceptance or rejection of evolution.

Question 2. What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?

Similarly to research question 1, respondents' views on evolution were elicited by the GAENE, ACORNS, and interview question 1 to answer research question 2. Interview questions 2, 3, 7, and 8 were used to specifically elicit respondents' views on the compatibility of science and religion.

Question 3. What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?

Interview question 1 and the GAENE were used to determine whether respondents accepted evolution. Various characteristics other researchers have found or suspected to be correlated with acceptance of evolution were determined as well. The ACORNS measure was used to determine respondents' understanding of evolution. VNOS-C was used to determine respondents' understandings of nature of science. Respondents' religiosity was examined using the Religious Beliefs and Practices survey. By examining a more detailed construct of religiosity than used by previous researchers it was possible to elucidate the specific aspects of respondents' religiosity that corresponded with their acceptance of evolution. Demographic information was elicited using the Demographic Information survey. Additional information came from Interview questions 5 and 6.

Data analysis. Data was analyzed using coding schemes developed for use with the various instruments from which the data was derived. An overview of data analysis is located in Table 4.

Qualitative interview questions. Interview question 1a was developed by Everhart and Hameed (2013) for use with Muslims, and was coded using their categories. If the respondents answer was "A. All species, including humans, have evolved over millions of years, but Allah guided the process", they were coded as theistic evolutionists, if they answered "B. All species, including humans, have evolved over millions of years, and Allah played no part" they were coded as naturalistic evolutionists, if they answered "C. Allah created humans, but all other species have evolved over millions of years, they were coded as having a belief in the special creation of humans, and if they answered "D. Allah created humans and all other species in the form they exist today" they were coded as having a belief in the special creation of all species. Coding of respondents' stances on evolution was also informed by answers they gave to the

follow-up questions for 1a, and in some instances to follow-up questions given during the administration of the GAENE. These were coded using the constant comparative method (Miles, *et al*., 2014).

Follow-up questions 1b, 1c, 1d, and 1e were written by myself and were coded using the constant comparative method (Miles, *et al*., 2014) to look for themes and patterns in the respondents' beliefs.

Interview questions 2, 3, 4f, 4g, 5, 6, 7 and 8 were coded using the constant comparative method (Miles, *et al*., 2014) to look for themes and patterns in the respondents' beliefs. These themes were compared with Barbour's 4 categories to determine whether the respondent fit one of these patterns.

ACORNS. Respondents' understandings of evolution were assessed using questions from the ACORNS instrument, corresponding to questions 4a-4e of the interview protocol. Respondents' answers were coded using the coding scheme used by its developers (Nehm *et al*., 2010; Nehm *et al*., 2012). See Appendix G for the coding key. Briefly, presence of key concepts, such as variation, heritability, differential survival or reproduction, competition, and hyper-fecundity were scored for each answer. Each received a score of 1 if it is present and 0 if not. Presence of cognitive biases, such as essentialism, teleology, and intentionality, were scored as 1 if present and 0 if not. Respondents whose answers contained at least the three most important key concepts, called core concepts (variation, heritability, and differential survival), and had no cognitive biases were considered as having an excellent understanding of evolution. Respondents whose answers contained at least the three core concepts (variation, heritability, and differential survival) and one or more different cognitive biases were considered as having a good understanding of evolution. Respondents whose answers contained two out of the three

core concepts and no cognitive biases or misconceptions were also considered as having a good understanding of evolution. Respondents whose answers contained more cognitive biases than key concepts were considered as having a fair understanding of evolution. Respondents whose answers contained one or two of the core concepts with one or more cognitive biases or misconceptions or only one core concept with no cognitive biases or misconceptions were also considered to have a fair understanding of evolution. Respondents whose answers contained one or more cognitive biases and no key concepts were considered as having a poor understanding of evolution. Respondents who were able to provide good or excellent answers to question 4e were considered to hold an abstract model of natural selection that could be applied to unfamiliar cases, while those who were unable to answer this question were considered to lack this ability to abstract the concept.

Dimensions of religiosity. Religiosity was scored according to the categories developed by Hassan (2007), the ideological, ritualistic, experiential, intellectual, and consequential dimensions of religiosity. The intellectual dimension of respondents' religiosity was gauged using question 1 on the Religious Beliefs and Practices survey "How much would you say you know about the Muslim religion and its practices?" by assigning numerical values to the answers of 4 = a great deal, 3 = some, 2 = not very much, and 1 = nothing at all. Some respondents indicated their level of knowledge was in between "a great deal" and "some," so their responses were assigned a value of 3.5. Respondents with scores of 3.5 and 4 were considered to be high in intellectual religiosity, those with scores of 2 or 3 were considered to have a medium level of intellectual religiosity. Both 3.5 and 4 were taken as indicators of high intellectual religiosity because some respondents lowered their self-assessment out of modesty because they were not religious scholars. In addition, if respondents indicated while answering specific questions about

religious practices and beliefs that they did or did not know much about these, this information was used to supplement the data from question 1.

Hassan (2007) constructed indices for each of the five dimensions he measured. For purposes of this study, respondents with top index scores for any of the dimensions were considered as scoring high in religiosity for that dimension. Questions 15-21 relate to the ideological dimension. Hassan (2007) constructed an Index of Orthodoxy for this dimension by scoring the first response from questions 15, 17, and 19-21 as 1 and all other responses as 0. Respondents with a score of 5 had a high Index of Orthodoxy, with 0 indicating a low index of orthodoxy. As there were 7 questions in this group, the scale for this dimension went up to 7 instead of 5. Although question 22 relates to this dimension, it was not used for calculating the Index of Orthodoxy for this dimension. Instead, it was used to look for patterns or trends in relation to evolution acceptance scores. For the purposes of this study, respondents with scores of 6 and 7 were considered to have a high ideological religiosity, those with scores of 3, 4, or 5 were considered to have a medium amount of ideological religiosity, and those with scores of 1 or 2 were considered to have a low amount of ideological religiosity. A score of 6 was accepted as high because Americans are less likely to choose "completely true" as a response to question 20 "Do you believe that only those who believe in the Prophet Muhammad can go to Heaven?" than people from other countries.[2] This is likely due to cultural differences in their interpretation of this question, so it seemed reasonable to accept both scores of 6 and 7 as high.

Questions 2-14 reflect the ritualistic dimension. Hassan (2007) constructed an Index of Ritualistic Behavior as follows: "Performance of prayers five times or more a day was scored as one and all other responses as zero; the yes response to both having paid *Zakat* and fasted during

[2] The percentage of Muslims worldwide who say that many religions can lead to heaven is 18%, compared to 56% of U. S. Muslims (Pew, 2013).

the last year was scored as one and no response as zero; the response indicating reading of the *Qur"an* once a day, or several times a week regularly, was scored as one and all other responses as zero" (p. 455). The resulting index ranges from a high of 4 to a low of 0. To this 1 point was added for answering "a lot" to question 8 and 0 points for the other responses so that the maximum value for my Index of Ritualistic Behavior was 5. For the purposes of this study 6 was considered to indicate a high amount of ritualistic religiosity. Due to the circumstance that the respondents were all students many indicated that they do not pay zakat because they are not financially independent, so their parents pay zakat for them instead. Since they do not consider themselves to be required to pay zakat, it did not seem reasonable to lower their religiosity in this dimension on this basis.

Questions 10-14 provided another means of measuring the ritualistic dimension. Rather than ask directly what practices the respondent engaged in, this question asked how important particular religious practices were to the respondent. These were coded so that an answer of very important = 1, and all other answers = 0. If the respondent had undertaken the pilgrimage, question 14a, rather than question 14 was scored. Respondents with scores of 5 were coded as having a high degree of religiosity for the ritualistic importance dimension. Respondents with scores of 4 were also considered as having a high degree of religiosity for this dimension only if the response to question 1 was "very important." Respondents with scores of 2 or 3 were coded as medium for this dimension. Those with scores of 1 or 0 were considered low for this dimension.

Questions 23-28 addressed the experiential dimension. To calculate an Index of the Experiential Dimension, Hassan (2007) coded the reply "Yes, I am sure I have" to questions 23 and 26-28 as 1 and the other responses as 0. I coded questions 24 and 25 similarly to give a

maximum score of 6 for this dimension. Respondents who scored as 5 or 6 for this dimension were considered to have a high degree of religiosity for this dimension. Those with scores of 3 or 4 were considered to have a medium degree of religiosity for this dimension. Those with scores of 0, 1, or 2 were considered to have a low degree of religiosity for this dimension.

Hassan (2007) wrote question 29 to investigate the consequential dimension. This dimension involves a competition between religious beliefs and ideologies and other beliefs and ideologies. The second question for this dimension involved whether or not a person accepted biological evolution. However, according to Barbour (2000) science and religion may compete or they may co-exist. Therefore, simply asking whether one agrees or disagrees with Darwin's theory of evolution may confound the issue. For my analysis, I coded question 29 as Hassan (2007) did, assigning a score of 1 for "agree" and 0 for the other responses. Instead of using simple acceptance or rejection of evolution, I assigned a score of 1 only to those who were coded as having a belief in the special creation of all species. This gave a possible high score of 2 for the consequential dimension. Respondents who scored 2 were coded as having a high level of religiosity for the consequential dimension, those who scored 1 were scored as having a medium level, and those who scored 0 were scored as having a low level.

A total score of religiosity was obtained by assigning scores to the level of religiosity for the ideological, ritualistic, experiential, intellectual, ideological, and consequential dimensions. A value of 3 was assigned to each high score, 2 to each medium score, and 1 to each low score. These values were then averaged to obtain a composite score with a possible maximum of 3 and minimum of 1. Respondents with scores of 2.4, 2.6, and 2.8 were considered to be highly religious in the context of the third research question. (It was not possible for a theistic

evolutionist to obtain a maximum score, because acceptance of evolution prevented the score from being higher than 2.8.)

NOS views. All questions on the VNOS-C were administered in the interview format, rather than all in written form supplemented by 15-20% interviews as suggested by the developers (Lederman *et al*., 2002). VNOS-C was scored according to the criteria used by its developers. The answers to each question were scanned for mention of key nature of science (NOS) aspects, such as tentative NOS, the difference and relationship between theories and laws, and the nature of experiments. These were then compared to the more informed views and more naïve views given by the developers to assign the respondents values of more informed or more naïve for each NOS aspect. In addition, when responses to questions in other parts of the interview touched on NOS aspects, these were included for analysis for NOS views and coded in a manner similar to the responses for the VNOS-C questions.

Demographic information. The demographic information was scored so that respondents were considered as having a particular trait or not. The degree of acceptance of evolution was measured using the GAENE (Smith, 2011). This was treated similarly to demographic data, as it described a trait of each respondent. Respondents' answers were given numerical values as follows: 1=strongly disagree, 2=disagree, 3= neutral, 4= agree, 5=strongly agree. The totals of the numerical values for each response were determined. The higher the value, the more strongly the respondent accepts evolution. Smith (personal communication, February 27, 2014) recommended the following cutoffs in interpreting these scores: 14 – 41 no/limited acceptance, 42 – 64 moderate acceptance, and 65 – 70 greater acceptance. However, he cautioned against considering these categories as "ontological realities."

Question 1. How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?

Interview question 1 was interpreted as explained above. The degree of acceptance of evolution was measured using the GAENE (Smith, 2011) as explained above.

The ACORNS instrument was designed to focus on the following four key ideas, "(1) prioritizing recall over recognition; (2) detecting students' use of causally central information; (3) permitting co-existence of scientific and naïve ideas; and (4) attending to task surface features (Nehm *et al*., 2012, p. 751). The items were scored to determine the number of key concepts students use. These correlate with high understanding of evolution. The number of cognitive biases, which correlate with low understanding of evolution, were determined as well. By using an open-ended instrument, coexistence of scientific and naïve views could also be determined.

Interview questions 2 and 3 were coded using Barbour's (2000) categories for the compatibility of science and religion (Dagher & BouJaoude, 1997). Respondents who believed science and religion were incompatible were coded as holding a conflict view. Respondents who believed science and religion occupy different realms were coded as having an independence view. Respondents who compared science and religion or who used analogies from one to explain the other while respecting the boundaries of each were coded as having a dialog view. Respondents who formulated a more complete picture of evolution using both the scientific and religious view were coded as having an integration view.

Question 2. What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?

Interview question 1, the GAENE, and ACORNS were scored as mentioned above. Barbour's 4 categories were used to score interview questions 2 and 3 as mentioned above. Questions 7 and 8 were scored using Barbour's classifications as well. Scores and categories from these questions and instruments were compared to discover if there were any patterns in associations between respondents' views on the compatibility of science and religion and their views on evolution.

Question 3. What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?

Respondents with GAENE scores of 65 and above or those who belonged to Everhart and Hameed's (2013) category of theistic evolution and who scored high on three or more aspects of religiosity were considered to represent respondents with both a high degree of religiosity and a high acceptance of evolution. These respondents were selected for further analysis.

Religiosity was scored according to the categories developed by Hassan (2007), the ideological, ritualistic, experiential, intellectual, and consequential dimensions of religiosity as explained above.

Interview question 1, the GAENE, and ACORNS were scored as mentioned above. Answers to demographic questions and interview questions 5 and 6 were examined to determine if there were any common patterns or trends in the relationships of these items to respondents with high religiosity and evolution acceptance scores.

Chapter 4 – Results

Respondents' religious views, their stances on the relationship between science and religion, their NOS views, and their understandings of evolution interacted in interesting ways to produce the positions on evolution represented in the sample. These interactions are discussed according to research question.

In order to answer the first research question, "How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?" the stances that respondents took on evolution are introduced. Respondents' ideas on whether a person's stance on evolution entails moral consequences are explored. Levels of respondents' religiosity and their relationships to stances on evolution are explored. Respondents' religious beliefs related to acceptance of evolution, including whether they consider the Quran to be the word of God, whether they interpret it literally or metaphorically, whether randomness could play a role in evolution, and their understanding of the time frame for evolution and the age of the Earth, are examined in light of their stances on evolution. The relationships between their stances on evolution, their understandings of natural selection and their acceptance of evolution are explored here as well. This section ends with a discussion of the development of respondents' views on evolution and the development of the interactions between their religious views and their stances on evolution.

Respondents' views on the relationships between science and religion are explored in order to answer the second research question, "What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?" In order to better understand what respondents mean when they talk about science, their views on nature of science are explored here as well.

Portraits of theistic evolutionists with high religiosity indices are presented in the third section in order to answer the third research question, "What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?" Each student is presented as a specific case with his or her demographic description. Respondents' understandings of natural selection, their views on the relationship between science and religion, and their views of nature of science are explored. The manner in which each student negotiated the relationships between their views of the evidence for evolution with their understandings of their religion is discussed.

Question 1: How are aspects of American Muslims' religious beliefs related to their acceptance or rejection of biological evolution?

Respondents' views on evolution were informed by their religious views. To gain more insight into their thinking on evolution, respondents were asked to explain their positions on evolution in depth. They were questioned to elucidate their understandings of the mechanisms of natural selection and their degree of acceptance of evolution. They were asked questions to determine their religiosity. They were asked to explain their understandings of religious scriptures to determine whether literal or figurative understandings had any bearing on their stances towards evolution. They were also asked about the sources of both scientific and religious aspects of their views on evolution.

Stances towards evolution. There are three main positions that the respondents take in regard to evolution. One position is that evolution happens and that God directs the process. We can refer to this as the theistic evolutionist position. The second position is that evolution occurs for all species except human beings and God directs the process of evolution and is also responsible for the special creation of human beings. We can refer to this as a belief in the

special creation of humans. A third position is that all species are specially created, and that God is responsible for this process. We can refer to this as a belief in the special creation of all species. The participants in this study were nearly equally divided among the three positions with 32% each holding the theistic evolutionist and special creation of humans positions, and the remaining 37% holding the special creation of all species position.[3] Participants who are theistic evolutionists are profiled in table 5 on p. 273. Those with a belief in the special creation of humans are profiled in table 6 on p. 274. Those holding a belief in the special creation of all species are profiled in table 7 on p. 275.

In mainstream contexts a belief in the special creation of all species is often referred to as "creationist." I have avoided the use of this term here, because all of the respondents in this study believed that God is responsible for the creation of all living things. They differed only in the manner they believed God acted to produce living things. Also, nearly all of the respondents accepted some form of evolution. They differed in whether they accepted only microevolution, or both macroevolution and microevolution, and they differed according to which species they thought could be affected by macroevolution, microevolution, or both. Because the respondents did not fall neatly into a category where they rejected all scientific evidence for evolution and accepted only religious explanations, I thought the term "creationist" might imply otherwise.

An interview question adapted from Everhart and Hameed (2013) was designed to elicit these positions on evolution. This question was posed to the respondents by giving them a set of cards or a Power Point file set to the slide sorter view with the four responses, A: All species, including humans, have evolved over millions of years, but Allah guided the process; B: All species, including humans, have evolved over millions of years, and Allah played no part; C: Allah created humans, but all other species have evolved over millions of years; D: Allah created

[3] In cases where the percentages do not add up to 100% it is due to rounding.

humans and all other species in the form they exist today. Everhart and Hameed (2013) state, "These categories broadly correspond, respectively, to theistic evolution, naturalistic evolution, the special creation of humans, and the special creation of all species" (p. 4). Respondents were then asked to choose the statement that was closest to their view with follow-up questions to elucidate their reasons for making the choice.

Respondents' answers to the follow-up questions sometimes indicated that their answer choice did not always correspond to the intended category. For example, some theistic evolutionists chose option D because they thought the wording more clearly stated that God was responsible for creation, even though they thought that living things arrived at the form in which they exist today by the process of evolution. For example, Nadira chose both options A and D. She qualified D by adding, "and in the form they existed prior to today." She explained this choice as follows.

> It is explicitly stated how in the Quran. The way Allah used to make species the way they are today. It is very logical and you can figure it out. So, that's why I have no *doubt* that Allah created in this way and that we were created by Allah.

Some people with a belief in the special creation of all species indicated they choose option A because they were thinking in terms of micro-evolutionary changes, rather than in terms of speciation. Sayyida chose option A, and explained, "I have the belief that Allah has made everything happen. He plays a role in our life, and He is the Creator of everything." She agreed with biologists' explanation of the kinds of microevolutionary changes elicited by the ACORNS measure. The GAENE elicited her objections to macroevolution. In response to the statement, "Evolution is a good explanation of how new species arise," she disagreed. She gave the following explanation for her disagreement.

> Allah created each and everything. I don't think evolution has a role in it. I don't think the whole new species can be created through evolution. I think it's Allah who creates it.

Zaki, who holds a belief in the special creation of all species, explained why he chose option A in terms of microevolution since the creation of Adam.

> The reason being is in the Quran Allah (swt)[4] explains the process of how He created man, and it says it clearly how we were created, how Allah (swt) set humans on this earth, and as far as scholars [inaudible] Adam, peace and blessings be upon him, the first person on earth, compared to us, for example, they explain that he was so tall, and he would be much taller than the tallest person now. As far as the correct measurements, they don't have the exact measurements, but that would fall under micro. I remember in the past reading how generations ago there were much taller people than, for example, now, now there are the people that are six, six five. Previous generations ago, there were people that were taller than that, and that's an example of a micro change.

Respondents holding the view that humans were specially created chose different responses to the first interview question depending on their perception of the word "evolution." Yasmine chose the fourth response, Allah created humans and all other species in the form they exist today, but explained this choice as being compatible with the idea of evolution.

> I think it's just my personal belief, because I know there's evolution and there's these facts, but we don't know how it actually started. We don't know what the starting point was, and that's why I choose to have my faith in religion instead of science because science may not tell me everything that has, like the beginning of people.

Yasmine articulated a view that although Allah is responsible for the origination of all living things, they do evolve. She stated later that she believes God is responsible for these evolutionary changes.

> I don't think the theory of evolution contradicts religion. I think it just, I think it enhances it, because I think it's showing that God is not something that just creates stuff and then moves away, but He is directly involved. He makes them change. So, God is, you see God is All-Magnificent and Always Knowing, so to say that God made something and just stepped away like that is to contradict what God's power is.

However, she does not believe that human beings differ from our ancestors.

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[4] Swt is an abbreviation for "subhanahu wa ta'ala" (سُبْحَانَهُ وَتَعَالَىٰ) which can be translated as "May He be glorified and exalted."

> Like in processing information, because now we process information at a much higher speed because of computers, because of calculators, because of the inventions that we made. But I don't think humans are different from their ancestors in. I feel that the ancestors could have reached that potential if they had all the resources. Because when we're born, we're born the same, unless, you know, God manifests, declares that this person … has a disease, or something like that. But we all are born the same, and society is the one that changes our thought, changes our behavior, our posture, our, the way, yeah, that's what I think.

Asiya chose the first response,

> Khadija: Alright. So, you agree with the first statement: All species, including humans, have evolved over millions of years, but Allah guided the process? So, why did you choose that one?
>
> Asiya: Because, I'm actually in an evolution class right now, and I do believe that animals and humans have evolved, but I don't think it happened on its own. I think it didn't happen on its own, of course, and I believe that God was part of it because I don't think that, because I do believe in a Creator and I don't believe in like the model where He just creates something and lets it go. So, I think that God is actively involved in our lives….And we do see changes in humans as well, because there's like one that says, Allah created humans, but all other species have evolved over millions of years
>
> Khadija: Yeah.
>
> Asiya: but humans have also evolved, so.

Asiya went on to explain her position on the creation of humans in the following exchange.

> Khadija: So, why did you disagree specifically with the statement about humans?
>
> Asiya: Just my belief in traditional Islam that idea of like Eve and Adam, and I try to hold a very literal idea of that, and so that is the reason why that I don't see why evolutionary principles couldn't apply to their descendants.
>
> Khadija: Me. Mmm, OK. So you, you have a conception that Adam was created at some point, but evolution of human beings has happened since that point? Is that what you're saying?
>
> Asiya: Yes.

The distinction between microevolution and macroevolution was not made in any of the instruments used, including the question from Everhart and Hameed, the ACORNS instrument,

and the GAENE. In all cases, words such as "evolved" are used without specifying what type of evolution specifically is meant. In the current sample, few of the respondents were familiar with these terms. Even if they had heard them before, many were unsure of their meanings. Since these instruments adapted for the current study were all designed to be used as written surveys, using terminology such as macroevolution and microevolution that were unfamiliar to the respondents would have been problematic in the original studies. Because the current study was conducted by interviewing participants, it was feasible to add a question to the interview protocol on respondents' views on macroevolution and microevolution and whether these impacted their answers to the other questions.

In addition, within each of the positions found in this study, there were many variations in the ways respondents viewed the relationship between science and religion and in the ways they conceived of both evolution and creation. Here we examine examples from all three positions in depth to give a fuller picture of the positions that the participants took on the theory of evolution.

Theistic evolutionist. One position held by respondents is that of theistic evolutionist (see Table 5). A theistic evolutionist who held this position because he was convinced by the scientific evidence that evolution has occurred is exemplified by Abbas' views.

> Abbas: There's a lot of evidence scientifically that proves evolution, but being Muslim, we believe that the source of all life or all matter in the universe comes from a Supreme Being, Allah, and it just makes sense this way without conflicting with my religious beliefs.
>
> Khadija: OK. So, why do you think that?
>
> Abbas: Just the amount of scientific evidence that proves that there are common ancestors amongst many species of animals and organisms. It's almost undisputable. So, that sort of reinforces my belief in evolution, but my faith in God reinforces the part where I believe Allah guided the process.

It is clear from Abbas' statements that he uses two types of evidence as support for his position, scientific evidence and faith.

Theistic evolutionists in this study had various ways of accommodating the idea of evolution with their belief in God as the ultimate creator of all. Most or 74%[5] of the theistic evolutionists said they did so mainly because they are convinced by the scientific evidence that evolution happens and because they do not see any evidence in the Quran that contradicts this. Others more directly connected evolution to Islam. Some or 37% claimed that it is consistent with God's attributes that He would have created organisms to evolve. The idea that seeking knowledge is important in Islam was expressed by 21%. Two Ahmadi theistic evolutionists claimed that evolution is actually mentioned in the Quran. One of them also claimed that evolution is an Islamic belief and that acceptance of evolution has been a part of her religious training in some way. In all cases, theistic evolutionists in this study believe that evolution is compatible with religion.

For example, Angela believed that it is an important part of Islam to seek knowledge. Because evolutionary theory is an important part of current scientific thinking, this would make acceptance of evolution consistent with Islam. She stated:

> I feel the evolution debate is null and void, considering the scientific evidence we have. As Muslims we are required to read and understand science, and be exemplary in learning. So, for me it's like the judgment of how basing Allah's creation on human understanding is a little faulty, so I really just don't see how evolution can't co-exist with a belief in Allah and His creation of Earth, because we don't, we can't even have any understanding of Allah's mercifulness. How can we have understanding of something as complex as how He decided to create the world?

Habib saw no contradiction between the Quran and the theory of evolution. He put it this way:

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[5] Totals do not add to 100% due to participants who used more than one of these methods of accommodation.

> [sighs] The thing is for me, I know some Muslims they feel a bit antagonized by the idea. You know, it's either God or evolution, but for me, I don't see how it's impossible for God to have a part in evolution, have this system sort of play through. I know it sounds sort of deistic, maybe, the Clockwork God, but, I mean there's no definitive rejection in the Quran towards that, so I-I don't understa-. For me, they seem like two things that could play together: God creating, but also God creating like a system for our evolution, whether it's from apes to humans, whether it's animals evolving.

Theistic evolutionists in this study have different ways of integrating their religious beliefs with the scientific evidence by envisioning that evolution is a manifestation of Allah's power and/or His mercy. For example, Habib stated, "I mean if as a Muslim you take it that Allah, along with His 99 names, if He's capable of anything, then He would be capable of implementing such a system as evolution."

Nadira explained:

> To think of how things change at the genetic level or the molecular genetic level, the amount of work that goes into it, makes you appreciate the fine-tuned work that Allah has in nature. It makes you appreciate how it happens together. It makes you gain an appreciation for the power of Allah, because He has power over everything.

Other theistic evolutionists integrate evolution into their beliefs as a manifestation of Allah's mercy. Nadira explained that the long time frame involved in evolution was a manifestation of Allah's mercy to creation in the same manner that the development of religion, which was lengthy in the timeframe of human history, was a mercy to human beings.

> Maybe longer. We can guess when the world started. When you look at religion in itself, it took a long time to develop. First, there was Judaism, then Christianity, then the Prophet (saw)[6] was sent. Maybe it took longer because people and all species take change very slowly. Allah is not unjust, so that is why it takes longer. First, we had Judaism. Then religion was changed in the form of Christianity, and then Islam. The same thing applies to physical biological evolution as well….Allah does not change things too quickly due to His mercy.

[6] Saw is an abbreviation for sallahu 'alayhi wa sallam (صلى الله عليه وسلم) which can be translated as, "May the blessings of Allah be upon him and peace."

Some of the Ahmadi respondents mentioned that the theistic evolutionist position was a part of their religious training. Nadira explained, "I started learning about evolution since I was very young. My mom taught us that things change and how Allah wills it."

Belief in the special creation of humans. Participants who held that humans were specially created while all other species evolved found the scientific evidence convincing for evolution of all non-human species (see Table 6). Some participants indicated that they excluded humans due to their interpretation of verses on the Quran referring to creation. Verses describing the creation of human beings are more specific than those describing other aspects of creation, and these respondents interpreted this to mean that humans were specially created, but that the possibility of evolution is open for other species, because their creation is not specified in the Quran. As Basel put it, "In Islam, there's more of a direct explanation for how humans came about, but there isn't such a clear direct explanation of how every other species came about." In these cases, they were interpreting the verses on the creation of human beings as excluding the possibility of evolution for humans. Some participants expressed the idea that humans are different from all other species and somehow special, and this prevented them from accepting the idea that humans evolved.

> Hasina: Allah created humans, but all other species have evolved over millions of years.
>
> Khadija: OK. And why did you choose that one?
>
> Hasina: Because I did take evolution, parts of evolution bio, so, like the hard evidence that I saw, it kind of shows that there is some type of evolution or progression of species from one thing to another. Does that make sense?
>
> Khadija: Yeah.
>
> Hasina: OK.
>
> Khadija: Why don't you think that humans evolved?

> Hasina: Only because Allah put Adam and Eve on this earth, and they were the first humans on this earth, and I don't think we've evolved from like as what the actual evolution is, like from before *Homo sapiens* and all that. I don't think that we've evolved from that to this.

Jason justified his disagreement with the idea that human beings evolved from a previous species by stating that he did not find the scientific evidence for this convincing. This evidence was sufficient to convince him that other species did evolve, however.

> Khadija : Evolution is a good explanation of how new species arise.
>
> Jason: Oh, new species. I would agree, yeah. I would agree.
>
> Khadija: Could you tell me why you have a specific disagreement about humans?
>
> Jason: Because I know, maybe, like parts of countries, you know, people with darker skins, they could evolve into darker skins, because the climate that they are in compared to those in different parts of the world that are light-skinned to adapt to different needs. I could see that could be part of the, you know, evolution over time. That's the part I would agree on.
>
> Khadija: Alright, what would you disagree with?
>
> Jason: Disagree is like evolving from apes to, starting from apes to humans. I would say that, evolving from apes to humans.
>
> Khadija: And why would you disagree with that part?
>
> Jason: Because, I mean they use the example that apes have five digits. I mean, I know koala bears also have five digits. I'm pretty sure I didn't evolve from a koala bear or it just doesn't, just that reason, I guess. I mean, I don't know. I can't really give you strong evidence why not.

Salahuddin did find the scientific evidence convincing, but was not willing to accept the idea that humans evolved because of his belief that religious evidence is stronger than scientific evidence. However, he was open to the possibility that he was misinterpreting the verses on the creation of humans in the Quran and that humans did in fact evolve.

> Salahuddin: The third one, Allah created humans, and all species evolved.
>
> Khadija: OK. And then, why did you choose that one?

Salahuddin: It makes sense to me, because if you look at the Quran and also the Bible, God says that He blew His soul into Adam, but it also says that the heavens and the Earth were as one unit of creation, and also, "We created from water every living thing."[7] So, I don't see them as being apart. The fact that God blew His spirit into Adam can be taken symbolically, but I think that might be stretching it, although I wouldn't be surprised if we did evolve with the other species.

Khadija: OK, and so why do you think that?

Salahuddin: What do you mean?

Khadija: So, you're telling me, alright, so it makes, C makes sense, that Allah created humans, but other species evolved, and so you're saying about God blowing His soul into Adam. So, but that could also be symbolic.

Salahuddin: It could be. I mean, I wouldn't be surprised if it is more evolution, but just from the way the verse is, it sounds to me like that Adam and the jinn and the angels were all created separately from that process.

Khadija: OK.

S: But at the same time, one of God's names is al-Bari, which has been translated as the Evolver.

Although Rafiq's views on human evolution were shaped by his religion, he gave other reasons for his objection to human evolution.

Khadija: Alright, so earlier you said humans and animals and plants and all living things evolved, but here you're saying evolution, you disagree with evolution as a good explanation of how humans first emerged on the earth. So, why did you disagree here?

Rafiq: Say, can you give me the questions again?

Khadija: So, before, like in the beginning you said, so I asked you about macro and microevolution, and you're saying, "It did happen, so I believe in both to humans and all animals and plants, and all living things."

Rafiq: Right.

Khadija: So, but here, when I said, "Evolution is a good explanation of how humans first emerged on the earth," you put disagree. So, I'm asking why?

Rafiq: That question is kind of worded differently. I disagree with that one. I believe that we did evolve from previous ancestors, but when you tell me actually that when we

[7] 21:30

> first evolved from like the very first human being, that's kind of, you know, that they're come from another species, we're not, we didn't come from monkeys. Do you see what I'm saying? Because religiously, obviously Adam and Eve were the first human beings on earth, correct?
>
> Khadija: Um hmm.
>
> Rafiq: According to my religion.
>
> Khadija: Yeah.
>
> Rafiq: So, that's why I'm telling you that we, the very first human beings did not evolve from previous species, but we did evolve from our ancestors, such as Adam and Eve. That's my view on it. I do agree that we did evolve, but not from other animals, from our own species.
>
> Khadija: OK. And then, why do you think so? …
>
> Rafiq: Because we, I mean we didn't evolve, although our genes are very similar to monkeys or even similar to mice, but we didn't evolve from those animals, because we are, humans are different than animals. We have, we're different in the aspect that we, we're different animals. We're have souls, we communicate, we have, we can talk. We're different. We're very different. We're unique and powerful animals. Our brain has so many capabilities that not any other animal has, and that's from Allah. We didn't evolve from the monkeys, although they do have similar brains, but I mean, still.

Belief in the special creation of all species.

A third group of respondents held that all species were specially created (see Table 7). They based this assertion on their religious beliefs. For them, their religious beliefs provided stronger evidence than science.

Umm Salama described her position on evolution in an e-mail she sent prior to the interview in reply to my e-mail attachment of the power point slides with the responses to the first question:

> I do not feel fully comfortable with any one answer. Can you clarify something for me? Although I am NOT an expert, should I interpret evolution to mean macroevolution as opposed to microevolution?
>
> I only have VERY basic biology background so I hope this question does not reveal my ignorance. If this helps, here is what I believe,

- Adam was created the way he existed, so we did not evolve from apes.
- Human beings vary by color, language, etc. etc. (microevolution?...)
- Species' appearance, disappearance, variation is guided by Allah (microevolution) and within His control, plan, *ruboobiya*,[8] etc.
- Our system of classification and our deficiencies as human beings may serve as an explanation as to why science in of itself suggests hypotheses that contradict Qur'an and Sunnah.

With these points in mind, which box do I fit in? I hope I am not ignorant of biology to be of assistance....

I asked her to elaborate further during the interview:

Khadija: OK. So, tell me your answer for both of them. So, if it's macroevolution, what would your answer be?

Umm Salama: No, I don't believe that people macro-evolved, and I don't think I believe in macroevolution across the board for animals as well.

Khadija: And then what about microevolution?

Umm Salama: Yes, I think that that's what we see and what there's actually a lot of evidence for, just from my basic understanding, my biology course for non-biology majors.

Khadija: OK, and then, so why do you think that?

Umm Salama: Well, look, the reason I think that, I don't think that they have evidence for the animals. Right, you're asking about the animals?

Khadija: Well, for, you can, yeah, you could do animals and people separately, if those are separate for you, however you want to answer.

Umm Salama: OK. For people, the reason I believe that, I believe that people are created on their own image, is because I believe that there's some evidence in the Quran and Sunnah for *ahadith*[9] that says that Adam was created on His own image, like from clay, and then the ruH [soul] was blown into Adam. Because of that I don't believe that people evolved from apes or there was some kind of an in-between people that didn't have language, because that was another thing that the Quran talks about is having different languages, that we're created with different languages and different colors.[10] To add to that, I would say that, from what I've viewed, the lectures that I've listened to, one

[8] *Ruboobiya* refers to God's qualities of having ownership and control over all of creation, of having planned for the creation and then creating, but also caring for the creation, nurturing it, and developing it.
[9] *Ahadith* is the plural form of Hadith.
[10] 30:22

> of the things that I've read, it's kind of like, it is still a theory, and they don't have a lot of in between examples. With all the fossils that they've found, and things that they've found and dug up, there aren't, it's kind of like there's big leaps between forms that they haven't found any proof for it.
>
> Khadija: OK, so you're giving me evidence from hadith and Quran for Adam (as), but for animals, what about them?
>
> Umm Salama: That's why I said I'm not really sure. I don't feel like, since I don't, I haven't come across Quran and hadith for it then I think it's open. You know, it's open for science, and I could go either way on it. If I'm presented with something, I'm not going to out and out just say no, like I would with things that are very, with proof from Quran and Sunnah.

Most of those holding the position of special creation of all species did not reject scientific evidence altogether. Many accepted the idea of microevolution occurring for all species, although they generally preferred to use the term "adaptation" for this process. This may have been because most respondents were unfamiliar with the term "microevolution" until I explained it to them during the interview. (Umm Salama was one of only a handful of respondents who understood the term "microevolution" prior to the interview.)

For example, Hadiyah gave some weight to scientific evidence for evolution by explaining that microevolution was a means for organisms to adapt their changing environments.

> Well, I know that I've seen different types of animals: birds and reptiles and different things like crocodiles and alligators. I'm sure that over time that their environment changed, and they changed with their environment. So, to me, this is a just another thing to marvel at. When you think about Allah and His creation, everything changes over time, but how does it change? Well, of course, as a Muslim, I believe it changes with the will of Allah, with the power of Allah, so I do believe that even the land, not just the animals, every creation, the trees, the plants, everything has changed over time, so of course it's only logical for the things that live in the environment to change with it, and I think that is something that, you know, it shows us the power of Allah, like how He, how He can adapt the things over time, and things change with their environment.

Some of those who held that all species were specially created nevertheless saw a stark difference between human beings and other animals. Lena expressed the contrast several times during her interview.

> Lena: Like I said, a large part of that, or portion of that lays its foundation in my religion, and being what I know from my religion that it, Allah tells us that we're not an evolved creature. We are descended from Adam. He created Adam. He didn't create Adam as a monkey. So, that being said, I, one, I can't believe it on a religious standpoint, and on just we're not animals. Well, I guess some people science-wise say that we are an animal, but I just don't believe that we are from, descended from animals. I think that animals are one thing and humans are another, regardless of our similarities.
>
> Lena: Because they are a different creature altogether. I don't think that humans and animals are the same thing. So, to say an animal could evolve is not out of the realm of impossible, but at the same time, I don't believe that humans evolve. It's like saying, for example, a shark has the ability to turn into a monkey over thousands of years, or however long lengths of a distance you would like to consider it in. A fish, or a shark, or whatever, it just doesn't have the capability to turn into a, a monkey. The same thing with a human, our genetic make-up doesn't, [sighs], doesn't have the capability of turning into a fish, because we're different species.
>
> Lena: OK, that's what, that's what I, correct me if I'm wrong, they believe that animals are, that humans are animals, therefore humans should be able to intermate with, for example, a monkey, and come out with a half-monkey, but that doesn't quite work, right? So, I would say completely inaccurate, if that was the case. You know there is a preschool song that, that I came across while teaching my kids, and it's called "The Animal Song." In "The Animal Song," it has humans. Basically, "The Animal Song" teaches them about the different sounds that animals make, and I completely refuse to use that song with my kids, because it lists humans as animals, and I'm just like, and it says the humans, what do the humans say? They go blah, blah, blah, or something, blah, blah, blah. And I'm just like, OK. With all these sheep and the cows and the monkeys, you've put humans in that song? OK, ha! Well, then, if that's the case, we should be able to interbreed, right?

In contrast, Umm Salama did not believe that humans are in any way superior to animals, but rather that all are God's creatures and subject to His will. For her, evolution of human beings was impossible solely due to her interpretation of religious texts, and not due to any aversion to the idea that we evolved from animals. In her reply to a question on whether the theory of evolution presents a conflict between science and religion, she responded, "The only reason I'm rejecting the macro part, it's not because I feel averse to apes, and I don't, you know, I feel like I'm better than them, but if Allah says that He created us in that process, then I wouldn't have a problem with that, but because of that hadith I reject that part of it."

These three positions, theistic evolutionist, belief in the special creation of humans, and belief in the special creation of all species, were present among members of all three denominations examined here, Sunni, Shia, and Ahmadi. Non-specific Muslims in this study held either the theistic evolutionist position or the belief in the special creation of all species. There were only six members of this group in the sample, so it is possible that members of this group who hold a belief in the special creation of humans exist and were simply not present in this sample. The three positions were present among White, Asian, and mixed participants. African-Americans in this study held either the theistic evolutionist position or the belief in the special creation of all species. There were only seven members of this group in the sample, so it is possible that members of this group who hold a belief in the special creation of humans exist and were simply not present in this sample. Converts in this sample held either the theistic evolutionist position or the belief in the special creation of all species. There were only twelve members of this group in the sample, so it is possible that members of this group who hold a belief in the special creation of humans exist and were simply not present in this sample. All three positions were held by people who were born into Islam. All three positions were held by both American-born and foreign-born Muslims in this sample, by both males and females, by both traditional and non-traditional students, and by students holding all four class ranks, freshman, sophomore, junior, and senior.

Moral consequences for acceptance or rejection of evolution.

Most respondents did not think there were any moral consequences related to acceptance or rejection of evolution. Many asked me to repeat or rephrase the question and it was clear that this was an issue that they had not thought to consider before hearing my question. This exchange with Afifah was typical of this reaction.

Khadija: Are there moral consequences for either accepting or rejecting evolution?

Afifah: Moral objections?

Khadija: Um hmm, yeah.

Afifah: I can't think of any.

Hamid explained why he thought there were no moral consequences.

Khadija: Are there moral consequences for either accepting or rejecting evolution?

Hamid: What do you mean?

Khadija: Like would it be a sin to accept or to reject evolution?

Hamid: That's a good question. I think everybody has the right to believe what they want. I don't think it's a sin or-- whether you believe it or not, that's 100% your choice just based on your own beliefs. So, I can't tell you whether if somebody believes it, it is right or wrong. Just because I don't believe it, doesn't mean I'm right, and just because somebody does believe it doesn't mean that they're wrong. It's just based on their own person so I don't think there's a moral sin to it or moral consequences.

Yasmine reasoned this way.

Because your belief should not contradict reason. It should, for, I mean, well, there are some things you just have to trust in your heart that they are true, but it shouldn't be burdensome to science and to common reason.

A couple of respondents found the idea of moral consequences being attached to evolution laughable. James exemplifies this response.

Khadija: Are there moral consequences for either accepting or rejecting evolution?

James: No. [He seems amused by the question and laughs.] There would be if it was against the common good or harmed humanity in some way, but I think it's almost trivial. It's almost knowing it or not knowing it either won't harm people.

Some respondents believed moral consequences could ensue from acceptance of evolution if it entailed a rejection of God. Jason explained it this way.

Khadija: Are there moral consequences for either accepting or rejecting evolution?

Jason: Accepting his, that thing, that the Darwin theory of evolution?

Khadija: Yeah.

Jason: I think definitely consequences, because that would lead the person go astray not believing in. I think that would cause moral consequences definitely.

Khadija: OK. Why do you think that's the case?

Jason: Because you have, I think that there's a denial, you're denying the existence of a Supreme Being. You're denying the, you're accepting the fact of you have nothing. Living things started from nothing, non-living matter to mono-cell, and then developed stage by stage to become a human being. So, basically, you have nothing from nothing, you have something, and that would cause ignorance. I mean that would eventually lead to jahiliyya [ignorance], or not believing in God would cause a person to go astray. However, it could cause awareness as well if the person is open-minded and looking from both sides, not just from one side of things. You know looking at this, how could nothing? I'm not sure, because I really don't have much knowledge about this, but if I'm wrong with any, like any, when I say anything to you, just let me know, because I don't really know much about the specific.

Khadija: Well.

Jason: Yeah.

Khadija: On that, I mean this isn't a right or wrong standpoint, these questions.

Jason: Yeah.

Khadija: It's just that I want to know what your opinion is. So,

Jason: Yes, I would say, I would say it definitely cause moral consequences, and it depends on the person. It could also cause awareness, you know, as long as the person's open-minded, knowing both sides, which is fine, which is OK. But just going into the subject of closed minds considering that there's no need for a Supreme Being, then yes, that would cause a person to go astray.

Interestingly, Jason perceived both positive and negative moral consequences from acceptance of evolution. It could lead a person to stray from religion, a negative consequence, but consideration of the theory of evolution could also lead to open-mindedness, a positive consequence.

For some, even if acceptance of evolution entailed rejection of God it did not have negative moral consequences. Rabia, a theistic evolutionist, explained it this way.

Khadija: Are there moral consequences for either accepting or rejecting evolution?

Rabia: When you say evolution are you talking about the godless framework of evolution?

Khadija: Well, you could answer that way. So, if it's the godless framework, what would be your answer?

Rabia: Gosh! I really don't know. I don't believe so, because I don't think, I think that if you don't believe in, obviously I think my view is right, but I don't think that because your view is different than mine that makes me wrong, and I don't think that God is up there looking for reasons to send us all to Hell. So, I think if my view is right, and your view is wrong, then maybe that's just an area where we are supposed to get together and communicate, and not so much an area where God is going to give you consequences for not hearing what I have to say and immediately following what I have to say.

Others, even if they did not accept evolution themselves, did not see any moral consequences if acceptance of evolution did not necessarily preclude belief in God. Latifa, who held a belief in the special creation of all species, explained it this way.

I just don't really see it as like a moral issue per se. I don't think that because, like I said before, I don't think because we accept the theory of evolution that we are rejecting God, because I don't think it has to be one or the other. Because of that, I don't think that there's necessarily moral consequences, or I believe that you could accept it, or you could accept it and also believe that God had something to do with it, or you could accept it and not believe in God, and that would be like, I think that aspect is more of like what constitutes good or bad, and the part that you think God has to play in nature, but I don't think you have to reject the existence of God or the role of God to believe in the theory of evolution.

Umm Salama, who had a belief in the special creation of all species, thought that acceptance of evolution might actually lead to moral behavior in people who did not have a belief in God.

Khadija: Are there moral consequences for either accepting or rejecting evolution?

Umm Salama: For Muslims? For me as a Muslim, for people in general, which?

Khadija: If you think it differs, you could tell me the different responses. That's fine.

Umm Salama: OK. Maybe it might if you were a person that was an agnostic or a humanist who didn't believe in God at all. It might I think if you accept the theory of

> evolution, I think you might have a more, feel like you are morally obligated to other parts of creation, other like animals and I could see it maybe having an effect to animal rights in that way. For a Muslim I think the morality is not affected at all either way.
>
> Khadija: What? How? OK, so you're saying animal rights. How would that play out? Exactly what would that mean?
>
> Umm Salama: I feel like that as people, it's accepted that we, that we are all part of the animal kingdom in that way. I'm not talking about Muslims, because Muslims are required be a certain way towards animals, that Allah tells us that regardless of whether we descended from apes or not, right? But somebody maybe who doesn't have a religious background telling them that which, it doesn't mean that because they don't have religious background they aren't already respecting animals, but it might be, like let's say, in a list of reasons to give animals more respect, more rights, not in terms of torturing them even, just preserving habitats and doing things so they aren't destroyed, all of those things would be, this might be on a list of reasons to have more respect for them and their habitats and their existence, because I think that you would feel more like they are family, I guess. That's for somebody who didn't have any other moral inclinations to treat them well.
>
> Khadija: OK. And then I interrupted you when you were talking about Muslims. Was there something else you wanted to add?
>
> Umm Salama: Just that I don't think it has any moral implications for Muslims. It doesn't change how we should treat animals or the Earth or each other. All that is, I guess, laid out, whether or not we descended from apes, or we just were created as we were. There's no. Nothing would change. It's a non-factor.

For Umm Salama acceptance of evolution could give non-religious people a reason to behave morally towards animals. For Muslims there would be no moral consequences either way, because they are already morally obligated to behave ethically towards animals as a part of their religious faith.

In contrast to Umm Salama, Carlene thought that the belief that humans were descended from non-human animals would itself entail moral consequences.

> Okay so the fact that you believe everything is ordained, I don't think there is any moral consequence, because I don't see how God can judge us for something that we aren't able to observe or repeat. I don't think a loving merciful God will be so harsh as to do something like that. Another moral consequence is, I guess, if you feel like people are in the same category as animals and we came from monkeys, I think you'll treat humanity differently, that you'll see other human beings in a less important right. Maybe you don't

have as much respect for life as if you are growing up having the thought, or adopt the belief that people are a special creation of Allah (swt) or where whoever you call God, I think you have a different level of reverence when you separate human beings from the rest of the animal kingdom. If you just see people as being like any other animal that supposedly came out of the water and transitioned from frog and tadpole, whatever, then I think that you have a different kind of respect for life, and so the moral consequences might be that you are more accepting of some inhumane practices or some different thing for people that you otherwise wouldn't regard as acceptable if you felt that they were significant and different and special and totally different from the other animals. I don't really think that things happen at random and there was no creator or perhaps the Creator left. I think that people who believe so and what reason is there to keep competing and trying to survive and stuff if everything is random, and there's really no intelligence behind anything, and it's just like survival of the fittest completely? So I think people do lose their morale. They're careless about their behavior, and that it's all about the individual themselves, and people lose respect for humanity and other people.

Some respondents mentioned social as well as moral consequences. Hanif viewed acceptance of evolution in a negative light.

Hanif : Because I believe the Quran is the word of God and I believe the story of Adam is literal, and not metaphorical or anything, so I believe that the story gives us a clear, and along with the hadith, the authentic hadith, hadith which I feel to be authentic that also refer to the creation of Adam. So, I believe Adam was created from clay and formed and shaped by Allah. So, these are the reasons why I would say human beings 100%. The other macroevolution I would say 95% on that, but it's not something I would, you know, would say you're stupid. You know, gee, I would say you're stupid for believing that.

Khadija: Yeah. [laughs]

Hanif: But if I got into a debate with someone about evolution, I couldn't say 100% I don't think that happened, but I'm pretty sure it didn't. So, I don't believe, like you said, like I said, reptiles turned into birds, but if someone's trying to prove it, oh, maybe they did have, and I'm not going to fight that tooth and nail.

For Hanif acceptance of macroevolution entailed moral consequences.

Oh, that's a, ha! Well I would say the moral consequences of accepting evolution, they can come into play if a person's belief in evolution causes them to reject, which many, a lot of atheists, their way of refuting the existence of God is evolution. I would say this can destroy a person's morals, because if they don't believe that there is a Creator they would have no, *some*, some people would have no reason to believe in right and wrong, no reason to believe that there's consequences for the way that you live your life. This doesn't affect all atheists. There are some, I've known some atheists who are generally good people. They're nice people. They believe in being kind. It's not every single one, but there *can* be moral consequences through evolution. It's not a blanket, I don't believe

> it's a blanket statement that affects all atheists or all people who, I guess everyone who believes in evolution is not an atheist, but if you go that route, it can happen. And I've heard theories before that in the past certain people who believe in evolution, and they felt that certain races had evolved, you know, more than other races, and this caused them to be better and they kind of used this as support for racism, and things like that. I haven't looked at it that deeply. I don't know how prevalent that is or has been, but things like that can happen as well. As opposed to, I think like in Islam or Christianity or Judaism where the general belief is, I mean if anyone can take a text and skew it to their view, I know that's been done before. Slavery was supported by people who used the Bible to support slavery in the United States, but that clearly I think anyone with common sense knows that's not what the text was meaning, but in general most people of faith I think a lot of times believe people were created equally, whether they put that into practice or not in the past, but, in general I think that is what most of the religions call to.

For Hanif acceptance of evolution may or may not lead to moral consequences, depending on the person. The moral consequences could be unethical behavior stemming from a belief that there is no Creator to hold them to account for their deeds. Acceptance of evolution could potentially be used to justify unethical behavior, such as racism.

Ayyoubou went into more detail on possible social consequences of accepting evolution.

> As far for accepting evolution as a Muslim, I think there might be a consequence because they will say this Muslim doesn't have the correct creed. For rejecting it, there are no, I don't see any other, another consequence. But as far as saying that evolution exists, and it's true, well, when a Muslim have such a view, well, most likely 99% of the Muslims would say you don't have a correct creed because this is not something that has been mentioned in the Quran, because Allah (swt) He told us that He created Adam. Was there another human being or another species before him? We don't know, but as far as I know, I would stick to what the Quran says. So, I believe that there is no major consequence when a Muslim believes in evolution, but some Muslims would-- I don't know what's the exact term I should use-- they'll say that he doesn't have the correct creed. I don't know. I think he would still be accepted in the community, not rejected.

Najila envisioned social consequences from people who might look down on someone who does not fully accept evolution.

> Najila: I don't think there are moral consequences, just social consequences.
>
> Khadija: Social consequences?
>
> Najila: Yeah.

Khadija: Such as what?

Najila: I guess if you have a conversation with someone who doesn't really believe in, not necessarily in God, but someone who doesn't believe that people were created as people, someone who just takes the hard facts of science and looks good into them, I think there are some social consequences that that person might think you're, I guess, inadequate in your thinking because you don't necessarily just approve of everything science throws at you. You're second guessing, and that person might not, so in that way social consequences, but morally, I don't think so.

Although social consequences were mentioned by several respondents, they were not severe, because they did not entail exclusion of the person from the Muslim community.

Although there were not moral consequences attached, Asiya viewed rejection of evolution in a negative light.

But I do think totally rejecting the idea of evolution when there is evidence of changes, I think it's a little bit ignorant. So, I don't know about moral consequences, but I do think it's ignorant to totally not pay attention to things that are kind of obvious.

Although Asiya accepted evolution for all but humans while Hanif rejected evolution for all, they were similar in their disapproval of those who did not interpret the evidence in the same way that they did.

Some respondents thought there might be moral consequences for rejection of evolution. Naima jokingly explained it this way.

Evolution in my mind is growing in time, things changing, changing to become better, or worse, depending on how you look at it. I believe that there's consequences in not believing in change. By being the same, you can't really learn from your mistakes. You do the same thing over and over again and get the same results. So, yes, I do believe that there is consequences in not believing in evolution. After all, if there was no evolution occurring, *Tyrannosaurus rex* would still be alive, and we would be eaten every day. By the way, you might be giggling a lot during this interview.

Sana explained it this way.

I think that if you reject evolution-- I guess it depends on the way that you look at it. If you look at it that God has put evolution into place so that the beings that he started life with can develop over time to be smarter, better adapted to their environment, even humans for that matter, if you look at it that way, then that might have moral

> consequences, because if you do believe that *Homo sapiens* started from, whether you believe it's from monkeys or from other organisms that we were allowed to become the thinking beings that we are today, thinking enough that we can even read the Quran or accept Ahmadiyya, then that would be problematic because then you're suggesting that even to go as far as to say Ahmadiyya wouldn't have existed in the first place, maybe even if you think of it that way, but if you reject evolution, meaning like you just reject the process of certain parts of it, then that might not be problematic, I guess. It depends on how somebody would specifically ask the question.

Most respondents did not believe that either acceptance or rejection of evolution had any moral consequences. A few (8%) ventured to say there might be social consequences, but even those were minor consequences. Overall, 58% of the respondents thought there were no moral consequences. This included respondents with all three stances on evolution: theistic evolutionists, those with a belief in the special creation of humans, and those with a belief in the special creation of all species. Alternatively, 27%, or 16 people thought that accepting evolution could have negative moral consequences. Of these five people specified that this was only if this led to disbelief in God, and not otherwise. Only one theistic evolutionist held this position. Only those with a belief in the special creation of humans and those with a belief in the special creation of all species thought that acceptance of evolution could lead to negative moral consequences. The idea that accepting evolution could have positive moral consequences was entertained by 12% of the respondents. These held all three positions on evolution. Interestingly, all four of the theistic evolutionists who thought there might be positive moral consequences for accepting evolution and/or negative consequences for rejecting it were Ahmadis.

Religiosity. Respondents' religiosity was measured using a modified version of Hassan's (2007) measure of the dimensions of Muslim piety. This measure divides religiosity into 5 dimensions: ideological, ritualistic, experiential, intellectual, and consequential. Numerical values of 1, 2, and 3 were assigned to responses rated low, medium, and high, respectively.

These were averaged to obtain a composite score of religiosity for each participant with a potential range of 1 to 3. Respondents' religiosity is profiled in Table 8 on p. 276 for theistic evolutionists, Table 9 on p. 277 for those with a belief in the special creation of humans, and Table 10 on p. 278 for those with a belief in the special creation of all species.

There were five participants with the highest possible score of 3 and all of these were people who held a belief in the special creation of all species. Both those with high religiosity scores of 2.6 or 2.8 and those with medium religiosity scores from 2 to 2.4 included people with all three stances on evolution. Of those with low religiosity scores between 1 and 1.8, there were six theistic evolutionists, three people with a belief in the special creation of humans and only one person with a belief in the special creation of all species.

The scale was set up so that theistic evolutionists could not obtain a score on the consequential dimension higher than medium or 2 because rejection of evolution was required for a high score of 3. Therefore the data was scanned to look for theistic evolutionists with scores of 2.6 or 2.8 to obtain highly religious accepters of evolution. There were three theistic evolutionists in this range, Nadira, Samra, and Sulayman, respectively. Two of these respondents, Nadira and Samra, had a score of 3 for four of the five religiosity scores. Sulayman had a score of 3 for three of the five. The data was scanned for other theistic evolutionists with scores of 3 on three of the five religiosity measures. This yielded three more respondents, Sauda, Ali, and Sana, all of whom had composite religiosity scores of 2.4.

The Quran is the word of God. Respondents were asked the following question. "Which comes closest to your view? The Quran is the word of God. The Quran is a book written by men and is not the word of God." All but five of the respondents chose the first

option, indicating that they believe the Quran is the word of God, as indicated in tables 8, 9, and 10.

Those respondents who did not unequivocally choose the first option went on to explain their choices. Salahuddin explained, "Word of God, but I would also qualify it with word of God, and in some instances, it refers to the history of men." It would seem from this explanation that he believes that God is the one referring to the history of men, because there are a number of historical references in the Quran.

Salahuddin thought that the Quran was a mix, because it contained the word of God, but spoke of the affairs of men. He is a Sunni Muslim, born and raised in Islam. At the time of the interview he was learning Hebrew and was studying the Old Testament and reading it in Hebrew. He was fluent in Arabic and was quite familiar with the Quran, frequently reciting verses and phrases from the Quran in Arabic throughout the interview. He was used to making thorough analyses of scriptures in general including the Quran, and so he analyzed the question posed to him, going into depth to answer it, rather than taking it on its surface. Even so, it was clear from his answer that he believes the Quran contained the word of God.

Four respondents indicated that they did not view this question as dichotomous and therefore their position fell in between the two positions or was a mixture of both. They were Salim, Rabia, Halima, and James.

Salim explained the following after taking a long pause to thoughtfully consider the question,

> I believe it's, I believe [sighs] I believe it's a mix. I believe the word of God is within the Quran, but we're only human. We make mistakes, and maybe some of the wording, some, maybe what the Holy Prophet was, maybe what the stuff the Holy Prophet said was received from Allah may have been interpreted the wrong way in some verses, or other verses here and there, and may not fully be the word of God, but I believe it's, a lot of it is the word of Allah, and a lot of it is the word of men of the age.

Salim, who was born and raised as an Ahmadi Muslim, was influenced by the Bible, because he obtained his K-12 education in Christian schools. He took a more analytical interpretation of the question and included both the word of God and human interpretation of that word in his conception.

Rabia explained her views in the following exchange.

> Rabia: I think it's somewhere in the middle. I think, how do I explain my view on this? I think that in the process of, in the same way, in a similar way that the Bible has been changed by man, but not exactly, I do think that certain things have been changed in the Quran, because, you know, I'm not a historian. I'm not a scholar, but my understanding is that there was a point in time when all of the Qurans, you know, like it wasn't really strict how things were written down, because of all the different dialects, whatnot, and so at some point, whoever it was at the time, Umar, or somebody, told everybody to burn all of the Qurans, except for this one particular translation, and everybody was going to use that translation, and so I feel like maybe some things were changed or missing or added, or something. I just don't think we have the whole picture. I'm not saying that I think the Quran that we do have today is not the word of God. I'm saying that I think some information is probably missing. Does that make sense?
>
> Khadija: Um hmm.
>
> Rabia: OK. In other words, let me just add to that.
>
> Khadija: Um hmm.
>
> Rabia: I don't believe that we can walk around and say, well, the Quran says it, and that's what's going to happen. When we're talking in terms of like people's lives, you know, people say, "Oh, well the Quran says to kill them, kill the infidel," or whatever. I don't even know if it says that, honestly, but I don't feel like that we can look at that when we're talking about somebody's life, somebody's very existence and say, "Well the Quran says it, so this is what we have to do." It's not absolute like that. That's only one piece of my opinion on that. I won't even go into the rest of it right now.

Both Salim and Rabia consider the word of God to be in the Quran, but they expressed concerns that people could misinterpret the word of God in a way contrary to its intended meaning. Rabia added the additional caveat that there might have been some parts of the Quran that were not included in the final official version.

Rabia was a convert to Islam for about 15 or 16 years at the time of the survey. Being Muslim was an important part of her identity. In response to the question whether she considered herself Muslim first or American first, she stated, "Certain things are like built into who you are, and Muslim is *one* of those things, but it's not *everything* I am, so, that's hard to answer." Despite having being a Muslim integrated into her identity, she struggled to answer some of the questions in the religion part of the survey, because she was experiencing some doubts about some of the traditional interpretations of these topics. It was in this spirit of critical analysis and questioning that she considered the interplay of divine revelation and human interpretation salient to whether or not the Quran is the word of God.

Halima indicated that her position was in the middle and that she was not sure which option was correct. She went on to explain that some parts of the Quran would make sense if they were from God, because only a higher being would know those things. She remembered her father speaking to her about the literary qualities of the Quran and how even the best poets could not write anything near it. She pondered, "Sometimes I think about where it's from exactly." Halima no longer self-identified as Muslim stating, "My beliefs no longer coincide with Muslim beliefs." When I asked her what she considers herself to be now, she replied, "Spiritual."

Halima was unsure whether the Quran was the word of God or not, but she had trouble reconciling the idea that it was not the word of God with what she knew about some of its subject matter and its literary qualities. She was in the process of distancing herself from Islam after having left the faith. Her ideas were greatly influenced by Islam in many instances. She was still in the process of forming an identity as a non-Muslim at the time of the interview and so

she had not thoroughly thought through all of the implications of this decision. As such, her opinion of the Quran was still ambivalent.

James indicated that he was unsure whether the Quran was revealed verbatim to the Prophet or whether it represented the Prophet's rendering of the ideas that were revealed to him in a language that would be intelligible to his people. James was a new convert to Islam, having been a Muslim for less than one year. As such, his views may have been due to a lack of knowledge about the process of revelation and compilation of the Quran rather than to a particular philosophical stance on these issues.

Nearly all of the respondents considered the Quran to be the word of God. These included people with all three positions on evolution as well as Sunnis, Shias, Ahmadis, and those identifying as just Muslim, as shown in Tables 8, 9, and 10.

Five respondents did not consider this to be a dichotomous question. Two were born Muslims, two were converts to Islam, and one was raised in Islam, but no longer considered herself to be a Muslim. Of these, four respondents did consider that at least some of the Quran was the word of God or that it at least contained ideas that were revealed by God to the Prophet Muhammad, and one was unsure whether it was the word of God or not.

Literal vs. metaphorical interpretation of scripture. Respondents were directly asked if they thought everything in the Quran should be taken literally word for word or not. All three groups, theistic evolutionists, those with a belief in the special creation of humans, and those with a belief in the special creation of all species, included both people who thought the Quran should be taken literally word for word and those who thought it should not be taken literally word for word, as shown in tables 8, 9, and 10.

Although the question on whether or not to take the Quran literally word for word was contained in the religious survey part of the interview, and did not include any follow-up questions for clarification or elaboration, twenty of the respondents volunteered explanations of their views on this matter. For them, this was not simply a yes or no question.

The necessity of a person having specialized knowledge to be able to properly interpret the Quran was mentioned by several participants. Neither Jannah nor Mustapha felt that they had enough knowledge to determine whether the Quran is literal or not. Mariam did not feel that she could say whether a particular verse was literal or metaphorical because she is only able to read the Quran in translation and not in the original Arabic language. She explained, "the best language to read it in is '*Arabee*, because that's the language it was sent down in, but even for me, I like to read the English translation to understand it better, because I don't understand all the '*Arabee* words, to be honest." Sana and Hanif thought that it was necessary to rely on a commentary when reading the Quran to understand its deeper meanings. Interpretation of the verses was an important factor for Ali. Salahuddin mentioned that interpretation could be affected by the grammar and also the manner of the recitation. Kohinoor and Ayyoubou stressed the necessity of having a learned person interpret the Quran. Kohinoor explained it this way.

> The Quran is perfect, is structured in a way that we are supposed to sort of, you know, that's why we need interpreters for the Quran, right? So, the Quran definitely has sort of a way of presenting its ideas so that we would need someone to interpret it, because it's just so layered at times, and there will be points where, there will be *ayaats* [verses] where some people will interpret them completely differently from another person, and I think that's, there is a reason for that. I do think that when trying to discuss something as complex as how a human being should live their life, it's going to be difficult and there's no, it's not going to be a simple instruction manual, you know, it's going to have variations. It's going to be sometimes specific to the case, and I think that there are times where you should take it literally, and I think there are some times where that, you know, you need someone to interpret it and understand what this means. Is there any sort of like, you know, is there some sort of understanding I need to know while interpreting this? Is there a reason why this is phrased this way instead of that way? So I think it's a very complex question, and sort of I don't think I could say for either that it should

> always be taken literally, or it should, you should just sort of not take it literally all the time. I think you need to sort of know what you're dealing with and you know have someone who's studied the Quran for years to understand it and sort of tell you, well, my interpretation, I don't even think, I may be wrong, but my interpretation is this.

For many of these respondents, understanding the context of the verses was critical to understanding their meanings. Hakim, Hanif, Rafiq, and Brittany stressed the importance of taking into account the historical context in which the verses of the Quran were revealed in order to properly understand them. Brittany explained it as follows.

> Um, hmm, I'm going to say something different. I want to say that the Quran should not be taken literally without tafsir [commentary] or understanding, because certain things in the Quran are not told to people to do. Some of it is history. For example, I debated on this with someone recently, where it says "kill them wherever you find them,"[11] and that's not telling Muslims to go kill people. You have to read the tafsir to make historic context. So, I don't know how to, that's people who take it literally. You need to read the explanation, the commentary, and certain things are not telling you directly to do anything.

Afifah, Nasir, and Hanif stressed the importance of the context of the verse itself. Afifah put it this way.

> I think everything should be taken into account, but in context because sometimes people would just cut out words. For example, they would say *laa takraba ṣalah*. That's a really known example, but that's-- it's like don't pray, but in context, don't pray when you're drunk.[12] So I think you should stick to the Quran and take it word for word, but not separately. Put it in context.

Naima, Carlene, and Nusaybah explained that the Quran was metaphorical and held underlying meanings like poetry. Nusaybah put it this way.

> I think the Quran, for me the Quran is like poetry. That's exactly how I think of it. I think of it as poetry, and sometimes poetry, you don't take it literally. You read in between the lines of what it's saying.

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[11] 9:5
[12] 4:43

Umm Salama mentioned that there were some verses that use figurative language. Ayyoubou and Cherif specifically referenced a verse from the Quran itself describing some verses as straightforward in nature and others as metaphorical.[13]

Hakim, Asiya and Carlene explained that the Quran is both literal and metaphorical at the same time. Hakim explained it this way.

> I'll provide my own answer to that one. I would say that the Quran, every *ayat* [verse] in the Quran has both a, cannot think of the term, has both a literal meaning and a metaphoric meaning. So, there's both the in your face, it means exactly what it says, and it also has the metaphoric side of it that's a lesson behind it. So, that would, and I'd say that for literally every ayat in the Quran with no exclusions – to my knowledge, I should say.

In some cases respondents explicitly discussed whether their interpretations of certain Quranic verses were literal or metaphorical and how this understanding impacted their views on evolution. Hanif, who believes in the special creation of all species, and Nasir, a theistic evolutionist, articulate opposite positions on evolution using literal interpretations of the same verses as a basis. In both cases, their argument hinges on their differing literal interpretations of verses describing Adam as having been made from clay.

Hanif explained why he was more certain that humans did not evolve than he was that animals did not evolve as follows:

> Because I believe the Quran is the word of God and I believe the story of Adam is literal, and not metaphorical or anything, so I believe that the story gives us a clear, and along with the hadith, the authentic hadith, hadith which I feel to be authentic that also refer to the creation of Adam. So, I believe Adam was created from clay and formed and shaped by Allah. So, these are the reasons why I would say human beings 100%. The other macroevolution I would say 95% on that, but it's not something I would, you know, would say you're stupid. You know, gee, I would say you're stupid for believing that.

When asked directly if he interpreted the Quran literally, Hanif replied:

> I believe literally word for word, but with, has to have the background information. You need to know the *tafsir* [commentary]. You need to know the *asbab al nuzul*, the reason

[13] 3:7

> for the revelation, because you have to take the context that it's provided in, because I guess if you just say word for word, then you could-- this is how extremists go, and use certain verses to support terrorism and things like that, when you go through some of the verses about jihad that were revealed specifically during battles against oppressors and things like this. So, I do believe word for word, but that's with a scholarly guide, and knowing the context, and knowing the background information of that verse. So, something could be, I guess I could say something could be more metaphorical and not literal. For the example the verse in *Surat al Baqarah* about fasting which says you can eat until you could tell the difference between the white line and the black line. So, one of the companions took that and literally put the two strings, a black line and a white line. So that shouldn't have been taken literally, because it meant when you can tell the difference between the *fajr* [dawn] on the horizon, see the white line on the horizon. So, if you just say literally, I guess, it could lead to some misguidance, but in general I believe literally, unless there's something to prove that you don't take that verse literally word for word. But I don't believe that there's a mystic hidden coding behind some of the verses. I believe that they're general, up front, and everyone can benefit from them with basic scholarly study.

Hanif thinks that the Quran should be interpreted literally, but within the constraints of taking it in context. Although he does recognize some verses as metaphorical, he is only willing to do that if he has proof that the verse should be taken metaphorically. This is not a determination he would make on his own. Because of this method of interpreting the Quran, Hanif believes that Adam was literally "created from clay and formed and shaped by Allah." This interpretation causes him to categorically deny that human beings could have evolved. Although he is highly skeptical that other organisms could have evolved he does not have a similar proof in their case.

Nasir uses a literal interpretation of the same verses to support his position that all organisms, including humans, evolved.

> Nasir: Which is that there are several verses in the Quran that, and again, I guess it's depending on interpretation, but many of the verses in the Quran talk, in my opinion, rather specifically about evolution. So, I would say that in general the concept of evolution can be seen in the Quran, and that it should be agreed with in a general sense of there may be specifics about evolution that maybe scientists are just coming up with new studies now, but maybe there isn't anything at all mentioned in the Quran. So I guess, in that sense it's kind of a moral obligation to kind of understand the general sense of evolution.

> Khadija: Would you be able to mention any of the verses, or if you don't remember them exactly, describe them to me, that you say can be interpreted as saying that the Quran--?
>
> Nasir: Yeah. I guess when we talk about verses about how, and I'm paraphrasing obviously, but the verses about how humans were basically created from clay. There are several verses about how clay was basically a major part in the creation of human beings. From some, at least some evolutionary studies-- I guess the essential role in clay throughout evolutionary history and throughout the process of evolution happen to be an essential part of that. Without the physical characteristics of clay, basically following the processes of evolution would not have taken place. So, I think within that specific verse there's something that goes along with science, but there's also mentioned, in my opinion, pretty specifically about the process of evolution. So I think within that regard I would say that it's kind of a moral obligation to at least look into that verse more.

When asked whether the Quran should be taken literally word for word or not, Nasir replied, "I would say that it should be taken literally and also within context of the rest of the Quran." For Nasir, a literal interpretation that Adam was created from clay supports his idea that God created him through the process of evolution.

Habib, a theistic evolutionist, and Hakim, who believes in the special creation of all species, articulate opposite positions on evolution using metaphorical interpretations of Quranic verses as a basis. Habib articulated how a metaphorical interpretation allowed him to accept evolution as an explanation of the origins of human beings.

> [sighs] OK, well, here's, here's the thing. It's whether, 'cause I know most people, Muslim or otherwise with monotheistic religions, they take the creation myth as something *literal*, something solid, you know, I [sighs] there's always the possibility that could be a parable. I know from studying, I took a class on Sufism, for example. I know Sufis, they take the creation myth as a parable. It's not to be taken literally. It's not seven days. There's no time frame. It's meant to be a parable of the idea that you can have a intimate relationship with God. So, you know, for me, perhaps it's that I haven't chosen a side. Perhaps, maybe that's my own fault in this whole matter, but, I don't know. Not to mention, in the Quran, now, I know this is a little bit off the topic, but there is some people that argue that, I can't remember the verse exactly, but there's a verse that they say correlates with the Big Bang theory. I mean that there's a possibility that you could understand evolution as just a system that God set up. I mean, there is obviously other systems, whether it's as simple as the water cycle, or whether it's gravity. I don't see how evolution couldn't fit in. I mean, once again, this could be my miseducation. I don't see anything in the Quran saying that evolution's not an idea that you can't agree with.

During the GAENE survey Habib paused when it came to the evolution of humans.

Khadija: Evolution is a good explanation of how humans first emerged on the earth.

Habib: Oo, huh, oh, man, could I have an unsure option?

Khadija: [laughs]

Habib: Oh, because I know, I know that's like the cusp of, you know, where religious people start having an issue with evolution. Oh! [sighs] I agree.

When questioned further he explained the reason for his reaction here.

Khadija: OK. So, what was it that gave you pause about humans? Is there some specific thing that you can think of that might make that not be a good explanation?

Habib: Oh, I mean the reason of my pause is because, once again, it goes back to that, do you take the creation story in, whether it's the Quran or, or the Bible, or what have you, you take it literally, or do you take it as a parable? But, even then, it may, once again, this is me being creative, oh, like, because I'm a non-science major, just that idea of Biblical seven days, the creation of man, the, well, of course, this isn't, Eve's not mentioned in the Quran, but in the Bible, Eve from the rib. That in itself, I mean, that, that *could* be, and this is probably *wild*, but I'm throwing it off here, that whole creation idea *could* be more ancient Semitic peoples trying to explain evolution. I mean, I don't, I'm not going to take a hardline definitive view, because, once again, is the creation idea, the story, it's supposed to be taken literally. Is it supposed to be a parable? So on, so forth. That's what gave me pause, but I'll lean on agree. I'll lean on agree.

For Habib not taking the Quranic verses on the creation of Adam literally allows him to use evolution to explain human origins. A literal interpretation would make this problematic for him.

Hakim's stance against macroevolution of humans is supported by his metaphorical interpretation of the verses on human creation.

Then, of course, from an Islamic context, within the Quran it talks about the creation of man and how man was created. So, I believe that that also is spoken of in more of a metaphoric sense and not in a literal sense, you know, literal metaphoric sense. So, there's, as you know, there is dichotomy within the Quran. Every verse has both a, what's that called? Every verse has a blatant meaning, and then it has kind of like an underlying meaning or a hidden meaning. So, just going off of those two things, that's why I've kind of come to this viewpoint of, yes, we could have, at one point, we were a

> lot, probably a lot hairier, we were probably a lot more hunched over, and so on and so forth, but we weren't necessarily monkeys *per se*.

For Hakim each and every verse of the Quran has both a literal and a metaphorical interpretation. Using a metaphorical meaning for Quranic verses on creation of humans he can interpret these verses as contradicting the idea that evolution is an explanation for human origins.

Both Ayyoubou, who thought the Quran has both literal and metaphorical meanings, depending on the verse, and Jannah, who did not feel knowledgeable enough to weigh in on the subject of whether or not the verses should be taken literally, discounted the idea that humans could have evolved because discussion of human evolution is absent from the Quran. Jannah explains as follows.

> Well the story of Adam and how he was made from clay. If he was made from a primate, I really think it would have been there. There's also, it talks about what Man's made out of, what angels are made of. He tells the source. He even tells about the creation of the animals, doesn't specifically *say* them though, so there is a possibility that the animals could have evolved. There *is* a possibility.

Both Jannah and Ayyoubou thought that if humans had evolved that this would have been mentioned in the Quran.

Carlene took a different stance. For her, absence of mention of something in the Quran meant that it was a possibility. For her, macroevolution contradicted the Quran, but microevolution did not, because it was not mentioned.

> All of these are examples of adaptation to environment, and I don't see any conflict in scriptures that would say that absolutely not. Like the Bible and the Quran, they're very poetic and a lot of words have different meanings. There's literal and metaphorical meanings, and I don't see a conflict for speciation or adaptation, but there's definitely a conflict for change of kind, because it says in both scriptures that I'm familiar with that God created all of, every kind for its kind to reproduce with its kind, that there wasn't just like three different kinds and then everything branched from those, but it's very specific in scripture that each kind was made individually for its time, but there's no conflict about change of species, like red birds becoming green birds or the beaks changing or the shape of them changing or their functions changing. There's no conflict in the scripture about that. And it doesn't seem nonsensical to me from a logical standpoint either, because we

> do see evidence of change, observable evidence of change in species and things like that, but we don't see change over—change of kinds. As long as the evolutionary, the standpoint of evolutionists come up as in push for change of kinds, then it doesn't conflict with my morals or my beliefs or anything like that. As far as I know, there's not conflict with scripture, either.

A third of the respondents felt the need to explain why they did not view the question as to whether or not the Quran should be interpreted literally word for word as a simple one. Respondents used both literal and metaphorical interpretations of the verses of the Quran to support stances for both theistic evolution and the special creation of species. Mention of evolution in the Quran was used to support a theistic evolutionist stance. On the contrary, lack of mention of evolution in the Quran was used to support the idea that it did not occur. Human evolution was more contentious than the evolution of animals. Whether human evolution was accepted or rejected revolved around the varying interpretations of Quranic verses on the creation of Adam.

Randomness. The participants had varying responses to the idea that evolution emerges from random processes. Some stated that they do not believe in random processes at all because everything is under the control of Allah. Fatimah explained why she did not agree with the idea of random processes.

> Fatimah: I don't think it's random. I think it's all controlled by Allah. I think-- I mean, if I understand correctly, it's like everything—it's like saying we're just happening on our own. Human beings are just happening on their own.
>
> Khadija: Yeah.
>
> Fatimah: Yeah, no, I don't. I don't accept that. I think everything is part of Allah's plan because everyone's-- down to everyone's fingertips are different. Our fingerprints are different, and I think that these things are all things that Allah (swt) has talked about in the Quran. It's just to me, to accept that these things all happened by *chance* is just not something I'm willing to accept. It just doesn't-- it's just not possible for me in my mind. It just doesn't make sense that these all just happened on their own without a control. To me, it doesn't click.

Some expressed the idea that although the process appears random it is in fact under the control of Allah. Nabila and Salahuddin expressed this view.

> Nabila: I: I don't think anything really is random. I mean, everything has its purpose, and I think only Allah, from a religious point, I think only Allah can distinguish a purpose or knows a purpose, but as scientists, I guess it would *seem* random.

> Salahuddin: Just the definition of random, I guess. If you define it as arriving without any predetermined or unknown action, like it could be random in that whereas humanity's given a free will, those were also, the species were also allowed to maybe mutate to better suit their environment, but that mutation was known that it would happen, or that those mutations happen specifically to facilitate how they could better interact with the environment around them. So, again, it's either random with the knowledge of God, or random without, and I guess it would be the second definition, random without any involvement of God that I would have trouble with.

Cherif explained from a logical standpoint that he does not think evolution is a random process.

> Again depending on I think the word 'random' depends. I mean random itself has to come from a selected number of choices. So, if I pick between five different colors, my choice is random, but it is limited by the five different colors that there are. If like green wasn't a possibility then I couldn't pick a green marble. So random does have its own set of confined parameters, and I do believe in that sense that if we do look at instrumental causality that God would play a role, even though it was random, and in a sense, nothing is random with God … so that's where it does become a little bit more nuanced if you look at it in the way that was explained to me that I found a little bit interesting was explain the instrumental causality, or if I'm writing, if I'm drawing something on a pen, or from writing something from a pen, I, myself am the one that the dictates what's writing, but I don't do it myself, I do it through the instrument of a pen, although technically it is the pen and ink making those markings on a piece of paper, I guide that from above from what I thought to do with it. So, I guess that's a similar metaphor for how those movements might even appear random, but would be guided from above.

Other participants stated that they had no issue with the idea of random processes. Samra did not see any incompatibility with the idea that God creates and random processes. As she explained, "I believe that Allah did it for a *reason*, but I don't have a problem with the fact that it could have been just randomly done." Similarly Kohinoor explained why she had no problem with the idea of randomness in evolution.

Kohinoor: I know many, many philosophers who have a problem with it. Then, you know, it's a little cold and that is sort of, it's a complaint of many people and especially since you have this, when you have the Islamic view of, well, Allah chose, wanted it to be this way. He wants the best for us and that's why it's like that. You know, it's a lot more reassuring than 'you are an accident, many, many accidents.' So, I do think that it is a little cold, but scientifically, I don't think there, I mean science has never been the warmest of studies. Not that it's a cold study, but you can't expect a heartwarming explanation for everything. So, and you know you have sort of, so, yeah, I can see why people would have a problem with that, but I do like personally have a problem with that, in its own right, not really. I do think that's what science is not about pleasing people. It's about finding out what is the truth. So, in essence I don't find a problem with it, but I can sort of see why. I mean, it's a little depressing, that idea, but then again, I mean, we're, the fact that we scientifically, if we are a bunch of happy accidents, then that's amazing how we managed to, how genetics and nature sort of experimented on hey, what works? What doesn't work? So many times-- and we're one of the most, we're the most highly intelligent crea-, I suppose organisms so far. We've gotten to the point where, like, well, mammals tend to, if they live in colder areas, have fur on them. We don't have any sort of fur on us. We're expected to have enough knowledge to clothe ourselves. We have more, we don't have more animalistic nature, you know, I mean qualities, instead we're more reliant on our thinking and our intellect, and just the idea that someone, nature, and genetics, and natural selection came so far that it created something highly complex, that is intelligent, that can, that reduces the need for a lot of these other adaptations is, I mean, that's pretty amazing, if you think about it, but you know, and I could see why that would appeal to people, because you sort of feel like a champion, you know! So, I do think, I mean, there's multiple ways to see it. You could see anything in a positive light. You could see anything in a negative light, so. I suppose how I feel about it, how if, you know, we were created from a lot of randomness, I suppose it's, I feel like it *should* bother me, but it doesn't, not as much as does other people, because, once again, when you study philosophy, you'll have, for example, Socrates who believes that the world was created by intellect, and the concept of intellect itself, which is very reassuring, because that means everything was created to be the best. Leibnitz, I believe, believed that we are in the best, was it Leibnitz who believed we were in the best version of the universe that is possible? I believe it was Leibnitz. I have to check that, because I know Voltaire did not agree with that sentiment at all, and yeah, and made fun of him in *Candide*.

Khadija: Yeah.

Kohinoor: But, yeah, so, you'll see the philosophers all the time, they'll try to make the universe sound very happy. So, you have what? Epicureans I think who believe that God was, not God, but happiness was basically, I have to look that up, but I do know that the Epicureans and happiness have some sort of divine connection and things like that. So, yeah, you see a lot of the times that people want to think that their world is happy and that the world's creation was a happy one and we were destined and the world, and the universe orbits around Earth, you know. You know, that's more reassuring than, so,

> you're here and there's bigger planets and bigger stars and bigger solar systems, but you're here, but that doesn't bother me as much as it bothers other people.

Participants holding all three positions on evolution, theistic evolutionist, belief in the special creation of humans, and belief in the special creation of all species were present in both the group who thought evolution emerged from random processes and the group who thought that these processes were not random.

Time frame for evolution. Most of the study participants did not have any objection to the idea that evolution occurs over millions of years. A few participants thought the time frame should rather be billions of years and not millions. On the other end of the scale a few participants thought hundreds of thousands of years was more appropriate. Only one of the participants held a belief that the earth is only thousands of years old.

Habib specifically discounted the idea of a young earth, deferring to scientists. However he did not view the issue as personally important.

> Khadija: Do you agree with the time frame given in in the question, which was millions of years? Or do you think it took a longer amount of time, a shorter amount of time, or the time is just right? Why do you think that?
>
> Habib: [sighs] When it comes to time frame, once again, I am not that well versed. I believe that's the scientists' to debate on. Is this question sort of related to the young earth idea?
>
> Khadija: Yeah, the idea is to figure out if a person has an issue with young earth or not.
>
> Habib: [sighs] I'm [sighs] I'm the sort of person, if I'm not that educated on it, I'm not going to take a definitive opinion.
>
> Khadija: Um hmm.
>
> Habib: If it's millions of years, I see no issue with that.
>
> Khadija: OK. And so why do you think that?
>
> Habib: Think?

Khadija: Why do you think millions of years is OK?

Habib: I mean [sighs] my thing is because I am not that educated on the topic, I'm not going to take – what is young earth? 5? What is it 5 or 6000 years?

Khadija: 6000, yeah.

Habib: 6 then. Alright if scientists find proof it's a million years, then I don't mind. Once again, I don't mind sticking to that, to that claim, so long as there's proof. I mean, to me it doesn't matter if it's 6000 years or a million years. Like, I mean, sure it's a point to debate, but maybe for practical reasons, I don't see the issue.

Habib, a theistic evolutionist, might be expected to agree with scientific evidence on the earth's age. However, similar sentiments were echoed by Hanif, who believes in the special creation of all species.

I don't have a problem with it. It's not really something that I feel strongly about either way. I think I'm more with the belief millions of years that life has been on earth. I definitely believe that. So, yes, I feel like millions of years is a good time. I don't believe in like this 6,000 year theory, the young earth theory. I don't believe in that. I think there's sufficient evidence that shows that things have been, life has been on earth for millions of years. I don't think there's anything in Islam that goes against that, or that would suggest that that's not the case.

Asiya had only a slight objection to the idea that evolution takes place over millions of years, because she thought the time frame should be longer. Even so, she also thought the actual time frame was unimportant.

Khadija: Do you agree with the time frame given in the question, which was millions of years, or do you think it was a longer amount of time, a shorter amount of time, or the time in the question is just right?

Asiya: Personally, I think the time frame should have been longer, but I honestly, that doesn't really matter to me. I think it would, I don't really think about the logistics of it.

Khadija: Um hmm.

Asiya: If that makes sense. I just think about how God is involved, and He's been involved since the beginning of time. That's my belief, right, so, the amount of years you want to put on it doesn't matter.

Khadija: OK.

Asiya: So, I guess, looking back, there shouldn't, there should not be a time limit on that question for me, or the answer.

Brittany thought the time frame was shorter than many millions of years, but thought that one million years was reasonable.

Khadija: OK. And then, um, do you agree with the time frame that was given in the question, which was millions of years? Or do you think it took a longer amount of time, shorter amount of time, or the time in the question's just right?

Brittany: I'll say, I don't know, a thousand, maybe? I don't know. I'll go with a million, but I think that's fine, millions of years.

Khadija: OK, and why do you think so?

Brittany: I mean, well, hmm. OK. Let me change my mind. I'm going to say thousands of years. [laughs]

Khadija: OK.

Brittany: I think millions is an awful lot!

Khadija: OK.

Brittany: I don't know how long … but I would say like, lots of thousands of years, and I just think that we have, that things have evolved.

Khadija: Um hmm.

Brittany: And I just don't think it was such a – I don't think a million years.

Khadija: Um hmm.

Brittany: I just think that's a long time. I don't know why. Do I have to have an answer for all of it?

Khadija: No, and, again, I'm just trying to get at your thinking.

Brittany: OK.

Khadija: So I just want to know where you are on these questions, basically.

Brittany: Yeah, it's like a million years ago is much. I don't think that everything has been in creations for millions and millions of years, personally. I think that's a bit, that's a stretch, like millions, maybe one million or less, but I wouldn't say millions and

millions of years. How will we even know? Nothing goes back that far. Religious texts don't go back that far, you know? I don't think there's been scientific studies. I don't know necessarily, but it just seems a little much of a stretch. I don't know if mankind, civilization's that long.

Khadija: OK. Alright. So, you're just talking about specifically human beings. You don't think they are millions of years, but what about other species?

Brittany: Well religiously, I believe that everything was created at once. Like, I mean as far as on Earth. Now, if you're talking about maybe the universes and galaxies and spaces and stuff or before.

Khadija: OK.

Brittany: But I think God created everything at once, and

Khadija: OK.

Brittany: So, I don't know how far back that would go.

Sayyida used similar reasoning to conclude that the process took only thousands of years.

Sayyida: I think it took a shorter amount of time. I just don't have a reason why. I just, yeah, I just think it's a shorter amount of time.

Khadija: So, you think it's shorter, but you don't have a reason for it? Okay.

Sayyida: Well, Allah created man, and he created Adam and Eve, and that was I don't know how many thousands of years ago. It couldn't have been millions of years ago. That's my belief.

Those who thought the time frame was longer mentioned that they learned it was a billion or billions in their biology classes. For example, Basel explained why he thought the time frame should be longer by stating, "When I think about what I learned about single-celled organisms evolving billions of years ago, not billions, but a billion."

Participants holding all three positions on evolution, theistic evolutionist, belief in the special creation of humans, and belief in the special creation of all species, thought that millions of years was a reasonable time frame. People holding all three positions ventured that they thought it might be a billion years instead, based on what they had learned about earth's history

in biology class. Some participants declined either to agree or disagree that it could be millions of years saying that they simply did not know the time frame. These people held all three positions as well. Only five respondents thought the time frame was shorter than millions of years. Four of these people held a belief in the special creation of all species and one a belief in the special creation of humans. Interestingly all of these respondents were of African-American ancestry except one, of Jordanian background.

ACORNS as a measure of understanding of evolution. The ACORNS was administered by asking the participants a series of questions about the evolution of animals and plants. Participants' ACORNS scores are shown in Table 5 for theistic evolutionists, Table 6 for those with a belief in the special creation of humans, and Table 7 for those with a belief in the special creation of all species. Their responses were examined for the presence of key concepts, cognitive biases, and misconceptions according to the rubrics in Appendix G.

The key concepts are (1) the presence and/or causes of variation in individuals, (2) the heritability of variation, (3) competition, (4) hyperfecundity or the overproduction of offspring, (5) resource limitation, (6) differential survival of individuals, and (7) generational changes in the distribution or frequency of variation. Items 1, 2, and 6 are considered necessary and sufficient to explain natural selection and are designated core concepts.

Cognitive biases are ideas that are present in learners even prior to instruction. Three biases that have been found to be important to the learning of biology concepts are essentialism, intentionality, and teleology. Essentialism involves thinking of a species as a reified whole rather than as a collection of individuals. Intentionality involves the belief events somehow unfold in a conscious manner. Teleology involves a belief that events are directed towards a goal or that they are inevitable.

Misconceptions arise when students misapply common understandings to scientific terms. The misconceptions examined here were pressure, adapt, must, need, use and disuse, and energy.

Students whose answers contained at least the three core concepts and no cognitive biases or misconceptions were scored as having an excellent understanding of natural selection. Students whose answers contained the three core concepts along with one or more cognitive biases and/or misconceptions or whose answers contained two of the three core concepts with no cognitive biases or misconceptions were scored as having a good understanding of natural selection. Students whose answers contained more cognitive biases than key concepts or whose answers had less than three of the core concepts with one or more cognitive biases and/or misconceptions, or only 1 of the key concepts with no cognitive biases or misconceptions were scored as having a fair understanding of natural selection. Respondents whose answers contained one or more cognitive biases and no key concepts or that reflected little to no knowledge of the mechanisms of evolution were scored as having a poor understanding of evolution.

An example of an excellent response is Afifah's explanation of development of a DDT-resistant species of mosquitoes: "They would say that maybe a mutation happened, and that was passed on to a few of the generation and then when everyone was not resistant to DDT and died, those few that remained reproduced and formed a bigger … group of mosquitoes." This answer included core concept 1 by mentioning genetic variation that was caused by mutation. Core concept 2 was included when she mentioned that the gene was passed on to a new generation. Core concept 6 and also key concept 7 were included when she mentioned that only the DDT-resistant mosquitoes could survive and reproduce. She also included key concept 5 by framing

her answer in terms of survival. Her answer contained neither cognitive biases nor misconceptions.

Parvaneh's understanding was coded as good. Her reply to the question on DDT-resistant mosquitoes was excellent, because it mentioned the three core concepts with neither cognitive biases nor misconceptions: "So, it was those that had resistance or those that lacked resistance where, died out over time, and those that had resistance, it could have been a mutation that occurred and resulted in this resistance, and the mosquitoes with it, the mosquitoes that had that mutation with the resistance, because they had higher survival rates over time, so that became dominant and so they survived over time." However, her answers to subsequent questions uncovered misconceptions and cognitive biases. In response to a question on the development of flightless birds from a species of birds that could fly, she thought, "Maybe it could have been that the birds, the species did not use the wings….or they consumed too much energy for them to keep those wings, so, it wasn't beneficial so it kind of disappeared over time." This answer reflected a misconception that the flying trait disappeared due to disuse, rather than to natural selection acting on variations in the bird population. The answer also reflected the misconception that the trait disappeared so that the species could save energy. In response to a question on the development of roses with thorns from a species of rose that lacked thorns, she replied, "So the thorns could be a way to fight off predators. That could be the new predators that began to attack the rose and so it developed thorns in order to fight off those species." This response mentions the key concepts of competition by using the term "attack" and resource limitation by mentioning predation. However, it contains cognitive biases. The answer reflects essentialism because it mentions "the rose" instead of a rose population of individual rose plants that varied from one another. It contains the cognitive bias teleology as reflected in the wording

"in order to" which implies a goal for evolution. It is this mixture of understanding of proper evolutionary concepts and mention of all three key concepts along with cognitive biases and misconceptions that resulted in a score of good for Parvaneh's understanding of natural selection.

Jason's responses were coded as fair because they contained more misconceptions than key concepts. In response to questions on the development of flightless birds from a bird species that could fly, he explained, "Oh, I guess maybe over time, definitely over time the birds would probably adapt to the need of survival, or adapt to the environment that they're in, and eventually they would begin, they would start to fly, and it's all part of natural selection." His answer contains the key concept of resource limitation by framing his answer in terms of survival. However, it also contains two misconceptions, adapt and need. His answer reflects the idea that organisms adapt in order to survive, rather than the idea that changes in species brought about by natural selection are adaptive. He also mentions that the organisms need to survive and that is why they evolve.

Respondents whose responses were coded as poor gave answers that indicated that they did not understand the mechanisms of evolution. For example, Ayyoubou simply stated that he did not know the answers to any of the questions on natural selection. Sauda gave googled replies that were technically correct, but not responsive to the particular questions I was asking her. Salma's responses did not contain any elements of natural selection. For example, her answer to the question about the development of DDT-resistant mosquitoes was, "clonage…like with the Dolly, the sheep." Masoud's answers were coded as poor because they reflected a misconception with none of the key concepts. For example, he mentioned environmental conditions with no indication of how these interacted with evolutionary processes in response to a question on how the plant species, dodder, developed haustoria.

> And by physical change, I literally mean these, like I said, Africa to Americas, from mount, they used to live up on the mountain. Now, they don't live on the mountain. Then, five years they didn't have rain, and now they have rain, or anything in that line.

These responses were a result of the respondents either not having learned about the mechanisms of evolution in school, or of forgetting about evolution from a class that they did take. Sauda reported that she did not take any biology classes. Masoud reported that his only biology class, in high school, did not cover evolution. Salma reported that her high school biology class did not include evolution and that she learned about it in a high school philosophy class instead. Ayyoubou reported that he had a high school biology class with a unit on evolution, but did not remember it.

Of the participants in this study 33% had an excellent understanding of natural selection, 25% had a good understanding, 35% had a fair understanding, and only 7% had a poor understanding. People with all three stances on evolution were found at each of the levels of understanding of natural selection. However 68% of the theistic evolutionists and those with a belief in the special creation of humans had either an excellent or a good understanding of the processes of evolution in contrast to only 41% of those who held a view that all species were specially created.

GAENE as a measure of acceptance of evolution. The GAENE was developed to yield a numerical score that could be used for generating correlations. The higher the score on a scale of 14-70 indicates more acceptance of evolution. The theistic evolutionists in this study had scores ranging from 36-69, as depicted on Table 5. All but one of these were in the range of 51-69. Those who held the position that humans were specially created had scores ranging from 30-62, as shown on Table 6. Those who held that all species were specially created had scores ranging from 31-59, as shown on Table 7.

GAENE scores could also be sorted into categories, if desired. Those scoring from 65-70 could be considered to have greater acceptance of evolution, those with scores of 42-64 could be considered to have a moderate acceptance of evolution, and those with scores from 14-41 could be considered to have no or limited acceptance of evolution. The participants in this study included five with greater acceptance, 41 with moderate acceptance, and 14 with no or limited acceptance. Unsurprisingly, all of those scoring in the greater acceptance of evolution range were theistic evolutionists. Those who were scored as having moderate acceptance included people with all three stances on evolution. Interestingly, there were a few people who scored in the upper 50s and lower 60s who held the positions of the special creation of humans or of all species because they interpreted some of the questions in terms of microevolution. Those who were coded as having limited acceptance were mainly those who held the positions of the special creation of humans or of all species. Surprisingly, one of the theistic evolutionists, Sulayman, also scored in this range. He indicated that this was because he could only partially agree with some of the statements, and so he had responded to these with "disagree."

Sources of respondents' ideas on evolution. Most respondents reported learning about evolution in middle school, high school, and college. This was most often in a biology class, but a few respondents mentioned learning about evolution in anthropology classes and one in a sociology class. In a few cases they reported learning about evolution in non-science classes, such as in a religion or philosophy class. Online resources were the next most common source of information. Participants learned about evolution from online videos, including talks by religious scholars, debates and documentaries. They also accessed articles, websites, and books online. In some cases they had access to advice from religious scholars in person, whether at a special event at the mosque or Islamic center, or because they attended a mosque with a scholar

in residence, or because they had a scholar in their extended family who they sought out for advice. Some reported being influenced by discussions with co-workers, friends, and relatives. Some respondents reported learning about evolution from their parents. Others specifically mentioned a special teacher who helped them negotiate the relationship between understanding evolution from a scientific standpoint and from their personal religious views.

Respondents had a range of abilities as to whether or not they could articulate the sources of their views on evolution. Some could articulate the sources precisely, giving names of specific sources and people, while others only vaguely remembered what influenced their beliefs.

Salahuddin, who reconciles science and religion by integrating them and who holds a belief in the special creation of humans, was able to explain in detail the sources of his views on evolution.

> Salahuddin: Before this interview, maybe half, or a year ago, I don't know, I was interested in this. So, I looked at Yusuf Ali's commentary was good, Muhammad Asad, who I like, he's more academic, and Zakir Naik's publication on, I think it was *The Miracles of the Quran*, but sometimes you have to know what is polemical and what is just fact…
>
> Khadija: Where did you get your ideas about evolution?
>
> Salahuddin: Reading, I guess. I mean, from in school I was taught about evolution, and then when I went back to Quran, it didn't really seem to conflict with anything, except that Man may have been, and I do think that Man was created separately from that process, and then that started me just looking online. Like, I said, there are the three authors, or the Quranic commentators, and then Zakir Naik, they helped me sort of formulate my ideas.
>
> Khadija: Is there other places such as a debate, or a speech by a religious scholar, or a speaker you heard, or from a You Tube video?
>
> Salahuddin: Yeah, I mean whatever knowledge I found, I somehow, subconsciously or consciously assimilated it into what I thought, as you tend to do with everything. I can't narrow down anything specific. Well, no, there was a book, *The Complete Idiot's Guide to Understanding Islam* by Yahiya Emerick.
>
> Khadija: Oh, yeah.

Salahuddin: It was somewhere in the 60s and 70s, but those pages I liked. Oh, and then I remember looking once at Maurice Bucaille's *The Bible, The Quran, and Science*. I don't know. I can't think of anymore.

Khadija: OK. *The Idiot's Guide*….

Salahuddin: I think it's the 2001 edition that I'm talking about.

Khadija: OK. OK.

Salahuddin: I haven't seen the revised one, the 2012, but it seems shorter than the other one.

Salahuddin's views did seem to emerge from the sources he mentioned. For example, *The Complete Idiot's Guide to Understanding Islam* by Yahiya Emerick (2000) was clearly the source of much of his position. Salahuddin described his position as follows.

Salahuddin: The third one, Allah created humans, and all species evolved.

Khadija: OK. And then, why did you choose that one?

Salahuddin: It makes sense to me, because if you look at the Quran and also the Bible, God says that He blew His soul into Adam, but it also says that the heavens and the Earth were as one unit of creation, and also, We created from water every living thing.[14] So, I don't see them as being apart. The fact that God blew His spirit into Adam can be taken symbolically, but I think that might be stretching it, although I wouldn't be surprised if we did evolve with the other species.

Khadija: OK, and so why do you think that?

Salahuddin: What do you mean?

Khadija: So, you're telling me, alright, so it makes, C makes sense, that Allah created humans, but other species evolved, and so you're saying about God blowing His soul into Adam. So, but that could also be symbolic.

Salahuddin: It could be. I mean, I wouldn't be surprised if it is more evolution, but just from the way the verse is, it sounds to me like that Adam and the jinn and the angels were all created separately from that process.

Khadija: OK.

[14] 21:30

> Salahuddin: But at the same time, one of God's names is *al Bari*, which has been translated as the Evolver.
>
> Khadija: Um hmm. Do you agree with the time frame given in the question, which was millions of years? Or do you think it took a longer amount of time, a shorter amount of time, or the time is just right?
>
> Salahuddin: For that, I would have to go to science, and I think science has its facts straight, and it might be millions of years.
>
> Khadija: OK.
>
> Salahuddin: Because 6 days are mentioned, but I mean, the Bible could be interpreted as also 6 eons, and a day doesn't have to be a 24 hour period.

The verses that Salahuddin refers to in this exchange are the same ones that Emerick (2000) uses in his discussion of Islam and evolution. Emerick (2000) also analyzes the term "yawm" to explain that it is not necessarily a 24-hour period, and mentions that Allah's name, *Al-Bari*, can be translated as the Evolver. Emerick (2000) summarizes the position of Islam on evolution as follows.

> What we can say for certain is that Islam takes a position somewhere in between the two extremes of evolution and creationism: accepting the gradual development of life while considering God to be the author of its initiation. Again, the place of human development is the subject of debate, and no consensus has yet been agreed upon. (Emerick, 2000, p. 81)

Elsewhere, Emerick (2000) mentions that the position that humans were evolved is the minority viewpoint. Salahuddin's viewpoint is similar to the one that Emerick describes because he believes that God is responsible for evolution and takes the position that humans were specially created while other organisms evolved, although he is not settled on the matter of human evolution.

In contrast Sulayman, a theistic evolutionist with an integration relationship between science and religion, did not remember where his ideas originated. For example, he stated that

he had not taken any biology classes although he had taken a biology class during his freshman year of high school that included a unit on evolution. He remembered that class as a chemistry class instead. Most respondents fell between these two extremes. They are able to articulate where some of their ideas came from, but often did not remember the names of the particular sources they read, the particular videos they watched, the scholars who influenced them, or exactly how evolution was covered in their biology classes.

Some patterns emerged from respondents' descriptions of where they obtained their knowledge on evolution. Some respondents described finding the evidence for evolution convincing when they first learned about it in school. Later on they began to question whether acceptance of evolution was compatible with the teachings of Islam. For others the biology class itself provided the impetus for further research because it challenged prior ideas about evolution. They engaged in an intense period of study, either involving classes or events at their local mosque or Islamic center, or on their own. They often emerged from this study with a change in their position on evolution. Some incorporated their understanding of evolution into their religious world view by accepting evolution for all organisms except humans. Others rejected evolution altogether after this period of study.

Hanif, who has an integration view of the relationship between science and religion and holds a belief in the special creation of all species, described his period of study on this topic this way.

> Well, I would say actually, I mean I don't really have a problem, because for me I don't really delve deep into it. I mean I've studied some, just to refute some doubts that are put up in certain books, or, you know, I guess when you, as you grow, your beliefs are developing, you have to go and you're wrestling with something in your mind, you need to go research it to put yourself at peace, or whatever, but I don't even say with macroevolution I can't say that 100% that I have a problem with any macroevolution, but when it comes to human beings, you know, but so I guess there's a difference between what I believe and what I feel is 100% right, you know.

Hanif's study was prompted by doubts that were raised in his mind by books that he read. His study included online articles and videos in addition to the books that he mentioned. He looked at material from both creationists, such as Harun Yahya, and evolutionary biologists, such as Richard Dawkins. He also listened to videos from Islamic speakers, such as Yasir Qadhi and Zakir Naik. It is clear from some of his lines of argument that he was impressed by creationist writings as exemplified by the following statement.

> So for me, and also I think some of the things I've read about a lot of the life forms, I think it was the Cambrian period, how a lot of the life forms just came, and just popped into existence, seemingly popped into existence … So, my view is more that species were created as they are, but they can change and adapt, but they still remain the same species. So, I guess that would go against macroevolution. And I think many, some fossils, some animals, they have fossils of that are millions of years old, and they are the exact same pretty much as they are today, like some turtles, they have some turtles' fossils that are over 250 million years old, haven't really changed.

These arguments are typical of those put forth by Harun Yahya. They mirror American creationist arguments, but without the constraints of belief in a young earth. He stated that he was critical of Harun Yahya material on the relationship between religion and science, but more accepting of the ideas on evolution.

> I think, I guess, generally I think a lot of his material is grasping at straws, I guess, when he goes, like a lot of times he'll use the, he'll relate Quran and science, and what he'll do is, he'll take a verse that's really, really general, and he'll try to apply it specifically to something in science. So most of the time, I don't like that material a lot. It seems like, it just seems like you're grasping at straws, but I think when I, some of the videos I watched when he wasn't really giving the Quran, he was more just talking about evolution, I like those a lot better, and thought some of that material was really, really good.

Hanif's view of evolutionary biologists was nuanced. He evaluated them based on his knowledge of them rather than based on rhetoric. He strongly condemned Richard Dawkins' polemic, but respected Charles Darwin and his body of work even though he disagreed with parts of his theory of evolution.

> Ha, I don't have a good opinion of [Richard Dawkins] at all. I think he has a hatred towards God, a hatred towards religion. He's not very professional in the way that he brings, he's very condescending and he has I think, one, he benefits monetarily from the atheist view. It's making him really rich, and I think he just, he has a personal agenda. So, there's just a lot of things I see when I listen to him, that just seem like he's very biased, and he doesn't look at people, he's already made, his mind's made up when he's coming to the, he's looking for things, instead of, I guess, looking at the evidence, and letting the evidence guide him, he's more looking for what can prove. I've already made my mind up. What can I use to skew or make my theory better? And he's very, has very hateful and he's looking down upon religious people and their intelligence.

> Ha! Hmm. You know, I don't know much about [Charles Darwin]. I mean, it seems, so it's hard for me to say an opinion about him positive or negative, because it could be that he just, you know, when he did his studies, he was honestly looking for what's right, and I don't know what his mindset was when he went into this studies. So, there's not, I wouldn't just, I'm not the person that's just going to come and say he's evil, or he's this or that. So, he could have just been a scientist going and looking and studying and he let the evidence take him to what he *thought* was the truth or whatever, but I do believe he was wrong, and that his theory is just a theory, you know, but as far, so, and I think even some of the things he mentioned, from some of the things, the material I've read and watched, you know, some of the things that he mentioned that, for the theory to be solidified, we need this, this, and this and that. Some of those things never actually came to, never surfaced. So, even from some of the things he said, you know, it seems like it's still *obviously* still a theory. But as far as my opinion of him personally, I don't really have one that's positive or negative. I don't know what his intentions were, or this or that, I guess. I think if it goes back to the question of morals, and I think some of the people who came after him kind of used his theory to benefit themselves, or things like that.

Hanif emerged from his period of study with well-articulated and nuanced arguments to support his belief in the special creation of all species. He accommodated evolutionary data by accepting microevolution as a way of explaining the adaptations of organisms to their environment and his religious beliefs by stating that God is responsible for organisms' ability to change.

> I think with the word random, it kind of, to me it points toward a thing happening by chance, so I do have a problem with that, as I think it's any of these changes is something that's programmed into these beings, into these species, the ability do these things are guided by the Creator, and so I don't believe it to be random.

In some cases, respondents had a particular stance on evolution in mind before they learned about it in classes, and this influenced whether and how they incorporated this information into their world views. In some instances, this predisposed them to accept evolution and in others, to reject it.

Angela, a theistic evolutionist who holds a dialog view of the relationship between science and religion, learned about evolution from her mother, a school teacher. This predisposed her to accept evolution, so that she had the following reaction to the other side of the debate.

> I do know that I have heard some of the debates that, I mean, I pretty much was pretty strong in my views of evolution already, so I didn't really absorb infor-, you know, I didn't compartmentalize it, and be like, I'm going to remember this. So, I'd say that the gist I got from the religious scholars in Christianity especially, debating evolution, and their views seemed very like, well God created us and that's it, and there's no evidence or the evidence that was presented like from a written pers-, you know, point of view their, from the Bible or whatever. It didn't really seem to match well with the debate. It didn't seem to, it just seemed very general and it didn't seem, it seemed taken out of context, and applied very haphazardly to the debate. But if you ask me what the evidence was, I wouldn't be able to remember.

Similarly Abeer, who has a conflict view of the relationship between science and religion and holds a belief in the special creation of all species, learned about evolution from her family and this predisposed her to reject evolution despite exposure to convincing scientific evidence in the classroom.

> Khadija: Do you believe that the theory of evolution presents a conflict between science and religion?
>
> Abeer: Yes, I do. Strictly speaking about, I guess, human beings. That's when I think, yeah.
>
> Khadija: And how does that present a conflict?
>
> Abeer: I guess, because I believe Catholics, the Christians, and Muslims, I don't think they believe in the fact that we came from apes. I think that's specifically scientific and just a theory. So I think it creates a conflict against some opinions or beliefs, especially

when taught to younger people, generations, like young people in middle school or high school, as I was taught to believe.

Khadija: So, you're saying it's especially problematic in, for people in high school? Is that what you were saying?

Abeer: I think so, because they're younger. I mean, sometimes people can, you know, when you're younger you hear things you could believe it, because maybe at that time you don't have your own set of beliefs, or maybe knowledge on the topic that lets you say otherwise, almost. I mean, I was taught otherwise when I was in high school, because my family, and my background, so I knew that, when we were first taught about the theory, I knew that it was incorrect, or something that I didn't believe in our faith. For other people, I do know people who maybe did believe at the time-- I don't know if they still do-- once we were taught it, because it makes sense, I guess, the way they presented it.

Khadija: Wait, make sense the way they what?

Abeer: The way it was taught, I guess.

Khadija: Oh.

Abeer: Or you know when you, when they presented, I guess, the theory, or we were taught about it. You know, the way they spoke of it, or the way we were taught about it was kind of convincing, all with the diagrams and the pictures of humans, one part almost looking like apes, or resembling them, or acting, or the way we act, or similarities, I guess.

Some respondents did not report going through this process of negotiation. Some simply had little interest in evolution and so they avoided thinking about it. For instance, Hadiyah, who holds a belief in the special creation of all species and uses integration to negotiate the relationship between science and religion, reported that she paid as little attention to evolution as possible and only learned enough to get her through her classes with a high grade.

Khadija: What about Charles Darwin? What's your opinion of him?

Hadiyah: See, this is where I feel like I didn't study enough in these classes. I remember reading about Charles Darwin in the textbooks and his theory stuff like that I just, I just remember feeling like I didn't agree, but like I've said I maybe should have paid better attention, because I didn't know I was going to do this interview.

Khadija: [laughing] That's fine.

> Hadiyah: [laughs] But yeah, I mean I know that he has many, there were many different theories attributed to him, whether they psychology, biology, stuff like that, but I would probably say I don't agree with him. I think the survival of the fittest, and those different things. I mean, Islamically I think the reason why I don't have very much of an opinion is probably because, and maybe this is a fault of mine, that whenever I took those classes, and did that work, I kind of didn't take it very seriously. You know what I mean? Like, I probably didn't take a lot of that in because I was just trying to get through it. Maybe I felt like I know I don't believe this, so I'm not going to research it too much. I'm not going to pay too much attention to it. I'm going to get through this class, and take it, and get the best grade I can. So, that's probably why I don't have a very good way of explaining or giving an opinion because, I don't know, maybe I thought that it wasn't important to learn a lot about that, which now, sitting here thinking about it, it probably really *is* important to learn a lot about that.

Others had not encountered any circumstances that caused them to consider the relationship between their religious views and evolution. For example, Sauda, a theistic evolutionist with an integration perspective on the relationship between science and religion, explained that she did not have any opportunity to learn about evolution prior to the interview.

> Actually, I need to do a lot of research. I like to do more research, more studies, because from 40 years, I didn't study. I was back home, so I was a housewife. Just now I went to college, so I want to know more, more, more, more about science and everything and Islam, in shaa Allah [God willing].

A few respondents reported that they had positive role models, either parents or special teachers, who helped them successfully negotiate the relationship between their religious beliefs and acceptance of evolution. For example, Cherif took a class on religion and science that was taught by a Dominican priest who was also a PhD in evolutionary biology. "He really kind of got into the more high level explanations of that and how he reconciled it with faith as a Dominican priest." Cherif's sophisticated understanding of the relationship between science and religion as quoted above in the section on randomness was informed by his interactions with this teacher. This helped him to develop his position as a theistic evolutionist who sees science and religion as integrated.

For some of the Ahmadi respondents Mirza Tahrir Ahmad served as a positive role model for the integration of science and religion in a manner that allowed for acceptance of evolution. They had either read his book, *Revelation, Rationality, Knowledge, and Truth*, or had watched videos of him discussing evolution on You Tube. For instance, Nasir, a theistic evolutionist, explained that the book, "took a lot of information from contemporary scientific topics as well as considering the hadith of the Prophet (saw) and also verses from the Quran, so I kind of looked at all of those and did analysis and determined, was trying to prove that evolution was a guided process by Allah."

However, exposure to Ahmad's ideas did not ensure that an Ahmadi would accept evolution. Rahima had read the book, but thought that evolution entailed only microevolutionary changes. What she took from the book was the idea that evolutionary processes, as she understood them, were guided by Allah. She explained this conception as follows.

> Allah created species of living things to be formed, but then, it's not like the theory of evolution that Charles Darwin, that humans evolved from apes, because apes and human are totally different species. That's why Allah already created every living thing in its own form. So, it is impossible for a living thing to evolve into another form, which the majority, the mainstream theory of evolution believe that, you know, it is impossible. Where Muslim evolution, it's not like that. It's the guided evolution, that's what I think the Muslim theory of evolution is.

For Ahmadis besides Rahima, lack of exposure to Ahmad's ideas allowed for positions other than that of theistic evolutionist. Salim, who had a belief in the special creation of humans, was influenced by teachers in the Christian school he attended. Amatullah, who held a belief in the special creation of all species, searched for an understanding of the relationship between Islam and evolution, but was unable to find it. As she explained, "I asked my grandfather about evolution, if Islam supports evolution, and he really didn't-- he didn't know exactly the answer either." Her grandfather, a missionary for the Ahmadiyya Muslim Community, would be

expected to be knowledgeable about religion. However, he was unaware of the group's position on evolution. She chose her position because, "I always question if this happened, like maybe Allah played a part in evolution, but I feel like from a religious standpoint that where everything is at today, that's how it was made to be." She also found the evidence from science class on one species changing into another to be unconvincing.

There is not a prominent scholar in the Sunni or Shia communities who is a role model for the theistic evolutionist position as Ahmad is for the Ahmadi community. Sunni and Shia communities in the United States are not centrally united. Because there are a variety of Sunni and Shia congregations, there is not one central scholar who would make decisions on issues such as the position on biological evolution for either group. A few respondents mentioned hearing from Yasir Qadhi, a Sunni, or Hassanain Rajabali, a Shia, who both hold the view that humans were specially created. These scholars had an influence on some respondents to also hold this position.

Other Sunni and Shia respondents mentioned classes given at their local mosque that shaped their views. Yusuf's belief in the special creation of humans was influenced by an Islamic Sunday school at his Sunni mosque. He explained, "My last year there we actually had a science class, and a lot of it was on scientific studies in the Quran, and evolution was a big topic that we talked about there from an Islamic standpoint." He described the content of the class as follows.

> They basically-- they showed us a lot of videos and stuff. The [inaudible] that there is no possible way that humans could have evolved from any species that. I'm trying to remember. It was two years ago, but they basically said as far as animals go, we really don't know, because it's not clearly stated in the Quran, or we haven't been told if they evolved or not, but as far as humans go, scientifically, it's just a theory, and there is no solid proof, and the chances of it being true are very minimal.

Lubna, a Sunni who held a belief in the special creation of all species, described a more informal treatment of the relationship between Islam and evolution. One of the sisters in the deen [religion] class at the mosque "used to talk a lot about it." Lubna described what she told the group.

> She was specifically describing how Adam and Eve came about and how the thought process of evolution through science was not denied or confirmed through Islam and through the Quran and Sunnah. It never says anything about it.

This viewpoint was reflected in Lubna's negotiation of the relationship between religion and science as shown in the following exchange.

> Khadija: Okay. And do you believe that the theory of evolution presents a conflict between science and religion?
>
> Lubna: Yes. Science-- there is, like you can't—in a sense you can't really-- like the Quran doesn't say it denies it or it confirms it of any kind of scientific studies or anything like that. So science can't really determine what Allah has created. They can't prove it or anything.
>
> Khadija: I don't, could you elaborate on that a little bit?
>
> Lubna: I feel like the Quran and the Sunnah, they don't talk about anything scientifically. It's whatever Allah created. Everything, it's in a pattern, a process. Like He, everything is written, but with science, you can't really explain how Allah has written everything, you can't explain how he created everything. It's just created.
>
> Khadija: So are you saying that science doesn't have the tools to understand the actual process of creation? Is that what you mean?
>
> Lubna: Yes.

Question 2. What are the relationships between American Muslims' views on the compatibility of science and religion and their views on evolution?

In order to understand whether participants' views on evolution were affected by their views on the compatibility of science and religion they were questioned on this relationship. They were also questioned in depth on their understandings of nature of science itself in order to

determine whether their NOS views affected their views on the compatibility of science and religion or their positions on evolution.

Understandings of nature of science. Participants in this study held a range of understandings of tenets of nature of science examined here: that scientific knowledge is based on empirical evidence, that empirical evidence is collected using a variety of methods, that observations are distinct from inferences, that creativity comes into play when interpreting evidence, that scientific knowledge is tentative yet reliable, that it is socially and culturally embedded and subjective in nature, that theories and laws do not have a hierarchal relationship, but rather that they perform distinct functions. Participants' NOS views are presented in Table 11, p. 279 for theistic evolutionists, Table 12, p. 280 for those with a belief in the special creation of humans, and Table 13, p. 281 for those with a belief in the special creation of all species.

What follows is a discussion of how participants' understandings of NOS were coded, the understandings of the participants, and the range of understandings they exhibited for each aspect of NOS. Coding was based on the rubric from Lederman and colleagues (2002), found in Appendix F.

Empirical NOS. All of the respondents understood that science is based on empirical evidence. Responses were considered to be more naïve if they reflected a type of naïve realism in which science is considered to consist of a series of "facts" that scientists discover. More informed views reflected the idea that observations are interpreted in some way in order to be of value to scientists, and that while these interpretations are based on empirical evidence they are ultimately human constructions.

An example of a response that was coded as more naïve for empirical NOS is Lena's, "Science does not go on faith at all, and … they believe their belief that it is completely 100%

based on factual information that they are basing their theories off of." Yasmine's view, coded as more informed, was, "I think science is a way of looking at the world to make sense of it."

Out of 55 participants who addressed empirical NOS in their responses, only 4 responses were more informed. Two of these were for theistic evolutionists and one each for a belief in the special creation of humans and belief in the special creation of all species.

Scientific methods. Science is conducted using a variety of methods, including controlled experiments, observational studies, and modeling. A more naïve view concerning scientific methods is that only controlled experiments lead to the production of scientific knowledge. For instance, Rabia was adamant that experimentation was required to further scientific knowledge.

Khadija: Does the development of scientific knowledge require experiments?

Rabia: The development of scientific knowledge? Yes.

Khadija: Why?

Rabia: [laughs] Because otherwise it would just be the religion of science. I don't know how to answer that. Yeah, I don't know how to answer it.

Khadija: Could you give an example to support your position?

Rabia: Oh! I'm trying, trying really hard not to be offensive.

Khadija: You can be as offensive as you want. You know this is going to be anonymous.

Rabia: I feel like we all have brains and reasoning abilities that were given to us by Allah. That's my belief, and we have this mechanism that Allah has given us to understand with our minds what, where we come from and what's going on in the world, and we have a method to do it, and I feel like when I'm talking about experiments, I'm talking about that, OK? I feel like to not do that like is, I don't know, I feel like it's almost sacrilegious to not use what Allah has given us to understand the world. That didn't answer your question. OK. Let me try again. We need experiments so that we can have concrete evidence to, in order to believe certain things, and to be able to prove it to others.

A conception that science consists of step-by-step procedures characterized some naïve views. Brittany described it this way.

> Brittany: An experiment is when you take a theory or a thought or a something, and you try to prove or disprove it through scientific procedures, step-by-step method, methods, you know, scientific inquiry kind of thing.
>
> Khadija: OK. And what do you mean by step-by-step method?
>
> Brittany: Like hypothesis, you start with a hypothesis, then you come up with your hypothesis for what you think's going to happen, and then kind of solve your theory and then you go through, you research it, you go through like step-by-step procedures to come up with a conclusion or a proof or disproof for the theory that you had.
>
> Khadija: Does the development of scientific knowledge require experiments?
>
> Brittany: Hmm. Well, I, I think so, I pers-, I feel like that they do.
>
> Khadija: Why do you think so?
>
> Brittany: Well, I feel like everything is, even if it's not a formal experiment, I think it requires you to question, test. You can read and study about scientific knowledge and gain it, but to really to come up with concrete conclusions, I think you must, you have to have experiments to see, to prove it, to prove or disprove. Not everything will just be a theory.

Although Brittany acknowledged other scientific methods, for her only controlled experiments provided solid evidence.

More informed views reflect an understanding that there are a variety of methods that are employed by scientists and that observational studies are a valid basis for forming scientific theories. Sulayman expressed this viewpoint as follows.

> Sulayman: I'd say science is just ideas, everything around you, trying to figure out what everything is, how it was made, or what it does and why it does it, the basic rule of where, when and how, and I don't know. I don't know how to answer how it's different from different trains of thought, because it just all depends on the person, as far as how they're studying.
>
> Khadija: OK. What is an experiment?
>
> Sulayman: You said what is an experiment?

Khadija: Yes.

Sulayman: An experiment would just be, I don't know, it could be several things. It could be like watching something, seeing, or playing it into a different variable, changing variables. It just depends on what you want to get out of it.

In Sulayman's view scientists can employ a variety of methods, including observational studies, depending on the type of question they are trying to answer.

Only 19 participants addressed the scientific method in their responses. Of these, only three responses were more informed. Two of these were from theistic evolutionists and the other from a person with a belief in the special creation of humans. The other 16 responses were more naïve. Seven came from theistic evolutionists, two from people with a belief in the special creation of humans, and seven from people with a belief in the special creation of all species.

On the general structure and aim of experiments 51 participants had responses that addressed this. Of these 13 were more informed. Six of the more informed responses were from theistic evolutionists, two from people with a belief in the special creation of humans, and five from people with a belief in the special creation of all species. The 38 more naïve responses were evenly distributed, with 12 belonging to theistic evolutionists and 13 each to people in the other two categories.

Of 14 responses that addressed the role of prior expectations in experiments, eight were more informed: three from theistic evolutionists, four from people with a belief in the special creation of humans, and one from a person with a belief in the special creation of all species. Of six more naïve responses, two came from theistic evolutionists, one from a person with a belief in the special creation of humans, and three from people with a belief in the special creation of all species.

The validity of observationally based theories and disciplines was addressed by 56 respondents. Of these six had more informed views: two theistic evolutionists, one person with a belief in the special creation of humans, and three people with a belief that all species were specially created. Of the 50 more naïve responses, 15 were from theistic evolutionists, 18 from those with a belief in the special creation of humans, and 17 from those with a belief in the special creation of all species.

Tentative NOS. Scientific laws and theories change as new evidence is collected and/or as scientists change the ways they think about existing evidence. Although scientific ideas are tentative in that they are subject to change, they are still reliable, because they are based on large amounts of empirical evidence, enjoy wide support in the scientific community, and are stable over time. More informed views of this tenet captured the idea the scientific theories and laws are tentative yet reliable. Hanif explained it this way.

> Hanif: I believe because in the initial, I mean, you have, first of all, it's a human being developing a theory based on what they observe on that which could be based on limited information, limited data, and then once that theory is made, either that person or someone else in the same field goes back and does more experimentation, more observation, they can find out flaws, or something that that person didn't observe, so it's building, I guess. So, the theory could definitely change due to those factors.
>
> Khadija: Can you think of an example?
>
> Hanif: Let me think here. I should be able to think of. What's the? What's his? I think Einstein had the theory that the universe was stable, and I forget, is it? He went to another scientist proved that the Earth was expanding, that the universe was expanding. I forget his name, but then Einstein actually changed his opinion based on that. So he had some equation or whatever that said the earth was, not the earth, the universe was-- what is the word? Static or there, just? Then he changed that opinion based on observation, the observation of another scientist, and that basically changed his theory.

Cherif put it this way:

> Cherif: Yes, sometimes the whole point of a theory is that it is always open to new additions and new evidence and new experiments on it, and if there, like the theory of evolution as first posited by Charles Darwin has definitely become more nuanced and

> more understood as time goes on, and yeah, for sure, definitely with new evidence and with new understanding a theory can be expanded upon.

More naïve views of tentative NOS reflected the idea that the tentativeness of scientific ideas means that they are unreliable, or the idea that scientific ideas do not change, perhaps coupled with the idea that this permanence means that they are reliable. Both of these naïve views are reflected in Fatimah's response.

> Fatimah: Yes. Law is like the laws of gravity, right? It is what it is. It's true. It's factual. There's no contradictions about it between the different scientists I guess you can say, but with theory it's more like the most accepted theory of all the different theories, but there are different theories on that topic if that makes sense.
>
> Khadija: Actually, yeah, I guess I think you lost me. You're saying-- so you're saying-- are you saying that--?
>
> Fatimah: With laws, it is accepted by everyone. There's no contradictions about these laws, but the theories, it's kind of just up in the air. You can-- it might change. It might not. Laws-- I don't think laws change. The law of what goes up must come down, for example. That's accepted by everybody. That's just, it is what it is. I guess it could be disproven and changed but I don't think so, not the way theories are. Theories I guess are weaker vs. laws are much stronger or just more factual. They have more facts to back them up.

Hasina expressed the naïve idea that theories do not change because they are "proven."

> Khadija: After scientists have developed a scientific theory, such as atomic theory or evolution theory, does the theory ever change?
>
> Hasina: No.
>
> Khadija: OK. Can you explain why they do not change?
>
> Hasina: Because I believe that they've already been proven true, and that there are no outstanding circumstances that would lead it to be disproved.

Aida expressed another naïve idea that theories change because nature itself it not static. In this conception theories are accurate representations of nature, and not human constructions.

> Aida: Evolution is change, so why can't evolution change, the theory of evolution change?

> Khadija: So you're saying it changes just because everything changes? Is that your point?
>
> Aida: I think change can cause the theory to change, not just because we decided to change it today, but because actual natural things change.

Understanding of tentative NOS might interact with students' willingness to accept evolution. A naïve view that theories do not change because they are "proven" could go along with the acceptance of the theory of evolution. Hasina, who insists that theories do not change because they are "proven," does accept evolution for all species except humans, for example. However, Fatimah, who believes that theories change and are therefore tenuous, also accepts evolution for all species except humans.

More informed views of tentative NOS are held by people with all three stances on evolution. For example, Hanif, quoted above, rejects macroevolution for all species, while Cherif, also quoted above, is a theistic evolutionist. Out of 56 responses that addressed tentative NOS, most, or 36, were informed. Of these 15 were from theistic evolutionists, six from those with a belief in the special creation of humans, and 15 from those with a belief in the special creation of all species. Of the more naïve views, four belonged to theistic evolutionists, ten to those with a belief in the special creation of humans, and six to those with a belief in the special creation of all species.

Hypotheses, theories, and laws. Scientific theories provide explanations for observed phenomena, while scientific laws describe regular patterns that have been observed in nature. As such they serve different functions and are not hierarchal in nature. Many respondents indicated that they did not really know what the difference between a scientific theory and a scientific law is because they had not been specifically taught this in any of their science classes. The

meanings of the words "law" and "theory" in popular vernacular suggested to them that laws were more concrete than theories. For example, Rabia explained it as follows.

> I don't know. I think that the name would lead me to believe that one's proven beyond a doubt and one's not, but I don't know whether that's true or not. Maybe a law is something that you could know, and a theory is something you could not possibly know, because, like evolution, we weren't there at the time evolution started, the Big Bang and whatnot. I don't know. I'm not sure.

Views were scored as more naïve if they reflected the idea that laws are more concrete than theories and that theories can become laws if enough evidence accumulates to prove that they are true. For example, Nadira put it this way.

> Yes. Theories can be changed. Laws can't. That's what we learned in school. Laws are statements about nature that you never see change. For example, Newton's laws, for any processes, it never changes. An object at rest remains at rest unless acted on by an outside force, and it's always true. A theory could become a law if it proves to be true in every circumstance. A theory is either proved or disproved multiple times. A theory can be disproved.

More informed views reflected an understanding that both theories and laws are based on the interpretation of large amounts of empirical evidence, and that both are subject to change as new evidence is uncovered or existing evidence is reinterpreted. They also reflect the idea that they serve distinct functions. Yasmine expressed her views as follows, "Isn't a theory one that has been tested multiple times and still stands up to argument, and a law is mostly mathematical presentation of a theory?" She gave the following example to illustrate this idea.

> Diffusion, that would be the theory, and then the law is: the diffusion is mass of one divided by mass of two to the square root to find the ratio of how one mass differs to another. Like, who would diffuse the fastest? So, the one that diffuses the fastest is the one with the lower molar mass. Who was it? Was it Graham's Law of Diffusion? That's what I was thinking of.

Some responses were difficult to classify. For example Sulayman had a mixture of more informed and more naïve views concerning theories and laws.

> Sulayman: Scientific theory would, it's just, I guess could be a statement that may not be true, subject to change, but at the moment, it's what they have, and then a law would just like something that they're almost positive is true, and they could base their knowledge off of it almost any time. So, a law would be like the sky is blue, but a theory would be why is it blue.

This answer reflects the mistaken belief that laws are more solid than theories. However, Sulayman was one of the few respondents who correctly identified the function of theories as providing scientific explanations for natural phenomena. He was also one of the few respondents who allowed for the tentative nature of laws, because he recognized that there was a possibility that they could change by qualifying his description with the word "almost."

Because evolution is a theory, understandings of theories may have some bearing on acceptance or rejection of evolution. Yasmeen's response, "Isn't a theory one that has been tested multiple times and still stands up to argument?" indicates that she has a more informed understanding of the nature of scientific theories. Respondents who gave some indication that they understood that a theory is not a tenuous concept in science were scored as more informed, even if their overall answer contained some misconceptions. An example is provided by Sana.

> A scientific theory is-- it's this idea that has been experimented over and over again and just basically looked at, at every single angle, to prove it or disprove it, and it's been proved to such a strong degree that you can say it's something like 99.999 % sure, whereas a law is something that does have the ability to be disproved still, whereas it has a lot of scientific support behind it, but not as much as a theory does.

Although she is clearly mistaken about the relationship between theories and laws, her belief that theories are on sound scientific footing was scored as more informed. This was in contrast to respondents, such as Aisha, who saw theories as being quite tenuous and whose answers were scored as more naïve.

> Yes. A scientific theory is something that there's no physical proof. It's just been looked at a bunch of times, and a lot of people agree with it, and a scientific law is something that can't change, like, gravity, and things like that.

Of 53 responses addressing the difference and relationship between theories and laws, only five were more informed: three from theistic evolutionists and two from participants with a belief in the special creation of humans. Of the 48 more naïve responses, 15 were from theistic evolutionists, 15 from those with a belief in the special creation of humans, and 18 from those with a belief in the special creation of all species.

Of 51 responses that addressed the nature of scientific theories, 13 were more informed: five from theistic evolutionists and four each from participants with a belief in the special creation of humans and the special creation of all species. Of the 38 more naïve responses 12 were from theistic evolutionists, 11 from those with a belief in the special creation of humans, and 15 from those with a belief in the special creation of all species.

Of 28 responses that addressed the functions of scientific theories, nine were more informed: five from theistic evolutionists, one from a participant with a belief in the special creation of humans, and three from participants with a belief in the special creation of all species. Of the 19 more naïve responses there were five each from theistic evolutionists and from those with a belief in the special creation of humans, and nine from those with a belief in the special creation of all species.

Of 24 responses that addressed the logic of theory testing, three were more informed: one from a theistic evolutionist, and two from participants with a belief in the special creation of humans. Of the 21 more naïve responses there were six from theistic evolutionists, four from those with a belief in the special creation of humans, and eleven from those with a belief in the special creation of all species.

Observation, inference and theoretical entities. Observation and inference are both used in science. According to Lederman and colleagues (2002), “Observations are descriptive

statements about natural phenomena that are directly accessible to the senses (or extensions of the senses) and about which observers can reach consensus with relative ease….By contrast, inferences are statements about phenomena that are not directly accessible to the senses" (p. 500). More informed views of this distinction reflect an understanding that in order to make sense of observations scientists must interpret them in some way. Scientists use observations and inferences to construct theoretical entities, such as atomic theory or the concept of biological species, which are their attempts to make sense of natural phenomena. More naïve views of this distinction blur the lines between observed phenomena, inferences about these phenomena, and theoretical entities that can be constructed to make sense of them. For example, respondents may hold the idea that atoms are something that can be directly observed, rather than that they are constructed on the basis of observations and inferences concerning a theoretical entity that cannot possibly be directly observed. Or they may hold the idea that biological species actually exist in nature, rather than that the species concept is a method scientists use to classify the dazzling multitude of living organisms in order to study them more efficiently, that the species concept is a theoretical entity imposed on nature by scientists and does not arise fully formed from nature itself.

Questions 6 and 7 from the VNOS-C on atomic structure and biological species are designed to elucidate respondents' views on the role of inference and theoretical entities in scientific thought (see Appendix C). For the question on atomic theory, some respondents remembered discussions of Rutherford's gold foil experiment or other experiments from which atomic structure was inferred from their chemistry classes. The following exchange with Kohinoor illustrates her more informed views gained from the treatment of the development of atomic models in her science classes.

Khadija: Science textbooks often represent the atom as a central nucleus composed of protons, or positively charged particles, and neutrons, or neutral particles, with electrons, or negatively charged particles, orbiting that nucleus. How certain are scientists about the structure of the atom?

Kohinoor: I feel like they're pretty certain, but they're not 100% sure about that. So far, because we went through a lot of models before we came up with the one we have now, and I think as of right now that's the best, it's the best we've got and it's not perfect, but it's pretty solid. I mean, we don't have, we haven't seen a lot of proof against it, substantial amounts of proof. So, I think for that reason, I think it's sort of, we're very sure, but we have no way to prove it exactly.

Khadija: OK. So, what specific evidence do you think scientists used to determine what an atom looks like?

Kohinoor: I do know they have ways to track electron movements, and I remember seeing, it's like a container, or like a room or something and they have some sort of atom, some marked or tagged atom to move around in the room, or a bunch of them, and they can see the movements of the electrons. I remember seeing something like that. I'm not too sure. I do also know there was that one – was it Rutherford – experiment with gold foil. So, they have ways of determining the shape. I remember one time one of my science classes was to prove just how difficult it is to determine the shape of an atom. We were given a box with an item inside, and it was sealed completely. We were told to figure out what the item was just by shaking it, and you know, and that's sort of what we're doing. We're just shaking this atom, trying figure out, well, we're shining beams through to figure out what it is. We're applying things to an atom to figure out what the shape is, and that's really, we obviously, we can't see it. We have electron microscopes that can see viruses. We can't, we don't have the technology to see an individual atom, and until then, I don't think we could ever completely determine what the atom looks like.

Remembering discussions of the development of the current atomic model did not necessarily prevent a respondent from simultaneously holding naïve views about inference and theoretical entities. Cherif's explanation involving indirect experiments nevertheless contained a reference to direct observation with an electron microscope.

Cherif: So, as I understand, that there is a nucleus and it houses both the protons and the neutrons is pretty sure of, but I know there has been, after Bohr's model there's been a lot of new talk and developed the quantum. We can only say with a certain, you can't really know what the electron orbit looks like, and because of that we really don't know much about the shape, and I think that's like what the whole quantum field is about. You can really only know from observation. There are no set orbits like there would be for maybe the planets.

> Khadija: What specific evidence do you think scientists used to determine what an atom looks like?
>
> Cherif: What kind of evidence?
>
> Khadija: Yes.
>
> Cherif: Well they used, I believe, microscopes, and different experiments at a quantum level. They use for example, understand how light waves work, they would shine light through the double slit experiment. That kind of thing sheds light on how the atom works and how it moves around.

Other respondents either did not take chemistry or did not remember discussions of these experiments. For these respondents, even though they were essentially guesses, their answers reflected their underlying philosophies of science. Revealing his more informed view, Bilal stated, “I think they just use their imagination, collaborative imagination as to what it looks like.” Samra’s more naïve view was typical of many, “I’m not even sure, probably with a microscope?"

Just as mention of the actual experiments could still be included in a more naïve explanation, mention of microscopes did not preclude a more informed understanding. Kareema’ mention of a microscope preceded her more informed understanding that the structure of the atom was derived from inferences.

> I don't know. Scientific evidence, observations through a microscope, I don't know. I feel like the way the atom looks is just a way for them to understand how it works. It might not even look like that. It's like molecules, and it's just the way that they tell us that molecules are shaped. It's just a way for us to be able to understand them.

Of 57 responses that addressed inference and theoretical entities, eight were more informed: four from theistic evolutionists, one from a person with a belief in the special creation of humans, and three from people with a belief in the special creation of all species. Of 49 more naïve responses, 14 came from theistic evolutionists, 17 from people with a belief in the special creation of humans, and 18 from people with a belief in the special creation of all species.

Theory-laden NOS. Scientists approach scientific investigations from a certain theoretical perspective. They are influenced by their backgrounds, education, discipline, and other factors which inform their approach to scientific investigations and their interpretations of their findings. More informed understandings of this NOS aspect reflect the understanding that various factors can influence scientists when they interpret data. For example, Hasina stated the following.

> They analyze the data differently. They took in different conditions. They had different hypotheses.

Nadira mentioned the background of the scientists.

> It would depend on the experience of the scientists that are analyzing the data, and the biases they come with. Some may think processes within the Earth are more plausible than something from outside. Religious biases, depending on religious background, this could affect biases. Personally I would read the Quran to see if it hints towards one or the other. Maybe the data are ambiguous.

More naïve understandings of this tenet would be that scientists approach things from a neutral standpoint. If they differ in their interpretations, it is because they have differing information, and not because they approach the data from differing theoretical perspectives. Akilah explained it this way.

> Khadija: Well, how did they have two different conclusions from the same data?
>
> Akilah: I don't know. They probably missed something, or-- I don't know-- they didn't do a good enough job the first time.
>
> Khadija: So if they had more information, you think they would agree?
>
> Akilah: Yeah, probably.

Of 55 responses that addressed theory-laden NOS, 22 were more informed: eight from theistic evolutionists, and seven each from people with a belief in the special creation of humans and people with a belief in the special creation of all species. Of 33 more naïve responses, eight

came from theistic evolutionists, 11 from people with a belief in the special creation of humans, and 14 from people with a belief in the special creation of all species.

Socially and culturally embedded NOS.

Science is practiced within particular social and cultural contexts and these influence the types of questions that are subjected to scientific inquiry, how scientific data is collected and interpreted, and the role that science plays in society. More informed views of this tenet reflect an understanding that science is shaped by social and cultural factors. Yasmine put it this way.

> I don't think science can just be like one thing. I think theories and [inaudible] math transcends cultural background, because there's no way you could plug something into a calculator a different answer if you're in China, or if you're in, I don't know, United States of America. But I think that theory definitely does affect, like if you're following a theoretical hypothesis, then you are, you *have* to get some of your ideas from philosophers, or past individuals from your culture that you have been influenced by, because you never break that bias away.

Less informed views do not reflect an understanding that science is socially and culturally embedded and instead reflect a view that science is universal. For instance Rafiq stated the following.

> I believe science is universal, because a nucleus is the same as a nucleus in India, USA. It wouldn't be, in Europe a nucleus isn't a nucleus. It's not different.

Sometimes more naïve understandings of this tenet also involve the belief that it is possible to approach science from a neutral standpoint, and that if scientists do not, they should. As Lena put it:

> Some scientific stuff, it does tie into social and cultural things, but I don't think that has anything to do with science. I don't think that true science it would…. I think that social practices have affected the scientific data, I guess you could call it….That's where I'm conflicted, because I don't find that that is true science. I don't think that true science can be affected by social and cultural and political. I don't think it has anything to do with that, but, of course, what people construe as science and discoveries and advances in technology based on those things, those, the social, cultural, and political, they think that they do. But I wouldn't call that true science. So, that's where I'm conflicted in that

> answer to that question. I would say no. I would say that true science has no, has no cultural, social bounds to it.

Of 56 responses that addressed socially and culturally embedded NOS, 23 were more informed: seven from theistic evolutionists, six from people with a belief in the special creation of humans, and 10 from people with a belief in the special creation of all species. Of 33 more naïve responses, 10 came from theistic evolutionists, 12 from people with a belief in the special creation of humans, and 11 from people with a belief in the special creation of all species.

Creative and imaginative NOS. Scientists use their creativity and imaginations throughout the investigative process when designing experiments, collecting and analyzing data, and when formulating explanations for their results. More informed views of this tenet reflect an understanding that scientific creativity and imagination come into play when scientists formulate hypotheses, analyze data, and develop scientific theories. For instance, Mustafa explained how imagination and creativity are used in hypothesis formation and in analyzing results.

> Mustafa: Of course imagination and creativity is a big part of science, because you really, when you put forth a hypothesis, especially if it's a big novelty, like something really new, you can't really base yourself off of much literature. You have to put a hypothesis that was created based on your, what you already know, but also on your creativity, your own imagination. How would you think the phenomenon that you're seeing right now is explained? After you put that hypothesis, you try to disprove it. So, the creation of the hypothesis, like, the start of the experiment is based on imagination, or not like based, but imagination does contribute to it.
>
> Khadija: OK, so at the start of the experiment. What about data collection? So, these other, so, planning and design, I think that's what you were trying to, data collection and after data collection?
>
> Mustafa: So, I think data collection, there's no imagination in that, like, there's no creativity. You set the experiment. You're doing the experiment. You're just collecting the data now. Perhaps in after data collection, you either prove, disprove the hypothesis, and then you come up with a conclusion. The conclusion might require some of your imagination and creativity to come up with. Because it comes back to the dinosaur question where you told me there's two views and there's a set of data. Where did these two views come from? From the data, from the phenomenon observed, and at the same time from the personal creativity and imagination of the scientists on both sides.

More naïve conceptions of creative and imaginative NOS may reflect views that imagination and creativity are not used at all. If they do acknowledge the use of creativity, it is limited to areas such as experimental design and presentation of results to various audiences, and does not involve the use of creativity and imagination in analyzing data and developing scientific theories. Amber's response exemplifies these ideas.

> Amber: I think they use their imagination and creativity when trying to figure out an experiment to try to figure out if their hypothesis is correct.
>
> Khadija: Might they use creativity during data collection or after data collection?
>
> Amber: I don't know.
>
> Khadija: Okay.
>
> Amber: They may use their creativity to try to form a graph a certain way, but I don't think they use it when trying to figure out numbers or the conclusion of their experiment.

Rafiq acknowledged the use of scientific creativity and imagination when developing a hypothesis, but his denial that it could be used when interpreting data makes his views more naïve.

> Rafiq: They may, but they also have to keep in mind that those imaginations or hypotheses might be wrong, or they have to have that possibility 100% that this may be wrong. It's possible, but it's wrong. It could be wrong. So, they have to keep that in mind, but, yeah, they may use their imaginations.
>
> Khadija: Alright, so at what stages of the investigation you believe scientists use their imagination and creativity: planning and design, data collection, after data collection?
>
> Rafiq: Are you saying when they use their creativity?
>
> Khadija: Yeah, when exactly? What do they use it for, and when would they use it?
>
> Rafiq: I believe that they would use it before conducting the study, research, or doing their study or research, and the reason why I think that is is because they want to test it. They want to see: Is it true? Is it possible? And they hope that it is, if that's what they're looking for, but I don't think that they imagine after doing the study.
>
> Khadija: Can you think of an example?

> Rafiq: I guess I can think of a dinosaur example, maybe. So a scientist may, so the study is, this is going to be a simple example.
>
> Khadija: Sure.
>
> Rafiq: So for example, they think, they want to know when exactly the dinosaurs were extinct. Let's just say they don't know yet. So, the scientists would imagine they're extinct let's just say I don't know how many years ago. They say like 5,000 years ago. I'm just saying that. So, using his or her imagination, but after doing the study, finding fossils, and all that his imagination, or her imagination might be proven wrong, and then obviously, that would prove it wrong.

Of 59 responses that addressed creative and imaginative NOS, 21 were more informed: eight from theistic evolutionists, five from people with a belief in the special creation of humans, and eight from people with a belief in the special creation of all species. Of 38 more naïve responses, 11 came from theistic evolutionists, 13 from people with a belief in the special creation of humans, and 14 from people with a belief in the special creation of all species.

Relationship between NOS views and stances on evolution. Both more naïve and more informed views of the various nature of science tenets examined were found among theistic evolutionists, those who held a belief in the special creation of humans, and those who held a belief in the special creation of all species. This was true for empirical NOS, general structure and aim of experiments, role of prior expectations in experiments, validity of observationally based theories and disciplines, tentative NOS, nature of scientific theories, functions of scientific theories, creative and imaginative NOS, inference and theoretical entities, theory-laden NOS, and socially and culturally embeddedness NOS. Concerning the scientific method, difference and relationship between theories and laws, and the logic of testing scientific theories, naïve views were held by respondents from all three positions on evolution. In this study informed views were held only by theistic evolutionists and those with a belief in the special creation of humans, but not by those with a belief in the special creation of all species. However, there were

only three participants with informed views on the scientific method and the logic of testing scientific theories and only five with informed views on the difference and relationship between theories and laws. Naïve views were much more numerous for each of these NOS aspects.

For most of the NOS aspects the majority of the respondents held more naïve views, and more informed and more naïve views were more or less evenly distributed among the three stances on evolution. One exception to this was tentative NOS for which about two-thirds of the theistic evolutionists and those with a belief in the special creation of all species held more informed views and two-thirds of those with a belief in the special creation of humans held more naïve views.

Views on the relationship between science and religion. Students' views on the relationship between science and religion were coded according to the categories given by Barbour (2000): conflict, independence, dialog, and integration. In some cases respondents' answers reflected more than one of these categories. These were scored according to the category that was most prominent in their discussions of the relationship. Three respondents' views could not be coded according to this scheme, so they were coded as "no conflict." One respondent did not have an opinion on this relationship and so her view was also coded as "no conflict."

Integration. Those with an integration standpoint use both science and religion together to formulate a more complete picture of the phenomenon being considered. As James put it, "That Islam and science are a, science can almost become like a, not a methodology, but a framework within Islam ... like understanding nature." He also said, "I think that science is just a way of like explaining the nature of God, so I don't see these two as conflictual, necessarily." He explained how he conceives of science and religion working together.

> I don't believe there's a conflict between science and religion at all, especially Islam, like especially, like specifically…Because, so my conception of Islam, in all my teaching incorporate the idea that – trying to think of the way to word this eloquently – that science and Islam are hand-in-hand, and one enriches the other as the other enriches. They're a balance, because science works to better humanity, better understand humanity's origins, and it also advances us medically ... so, benefitting the public good, ... and, also since the first commandment is to read. The first command is, "Read!"[15] So, I feel like strategically that's emphasized because of its placement.

The phrase "hand in hand" was used by several respondents when describing the relationship between science and Islam specifically or science and religion in general. From Jason's viewpoint "science and religion, they go hand in hand" as long as a person accepts the idea that there is a Creator.

> Jason: As long as science, as long as they do not shun, or do not deny the existence of a Supreme Being, then I have no problem with that. And why? Because like I said before, science and religion, science is a subset of religion.
>
> Khadija: Wait, science is what? I'm sorry.
>
> Jason: is a subset.
>
> Khadija: OK.
>
> Jason: of my religion, of our religion, yes, and I would say the greatest gift that God has given us, the greatest tool that we have been given to use. In fact, in one of the verses, God encourages the believers to seek and learn the universe and study it, and to learn biology, you know. "He who knows himself will know his Lord,"[16] which can be translated from my point of view, as understand how your body works, then biology, human physiology, the miracles of your body, and then you understand the work of God.

Dialog. People with a dialogue standpoint may compare science and religion or use analogies from one to explain the other. Hakim's contemplative answers were coded as having a dialog perspective.

> [The theory of evolution harmonizes with my beliefs about the physical and biological world] because it gives greater depth to the complexity of nature. It gives greater depth to, I mean, prime example, the example of the banana and human. So, we share 50% of our DNA with a banana. Like, why is that? What does that mean in the construction of

[15] 96:1
[16] This is a saying attributed to Prophet Muhammad.

> life? You know, what does that tell us about that as a whole? So, it keeps the human intellect going, I feel like the theory of evolution does, and it keeps it going on a very, it's highly scientific, but at the same time it can't help but be, I can't think of the word. I want to use transcendental, but I don't think that's the word, but it brings you into almost a transcendent level of thought, because it's so much deeper than just the science behind it. You could tell yourself it's only just being the science. It's like oh, genes and this and that, and they make up this, and it brings about these different traits in people. Yes, that's fine, but why? You know, why do these genes brings out these different traits? You know, why do these things differ between? For instance alligators, their medulla oblongata, like, why is theirs so enlarged that they're so angry all the time? What function does that serve their survival? So, just things like that, it gives to me, especially as a person who comes from a very religious background, it gives me kind of that wondering of what, how does this play into God's plan and our role on earth as human beings when we look at these things, these correlations between life?

Dialogue may arise "when science raises at its boundaries limit questions that it cannot itself answer" (Barbour, 2000, p. 3). Respondents who used religion to answer questions that science could not answer were coded as having a dialog perspective. Adam put it this way.

> There is a big gap in science. How did something come from nothing? It's a gap they try to fill up with reason, but it's God, not science.

Independence. Those respondents holding an independence view see science and religion as fulfilling different functions. They do not conflict because they are separate and independent. Carlene explained it this way.

> OK. Religion and philosophy it seems that those fields, they function to tell us why things happen, and science and physics and all the rest, they tell us how things happened. That's the difference that I get from those. Some tell us how things work and others, the philosophy and religion tell us why.

Nafisa explained it this way.

> I think science tends to explain what's going on in the world whereas religion kind of gives it a purpose, I feel like that's what the biggest difference between science and religion.

Asiya consciously used independence as a strategy to keep religion and science from conflicting with one another.

> I think the *main* idea where people *think* it does conflict is about humans, and where humans originated from. If I just keep in my mind that God created Adam and Eve and that was the start of humans, then I can just keep believing in my faith and also believe in evolution while seeing the changes within the species of animals and humans. You know I believe in evolution, because I do feel it changes, but I don't think that there's no reason that God couldn't operate through evolution, because God isn't limited, so … sometimes when there are things that might not go together I just keep them parallel. I keep my Islam parallel, and I keep evolution parallel, because, you know, it's science and it could be wrong, you know, but not necessarily the theory of evolution, but maybe something specific that they saw and that's like challenging my faith maybe, I just keep it parallel, because my belief in Islam kind of overrides everything.

> I think that science is the study of what God has created. My mental, I guess my perspective, or the window through which I see it through is God is operating and doing these things, and in fact, you know science complicates or it simplifies, whatever, the things that I see every single day, and it just makes me a lot more conscious of God, because I don't think that something that significant, and when I say significant, I mean everything, from our ecosystem to the biochemical processes and pathways. I don't think all that could have happened on its own from nothing, so, and I do have a hard time consolidating this with, I think it was the Urey-Miller experiment where they first showed how it's all evolved and then that leading on to different species and humans. It's hard to consolidate that with religion, and so I don't. I just keep that parallel. Or whenever I find a difficulty, I keep my faith, and I just go parallel with the bio, because, you know, if the theory makes sense, then just follow it, but don't necessarily need to believe in *every* single thing.

Conflict. Some respondents found that religion and science do conflict, particularly when it comes to evolution. Respondents were coded as having a conflict viewpoint if conflict was a major theme for them in discussing the relationship between religion and science. Lena saw major conflicts between science and religion which permeated many aspects science outside of evolution, including biotechnology and classification. This can be seen from her quotes above as examples of those who held that all species were specially created and of those with a more naïve views of socially and culturally embedded NOS. The following exchange clearly exemplifies her conflict standpoint.

> Khadija: Give me an instance in which science and religion would not be in conflict, and then give me an instance in which it would be.

> Lena: I think in which it would be medicine. Medicine is a part of science and discovery that goes back into religion, because it's what, and I'm going to go back into religion because it's what Allah has given us knowledge about. So, it's not something that it can go hand-in-hand, because medicine is derived from so many things, plants, and chemicals, and I think that these are things that God gave us knowledge of in the first place, in order for us to be able to heal ourselves, whether it's organic or not. But I think that medicine has one part of science, and then goes back in hand with religion. And then science, a big one is evolution. That I don't think that goes hand-in-hand with God's teaching, obviously, any kind of cloning or making something that didn't come from God, is not from, is in conflict with religion as well. I think that being able to heal ourselves, like, for example, what doctors can do, a lot of that comes from science and discovery. But at, at the same time it's mostly what Allah just deigned to enlighten us with. There's only a certain amount of percentage we can use from our brains. Why is that? From a scientific perspective why can can't we just tap in something and unlock the other portion of our brain. Because God hasn't deigned to enlighten us with that information yet, well, if at all. So, in some perspectives it is, they can hold hands, but in this, in other perspectives, it is, not *innovation*, but it, I think that we have, we have learned to believe what we want to believe out of science. With science you can only take one edict, I guess you could say, one perspective, and I don't think that there is one perspective on something…. I think that scientists think that they know it all and that their answer is the only answer that can be found, which is, I feel is blasphemy. Ha! So, to answer your question, yes and no, and in some things yes, like medicine, and what doctors can do and things like that, yes, and in evolution, cloning, and all of these things that they take and do under a microscope I don't think should be done, and it conflicts with religion, because at one point, yes, of course, we have free will, but what we do with our free will is what I guess goes back to your morals. Can you stand before God and say, this what you wanted from us? Scientifically, they'd say yes, religiously, I would say no.

No conflict. Four respondents were difficult to place into one of Barbour's (2000) four categories. They did not hold a conflict standpoint, but they did not fit neatly into one of the other three categories, either. They were coded as "no conflict."

Hasina did not hold a firm conflict standpoint, but she had elements of the three other categories, independence, dialog, and integration, in her thinking. She rejected the conflict standpoint, because she believes that a person needs to take both science and religion into account. From her standpoint someone who only considers science has an incomplete picture. Here she rejects scientism which is a conflict perspective.

> Khadija: Do you believe that the theory of evolution presents a conflict between science and religion?

Hasina: I do only because it doesn't take into account religion, and the people who did come up with the evolution theory, they're most likely just hard science. They don't believe in a higher power.

Hasina held that both the evidence used for science and that used for religion are valid. When they do come into conflict, religion holds sway, as illustrated by the following exchange.

Hasina: Because I did take evolution, parts of evolution bio, so, like the hard evidence that I saw, it kind of shows that there is some type of evolution or progression of species from one thing to another. Does that make sense?

Khadija: Yeah.

Hasina: OK.

Khadija: Why don't you think that humans evolved?

Hasina: Only because Allah put Adam and Eve on this earth, and they were the first humans on this earth, and I don't think we've evolved from like as what the actual evolution is, like from before *Homo sapiens* and all that. I don't think that we've evolved from that to this.

The following exchange seems to indicate that Hasina has not finished sorting out the relationship between science and religion for herself. Perhaps she does not neatly fit into any of the categories because she has not decided for herself what the relationship between science and religion is.

Khadija: Does the theory of evolution clash with your own beliefs about the physical and biological world?

Hasina: Yes and no.

Khadija: OK.

Hasina: If that makes sense?

Khadija: If you could explain.

Hasina: Like, if you think about it from a religious point of view, it kind of conflicts, but if you think about it from like a science point of view, it doesn't.

Khadija: Alright, so, why would it conflict from a religious point of view?

Hasina: Because just the idea that, I'm not really that educated, but just the idea that we sort of came from monkey-like animal type to like actual humans that we are today, I just, I don't think that … makes sense at all that we evolved from monkeys, from humans animal-like to humans, because Allah created everything that there wasn't any evolution of humans, involvement.

Khadija: And from the science point of view, why would it not clash?

Hasina: Because there's evidence. I believe there's evidence, or else this would not have been such a theory, but there's evidence that shows that we might have evolved from monkey-like animal things. [sighs]

Nusaybah's position was difficult to categorize according to Barbour's (2000) categories because she was disengaged from the process of sorting out the relationship between science and religion. She did not perceive any conflict because she avoided engaging with science and with evolution. The following interchanges in response to two of the interview questions illustrate her disengagement with science in general and evolution in particular.

Khadija: OK. So do you believe that the theory of evolution presents a conflict between science and religion?

Nusaybah: Presents a conflict between science and religion. I really don't know. Because I've heard both sides, Muslims and non-Muslims. Some Muslims say they don't believe in evolution and then some of them say that they do. So, I really do not know. I really do not know the answer to that one.

Khadija: OK. So.

Nusaybah: Some, quite a few people say they don't believe in it in debates about it, and then other people say that they do believe in it.

Khadija: OK, so you personally, would it be fair to say that you don't feel you know enough about it to know whether there's a conflict or not?

Nusaybah: Yeah, I would say that. I really couldn't take a side, honestly, I really don't take sides.

Khadija: Does the theory of evolution clash with your own beliefs about the physical and biological world?

> Nusaybah: Physical and biological. I don't even know. I don't know that much about evolution.

These respondents were difficult to categorize due to lack of knowledge about or lack of interest in the relationship between science and religion, or because they were still sorting out this relationship for themselves.

There is conflict for others, but not for Islam. Many respondents stated that there was no conflict between science and religion for Islam, but that this was not the case for others. For example, Habib discussed this contrast from a historical perspective.

> I think for this I can get a bit more specific, because when it comes to the West, yeah, there's always been a conflict, religion and science. When it comes to studying the, I guess you could say, the Orient, the Middle East and further east, I mean, it seems like religion and science went hand-in-hand for them. The Abbasid caliphate's an example. You have these various polymaths. In the West, I mean there's many variables. I'm not going to try to simplify it, but I think especially the conflict with the Catholic Church and the rise of secularism led the West to always perceive that religion and science was at conflict, and so, as a Muslim, I can respect that conflict. I can understand that that occurred, that that division is still going on. As a Muslim, no, I don't think there's a conflict between religion and science.

Abbas believes that this is the case because in Islam the scriptures are in accord with scientific understandings, while for other religions they are not.

> Abbas: Between science and religion, yes. I don't think there should be a problem between science and Islam, though. Some religions have major conflict with science. I think that Islam and science can work together in unison throughout every topic in science.
>
> Khadija: Well, why do you think so? Why do you think there's no conflict between Islam and science, but there is between some other religions and science?
>
> Abbas: Some other religions clearly state some facts about the world that science clearly goes against, such as the age of the earth and other things, but I think Islam never truly conflicts with science, and throughout history Islam has always been promoting science and math and education and has been a very open-minded religion throughout history.

Nearly half, 48%, of the respondents viewed science and religion as integrated. Only one-fifth, 22%, viewed the relationship between the two as a conflict. Of these, nine held the

position that all species were specially created and the remainder held the belief that humans were specially created. None of the theistic evolutionists in this study held a conflict view. Those holding an independence view were 10% of the sample, and 13% held a dialog view. The integration, dialog, and independence categories included those with all three stances on evolution. Those holding the no conflict position either held the position that all species were specially created or that humans were specially created.

Question 3. What are the characteristics of very religious Muslim acceptors of evolution? How do they reconcile their acceptance of evolution with their religious beliefs?

Six highly religious theistic evolutionists were identified by scanning the data for theistic evolutionists with religiosity indices of 2.4 or greater on a 3 point scale as depicted on Table 8. These were Samra, Nadira, Sulayman, Sana, Ali, and Sauda. Here we examine their thinking on evolution and the manner in which they reconcile their religious beliefs with their acceptance of evolution.

Samra. Samra identifies as just Muslim. She was born a Muslim to an Arab immigrant father and an American-born European-American mother who both identify as just Muslim. She was 18 and a sophomore at the time of the interview.

She took two biology classes, one in high school and one in college. Both taught evolution. She had a fair understanding of evolution according to ACORNS.

Samra had a mixture of naïve and informed NOS views. She had a more informed understanding of tentative NOS and theory-laden NOS. For the difference and relationship between theories and laws her understanding was more naïve in the sense that she did not know what these are. Her understandings were more informed in the sense that she did not think one is more tentative than the other or that they are hierarchal in nature and because she understood that

tentative NOS applied to both. Her understandings were more naïve on inference and theoretical entities, social and cultural embeddedness of science, and creative and imaginative NOS.

Samra considers evolution a "scientific fact." She explained that for her, "I just believe that evolution has occurred, that God did it." She explained further, "I believe that it happened, just Allah guided it and made it all happen." She did not have any problem with the idea that evolution emerges from random processes. She explained, "I believe that Allah, you know, did it for a *reason*, but I don't have a problem with the fact that it could have been just randomly done." Her GAENE score of 57 was in the range of moderate acceptance of evolution.

Samra saw the relationship between science and religion as one of integration. She explained that there was not a conflict between science and religion, "because in my religion, Islamically, Allah does everything for a reason, and science just helps prove the reasons that His, what has happened happened."

Samra was able to accept evolution by integrating science and religion. She saw evolution as a credible explanation for the scientific evidence of species change. For her science was a means to learn about what Allah has done. This allowed her to incorporate both scientific explanations and her religious beliefs into her conceptions.

Nadira. Nadira is an Ahmadi Muslim who was born in the United States as a Muslim to Ahmadi parents, both of whom migrated from Pakistan. She was aged 21 and a senior in college at the time of the interview.

Nadira had a good understanding of evolutionary processes according to the ACORNS measure. She reported that her understanding came largely from a science class she took in eighth grade and from biology classes she took in high school and college. As a biochemistry

major, she had detailed knowledge of the molecular basis of inheritance which also informed her understanding of evolutionary processes.

Nadira had a mixture of more naïve and more informed NOS views. She had more informed views of tentative NOS, inference and theoretical entities, creative and imaginative NOS, theory-laden NOS, and of socially and culturally embedded NOS. She did not understand the difference and relationship between theories and laws. She thought that, "A theory could become a law if it proves to be true in every circumstance." She believed that theories could change, but that laws could not. She also had more naïve views of the scientific method, the aims of experiments, the role of prior expectations in experiments, and of the validity of observationally based theories and disciplines.

Nadira chose both "All species, including humans, have evolved over millions of years, but Allah guided the process," and "Allah created humans and all other species in the form they exist today," adding, "and in the form they existed prior to today," as being closest to her view on evolution. She explained her choices as follows.

> When we read in the Quran the story of Adam and Eve and how they came along. Allah created humans and creatures in a way for humans. All creatures submit to God and all creation is Allah's creation. [This is a conclusion from what she's learned in the Quran. She qualifies this by saying she is not a scholar, so she doesn't remember a specific ayah.] It is explicitly stated how in the Quran. The way Allah used to make species the way they are today. It is very logical and you can figure it out. So, that's why I have no *doubt* that Allah created in this way and that we were created by Allah.

Nadira views evolution as being consistent with what the Quran says about the creation of human beings and other creatures because she believes that Allah is behind the process of evolution.

Nadira used a dialog between Islam and science to negotiate the relationship between the two. To do this she used a religious analogy to explain why evolution is a slow process.

> [The time frame for evolution was] maybe longer [than millions of years]. We can guess when the world started. When you look at religion in itself, it took a long time to develop. First, there was Judaism, then Christianity, and then the Prophet (saw) was sent. Maybe it took longer because people and all species take change very slowly. Allah is not unjust, so that is why it takes longer. First, we had Judaism. Then religion was changed in the form of Christianity, and then Islam. The same thing applies to physical biological evolution as well.

Nadira then went on to explain how this slow process of evolution could benefit human beings.

> Science is a tool in order to understand religion. Writers use different writing styles for readers to understand. Allah has made science as a tool for us to understand creation. If He had us evolve too fast we wouldn't have time to acquire as much knowledge about Him. Science is a tool to understand Allah's word.

Nadira explained how her mother was instrumental in helping her negotiate the relationship between religion and science so that she could accept evolution. She also relied on guidance from the Ahmadi khalifahs, particularly the fourth khalifa, Mirza Tahir Ahmad.

> From the Quran and whatever my parents taught me. Some parts my parents guided me towards. This is what the khalifahs said. It was reiterated in school because I had to take biology. I started learning about evolution since I was very young. My mom taught us that things change and how Allah wills it. In school in eighth grade was the first time we discussed it. I didn't have any conflicts because I was already, I was taught very early on, so there was no conflict. I never felt the need to go online and look at it, no need to expand it. When taught early on, one is not as curious about them, I guess. The story of Adam and Eve was taught very early on and how they were made. Although when you're young, it's intriguing. When you actually go into science, it makes sense. As a Muslim girl, I was taught this from early on. I studied science all through high school by taking courses. It's reiterated or added on with more specificity.

Nadira was able to accept evolution because she used dialog to negotiate the relationship between religion and science by drawing an analogy from the gradual development of religion to the gradual development of species. In her view gradual creation was an expression of Allah's mercy, because it allowed human beings to come to a greater understanding of the process of evolution and also to appreciate the power of Allah. Integrating evolution and her religious beliefs was made easy for Nadira because she had been taught how to do this by her mother from a young age. She also relied on the example of a religious scholar and past leader of her

religious community, Mirza Tahir Ahmad, to help her negotiate this relationship. Because of these positive examples of how to negotiate the relationship between evolution and her religious beliefs, she did not find it necessary to go through a process of intense questioning and study to help her negotiate this relationship.

Sulayman. Sulayman is a Sunni Muslim who was born as a Muslim to Sunni parents. He identifies as African-American, although he has ancestors who originated in Europe and North America as well as Africa. His family has deep roots on the North American continent because his African and European ancestors were not recent immigrants. He was aged 21 and a sophomore in college at the time of the interview.

He took a biology class in high school and was taking another in college, but neither class spent much time on evolution and he did not remember their coverage very well. According to ACORNS Sulayman had a fair knowledge of the mechanisms of evolution.

Sulayman had a mixture of more naïve and more informed NOS views. He had more informed understandings of the concept that there are a variety of methods that scientists use to investigate, including controlled experiments and observational studies. Sulayman had a more informed view of tentative NOS because he thought that both theories and laws were subject to change. He was also more informed in his understanding of the nature of theories, because he recognized that they are explanatory in nature, but less informed because he thought they were not too reliable. He was more naïve in his understandings of creative NOS, socially and culturally embedded NOS, theory-laden NOS, and inference and theoretical entities. This was because he did not understand the role that these factors play in the interpretation of observations and the analysis of data.

Sulayman accepted both macroevolution and microevolution. For example, he thought it possible for a fish to evolve into a land animal. He was reluctant to speculate on the time frame because he did not feel knowledge about that aspect. He described his position on evolution as follows:

> Khadija: So, A is All species, including humans, have evolved over millions of years, but Allah guided the process....
>
> Sulayman: A, definitely A.
>
> Khadija: OK. And why did you choose that one?
>
> Sulayman: Because just judging from how you see other animals adapt to, maybe evolution and other things have to do with the different species adapting to their surroundings, so you see like fish or any kind of animal these days adapting to changes in the weather, or changes in the water, so I feel that the same thing happened to humans and Allah guided them through that process.
>
> Khadija: And why do you think that?
>
> Sulayman: Survival.
>
> Khadija: And why do you think Allah guides the process?
>
> Sulayman: I think Allah guides the process I guess for people to eventually become more intelligent and the more intelligent you become, the more you can see Allah's presence in your life. So, I guess you could say over time whenever people figure things out they learn new things. They are able to see the real beauty in everything that Allah's created, which is why a lot people nowadays are being guided to Islam, because they're starting to see the actual beauty in it. So, the smarter people become, the more they're able to see religion clearly. I say it's a thing of intelligence.

Sulayman is able to integrate his view on evolution with his strong religious beliefs by conceiving of it as a mechanism used by God to produce intelligent people who could worship Him with understanding.

Sulayman shared some characteristics with people who held that all species were specially created. Although Sulayman agreed with statements such as that evolution applied to all plants and animals, including humans, while taking the GAENE survey, he disagreed with

statements that it was a good explanation for how new species arise or how humans first arose on the earth. His GAENE score was only 36, which can be interpreted as no or limited acceptance of evolution. When asked about his responses to the GAENE items, he replied, "I mean back to whatever I said at the beginning part of it, as far as how it was put on this earth or, I wouldn't agree with all of it, but some of it I would agree with, not all of it." All of the other theistic evolutionists in this study had GAENE scores in the 50's and 60's. All but one of the other respondents with GAENE scores in the 30s were people who held a belief in the special creation of all species. The exception to this was a person who held that humans were specially created, but was not sure about other species. Sulayman was the lone African-American respondent who was a theistic evolutionist. The other six thought that all species were specially created. Sulayman was also the lone theistic evolutionist who thought there could be negative moral consequences for accepting evolution. He explained his position as follows.

> Sulayman: Hmm, I mean if you partially accept it, I don't see anything wrong with that. If you agree and disagree with some things with some things in it, I don't see any problem with that, but if you like fully accept it, then there might be some conflicts and issues.
>
> Khadija: OK, so what would be the conflict in fully accepting?
>
> Sulayman: Conflict in fully accepting? Hmm. That, I mean they sometimes believe that there's absolutely no start, like there's no link to God and everything existed, because nothing can just come from nothing. Like something just can't naturally just came from nothing. I guess that's where the logic comes in. It's just that one missing piece that people don't want to agree with.

Most of the other theistic evolutionists thought there were no moral consequences for either accepting or rejecting evolution. The exception to this were three Ahmadi respondents who thought there might be positive moral consequences for accepting evolution and one who thought there might be negative moral consequences for rejecting evolution.

Sulayman was considered as having an integration view of the relationship between science and religion. When asked if he thought there was generally a conflict between science and religion, he gave the following reply.

> I mean, most definitely, yeah, but that was geared towards people who reject religion and just the extreme science. I mean that there's Muslim scientists that, because they're scientists, their religion gets stronger, because all the things that they find out that's true, and all the things that Allah talks about in Quran and how it links to the world, they used to get stronger, but there are some scientists just completely reject religion, I guess because they haven't found out complete truth, because everything's always incomplete as far as the studies. Things are always changing.

Because he sees scientists who are religious as having the complete picture and non-religious scientists as missing part of "the complete truth" he was considered to have an integration view of the relationship between science and religion. There were also some elements of a conflict orientation in his views as exemplified by the following exchange.

> Khadija: Does the theory of evolution clash with your own beliefs about the physical and biological world?
>
> Sulayman: I don't have a lot of knowledge about it, but the little bit of knowledge I do have about it would definitely clash.
>
> Khadija: In what way?
>
> Sulayman: I mean just, like I stated earlier, just like something coming from nothing. I mean that really wouldn't make sense. And then there being no Creator Who fashioned things for a reason.

Of twelve respondents with a conflict view, nine held a belief in the special creation of all species and three held a belief in the special creation of humans. Although conflict was considered to be a lesser component than integration for Sulayman, to the extent that he holds some conflict views, this makes him similar to respondents who hold a belief in the special creation of all species, nearly half of whom hold conflict views.

Sulayman is able to accept evolution because he is able to integrate the concept of evolutionary change with his religious beliefs. For him, evolution is a means for the Creator to fashion living things and He does so for a purpose. He said, “So I think that the theory may be true in some aspects, but it would be better navigated if religion was thrown in it, and maybe you could make sense out of it a little better than just sticking to straight science.” By using both his religious views and his knowledge of science he is able to accept evolution by integrating both science and religion.

Sana. Sana was a 22-year-old senior at the time of the interview. She was born as an Ahmadi Muslim in the United States to Ahmadi Muslim parents. Her parents and grandparents migrated to the U. S. from Pakistan.

She explained her position as a theistic evolutionist as follows.

> Khadija: Alright, and so why do you think that all species including humans have evolved over millions of years, but Allah guided the process? Why do you think that?
>
> Sana: Well, I mean, I can't even tell you that I know from the specific verses you can find in the Quran anywhere that says that, but I think that all of life, that not even just on earth, started with Allah, and He is the Almighty, and I don't have like a general source or reason to that. That's just like what I believe, and I don't think that human hands played anything in it. I think that He definitely started it, and that we're a part of it. So like all those things people talk about, like the Big Bang theory and things like that, I don't necessarily believe in those, and even those theories actually still have holes in them, and I think the reason they have holes in them is because the truth is, that scientists don’t want to say, that Allah is actually the one that started it, which is why they can't find a solid reason to the pinpointing part of when the universe began.

While taking the GAENE survey Sana hesitated when it came to the evolution of humans, “Because I feel like I’m not educated enough to answer that question, and by that I just mean that I can't remember what exactly it says in the Quran about how humans came to be, and I wouldn't want to answer that question without going back and reading that passage, or reading all the verses on what it says about that, because I don't believe that-- because I still really firmly believe in science, the way it works, and I really don't think that it conflicts with evolution, and

that religion conflicts with evolution, but that I would want to look in the Quran and see what it says about the process of how humans came to be before I said yes for sure."

Sana was comfortable with her position as a theistic evolutionist because she was not aware of any contradiction between the verses of the Quran and the idea that all species, including humans, evolved. She thought that scientific evidence was valid and that it is important to take it into account, but that the standard against which science and everything else should be judged is the Quran. For Sana, the Quran is the word of God. She explained her thoughts on interpreting the Quran in the following exchange.

> Sana: That's such a good, not black and white question.
>
> Khadija: Alright. Well, tell me your view on that.
>
> Sana: Well, I think that there's some time where even the Quran has, it can come in a version, you know where it comes with a sort of a, not just a translation, but-- what is the word I'm looking for? It comes with a commentary, right? And I think just the need for commentary alone shows that it does give us words, but we need to read more in depth besides what those words say. I wouldn't say that it's like, yeah, you don't have to take it word for word, like with that column, but I think of it more as like what it says, you need to take it and think a little bit deeper about what it says. I think there's a good distinction between those two.
>
> Khadija: All right. It sounds to me like you're saying that if you just take the surface meaning, you might miss the true meaning. Is that perhaps what you?
>
> Sana: Yeah, yes.
>
> Khadija: Okay.
>
> Sana: Thank you.

Sana used integration to formulate her view of the relationship between science and religion. She believed that scientific evidence could prove the existence of God, as shown in the following exchange.

> Khadija: What do you think of Darwin?
>
> Sana: I think he's pretty brilliant. I think his scientific research and commitment was absolutely amazing. What I also think though is that sometimes people don't necessarily

> appreciate, well people who have, I shouldn't say that. I think that when people appreciate people like Darwin they should also appreciate the creator behind evolution in the first place. I mean the way that he compared the different beaks of the birds that he found on Galapagos Islands, like the time and detail that it took him to find those things. I think it's really interesting that people don't take a second to think that even nature couldn't have caused something as perfect and as useful as evolution. I think that proves the existence of God, but that was kind of a tandem. I think that his work proves evolution, but I don't think it disproves the fact that a God exists. It rather supports the fact that a God exists.

Sana explained that science was a means of understanding Allah's creation.

> I think you need to have the faith, but I think at the same time it is important to understand what we've been given, and I think the way to do that is through science, which studies everything that's happening around us. In other words, I think they go hand in hand.

Although Sana did not see any conflict between science and Islam, she acknowledged that there might be a conflict for people with other belief systems.

> I think that it depends on which religion you're talking about because we had this discussion a few times in my masjid, and with other religions, not Islam Ahmadiyya, there can be issues, but in our Quran, there aren't any issues that I have ever heard or read of that conflict with the idea of evolution, because the idea of evolution really just says that a species could adapt to its environment and as a result of adapting to its environment, certain features can become or certain features might go away, not necessarily go away, but I don't know how to say it scientifically enough, but one is preferred over the other over time. It's not saying that one day species just arrived. It's saying it's like a slow process, and I don't think any that is something that God doesn't exist.

Sana had a good understanding of the mechanisms of natural selection according to the ACORNS measure. She learned about evolution from a biology class she took in high school and another she took in college. She supplemented the course material with You Tube videos explaining specific aspects of evolution. She was also active in the Ahmadi Women Scientist Association at her local mosque, which gave her opportunities to participate in discussions about science with other women. This exposure gave her what she described as "just a basic knowledge" of evolution.

Sana integrated her understanding of evolution with her religious beliefs on her own, as illustrated by the following exchange.

> Khadija: Where did you get your ideas about evolution?
>
> Sana: Generally, from school. The interesting thing about my view on evolution was that in the masjid maybe up until a year ago the topic of evolution actually never came up. I think that my general view on evolution is that I think God sets science into motion, which is why I believe in science, and I don't think it conflicts with Allah, but at the same time, I'm not really sure-- I think it's just my faith is strong enough to where I do believe that, because God sort of plays a hand in things, but my actual views on the scientific part of evolution came from school and came from college. I even learned from professors who are atheists and who don't believe, or try to separate religion from science, and even still it hasn't hindered my idea that God plays a role, even though nobody's ever said that to me.

Sana's process of integrating science with her religious beliefs was not without conflict. Her biology professor was not supportive of the idea of integrating science and religion. Discussions with others who supported an independence view for science and religion caused her to express concerns that her belief that the two should be integrated might hinder her in a scientific setting.

> Khadija: Okay. Do you think there is a natural conflict between being a devout religious person and living in a modern society or you don't think so?
>
> Sana: I think there is. I think it can be very hard. I know when I took my evolution class my teacher was not in agreement with my views at all. He really didn't think that there was a God. He just didn't believe it. He said that the way evolution functions, there's no place for God in that, whereas I really disagree with that statement and that could be hard because he controls my grades. He's my superior in that setting, and for me to like disagree profoundly with his beliefs could be [inaudible] the position that I defend. Alternatively, if you are an evolutionist, I would say that most of the evolutionists that I have met believe that religion and science are separate at the very least, even if they believe in God. Somehow they find a way to separate that, even though I've never seen justification for that, so it can be difficult to believe the way that I believe and try to function in a scientific setting.

Sana rejected the independence view of science and religion because it did not make sense to her. Using integration to negotiate the relationship between science and religion caused her to differ from other people who accept evolution.

Sana thought there might be moral consequences for rejecting evolution because that would mean denying God's purpose in using evolution for the development of people.

> I think that if you reject evolution-- I guess it depends on the way that you look at it. If you look at it that God has put evolution into place so that the beings that he started life with can develop over time to be smarter, better adapted to their environment, even humans for that matter, if you look at it that way, then that might have moral consequences, because if you do believe that *Homo sapiens* started from, whether you believe it's from monkeys or from other organisms that we were allowed to become the thinking beings that we are today, thinking enough that we can even read the Quran or accept Ahmadiyya, then that would be problematic because then you're suggesting that even to go as far as to say Ahmadiyya wouldn't have existed in the first place, maybe even if you think of it that way, but if you reject evolution, meaning like you just reject the process of certain parts of it, then that might not be problematic, I guess. It depends on how somebody would specifically ask the question.

Sana's NOS views were a mixture of more informed and more naïve views. She had a more informed understanding of the nature of scientific theories, because she understood that they were well-supported by scientific evidence. "A scientific theory is-- it's this idea that has been experimented over and over again and just basically looked at, at every single angle, to prove it or disprove it, and it's been proved to such a strong degree that you can say it's something like 99.999 % sure." However, her notion that scientific evidence proves or disproves theories, rather than supporting or refuting them stems from her more naïve views on empirical NOS. These views also colored her understanding of inference and theoretical entities. Sana knew that the structure of atoms was determined by indirect evidence. Despite this, she generally saw science as being based mainly on things that have been determined to be "true" by experimentation. She had more informed views of creative and imaginative NOS, explaining how a chemist would use creativity and imagination at every stage of an investigation, from the initial design, to trouble-shooting during data collection, to explaining the results at the molecular level. Sana thought that science might be universal. However, she thought it possible

that she might be incorrect in this because she was still in school and had not had an opportunity to work as a scientist in the scientific community yet.

Sana had expressed a great deal of respect for scientists and she viewed scientific evidence as a valid means of understanding the natural world. She accepted the theory of evolution in part because she considered scientific theories to be backed up by large amounts of scientific evidence. However, she viewed religious understanding as the standard by which to judge other forms of knowledge. Sana used integration as a strategy to form her ideas about the relationship between science and religion despite not having had a role model to guide her through this process and even despite facing opposition from people who did not view integration as a valid way of negotiating this relationship. As an Ahmadi Muslim she did not encounter anyone at the mosque who objected to the position she had taken as a theistic evolutionist. According to her understanding evolutionary theory did not contradict verses of the Quran. She was able to integrate the theory of evolution with her religious beliefs because she thought of God as using evolution for His own purposes.

Ali. Ali was a 25-year-old senior at the time of the interview. He was born in the United States as a Shia Muslim to Shia Muslim parents who emigrated from India.

Ali placed value on both the scientific evidence for evolution and also on his faith in God as Creator. He described his position as a theistic evolutionist.

> I believe that science to like adapt and evolve and continue a time did have a role, but I do believe God also played a role in it as well. It's not just God played a role in just humans, but also all species. He created all species, so I do believe in that as well. So, I believe that God did have a part. God created species and flowers, everything, and then allowed this to change, and allowed science to do its course. That's pretty, that exactly describes what I would believe.

Ali crafted his position as a theistic evolutionist by studying both the scientific evidence for evolution and then reading about the position of Islam on science in general and evolution in

particular. By listening to speeches from religious scholars at the Islamic center he learned about how God played a role in evolution. The Islamic center also "hosted a science fair where it would incorporate science and Islam, the teachings about Islam say, from the Quran or different other hadiths, but also incorporating science as well into it, so not forgetting the science part, but also not forgetting Allah's role in it as well." He considered this evidence and formed his position. He also thought there could be a generational factor in his willingness to accept evolution because in the Indian Muslim community his generation was more "open-minded" than his parents' generation.

Ali negotiated the relationship between religion and science using integration.

> I personally believe religion has a big part in science. Just I personally believe God has a role in everything, in everyday lives, what you do, what you eat, what, so I that's how I personally believe. So, I do believe God has a big part in science as well, just creating mankind, creating species, and I also do believe the science part as well where, I don't disprove it. I do believe, but I guess therefore I believe there should be balance where people shouldn't be closed-minded or think that science doesn't have anything to do with religion, especially the part where many hadiths, many sayings, even in the Quran, where knowledge of science is a big part of religion as well. So, I believe that they co-exist together and there's a balance between them, and like the whole theory of evolution is I believe more of God has more of a major role, but I do believe more to things do change over time where science has evolved, but God is in there as well. God is the first Maker who created anything which allowed science to do its part.

However, Ali thought that science and religion would conflict for people who only accepted the religious evidence or only accepted the scientific evidence, and not both.

> Because science, from what I believe, from what I know science believes that there's a yes and a no, black and white. There's no like grey area, this happened because of this, and people who are really religious, they believe God had, there was this God who created man, and it was God Who had the processes, people who believe in the science of evolution believe that it was because of science, and not because of a Supernatural Being, so there's a big conflict where you can see like a lot of people do believe that God did play a role, but some people believe it's just God, and they don't believe in science where we evolved from like, you could say apes or monkeys, a lot of people don't believe that. A lot of people just try to see the conflict in that where scientists, where people who are religious don't believe where they do believe that God had a major role, but scientists don't, so you could see a big conflict in that.

Ali saw a conflict between the science-only camp and the religion-only camp, but also between these two camps and those that think science and religion should be in balance. He also believed that to fully understand a phenomenon, one needs to take into account information from both religion and science.

Ali had a fair knowledge of the mechanisms of evolution according to the ACORNS measure. He learned about evolution in middle school, in a high school biology class, and in two biology classes he took in college.

Ali had more informed views of tentative NOS, because he thought that theories could change as new technologies are developed which provide additional information. He was more informed on the functions of theories as explanatory in nature. About theories, he said, "theory is more of knowing or thinking what the cause and effect that can, if you do this, this will happen." He was also more informed on social and cultural embedded NOS, because he thought that social and cultural values could have an impact on scientists' research and the conclusions they draw from it.

Ali's other NOS views were more naïve. He explained his conception of science.

> Science pretty much is a yes or no. Yes or no, if you have a question, it's a yes or no answer. Where with philosophy and religion there's many different problems with different answers, or, of course, you have like the miracles, or you have something that's unexplainable, but with science, everything can be proven or disproven through the scientific method, through research or, yeah. It's more a black and white.

In Ali's view, scientists follow a step-wise method to perform experiments that can prove or disprove a theory or hypothesis.

> In science I think you can't just make a claim. You would have to prove it, so you have to show the research and show in order to prove your point or your theory or your hypothesis, because a lot of people can just believe you, but if you have the facts or if you have the facts to back it up, then you're more credible, and I think with science you have

> to do that or in order to have your experiment be proven or backed up, you need to experiment, you need to prove it correctly.

Ali's view that science deals with facts that can be proven or disproven was more naïve because it disregarded the role of scientists' interpretations of empirical evidence. Ali also had more naïve views on inference and theoretical entities stemming from these more naïve views on empirical NOS. He thought that the structure of atoms was determined by observing them under a microscope and that species were defined by data collected during scientific observation. This also colored his more naïve interpretation of creative and imaginative NOS. He explained his views in the context of a manufacturer testing a new product. Creativity and imagination would go into designing the new product and in planning tests for it, but not in analyzing the results of those tests, because "in the planning process you can get creative and innovative, because after, you have to follow the procedures, and the steps of the scientific method"

Ali was able to accept evolution while maintaining his religious beliefs by integrating religion and science. He found the scientific evidence for evolution convincing and integrated his religious beliefs by saying that God had a role to play in evolution and in other processes that science explains.

Sauda. Sauda is a Sunni Muslim, born Muslim to Sunni parents. She hails from India and had been living in the United States for eight years at the time of the interview. At that time, she was a non-traditional student, a freshman in college in her early 40s.

Sauda had more naïve understandings of all aspects of NOS. She had a poor understanding of evolution according to the ACORNS measure and was unable to articulate any understanding of it during other parts of the interview. She had never heard of Charles Darwin. This is likely because she reported not having had any biology classes prior to the interview. When I asked her where she learned about evolution she mentioned online sources, such as

Wikipedia, and she quoted from this source during the interview. She quoted extensively from the Berkeley evolution website as well. Since these were not her own opinions or understandings it is hard to interpret her use of these quotes, except that she thought it necessary to defer to an authority due to her own limited understanding at the time of the interview. When she did speak from her own understanding, it was clear that she viewed the acceptance of evolution favorably. On the morality of acceptance or rejection of evolution she said, "By accepting this kind we can see what we are, what's happening in the history." For her, evolution was a means of understanding what happened in the past. She accepted what scientists say about evolution because they are the authorities on that subject.

It was clear that Sauda was aware of her limited knowledge and that she eagerly anticipated the opportunity to gain more understanding. She was thrilled to be starting her post-secondary education.

> Actually, I need to do a lot of research. I like to do more research, more studies, because from 40 years, I didn't study. I was back home, so I was a housewife. Just now I went to college, so I want to know more, more, more, more about science and everything and Islam, in shaa Allah [God willing].

Overview of highly religious accepters of evolution. The highly religious accepters of evolution in this study all found ways to reconcile their religious beliefs with scientific evidence in support of biological evolution. As depicted in table 14, five of the six used integration as a standpoint for the relationship between science and religion and the other used dialog. Two had a good understanding of natural selection, three had understandings that were fair and one poor. Members of all the groups of Muslims included in this study, Sunni, Shia, just Muslim, and Ahmadi, were among the highly religious accepters of evolution identified in this study. None were converts, and all but one were born in the United States. Four of the six had ancestry from the Indian subcontinent (Asian) while the other two were white (mixed European and Middle

Eastern ancestry) or African-American (ancestors immigrated involuntarily). The group included both males and females. They included a freshman, two sophomores, and three seniors. Most were traditional students, but one non-traditional student was included as well.

Table 14
Highly Religious Theistic Evolutionists – Demographic Information

Alias	Science & Religion	Acorns	GAENE	Religiosity	Gender	Age	Year in School	Group	Race	Con-vert	US born
Sauda	integration	Poor	58	2.4	f	43	Freshman	Sunni	Asian	no	no
Ali	integration	Fair	53	2.4	m	25	Senior	Shia	Asian	no	yes
Nadira	dialog	Good	54	2.8	f	21	Senior	Ahmadi	Asian	no	yes
Samra	integration	Fair	57	2.8	f	18	Soph-omore	Muslim	White	no	yes
Sana	integration	Good	63	2.4	f	22	Senior	Ahmadi	Asian	no	yes
Sulayman	integration	Fair	36	2.6	m	21	Soph-omore	Sunni	African-American	no	yes

Note. The mean GAENE score is 53.5 with a standard deviation of 9.27. The mean religiosity score is 2.567 with a standard deviation of 0.197.

Table 15 depicts the NOS understandings of the highly religious accepters of evolution identified in this study. All but one had a more informed understanding of tentative NOS. Sauda, the lone exception, generally had naïve views of all NOS aspects. The others had informed views of two, three, four or five of the 14 NOS aspects examined in this study.

Table 15
Highly Religious Theisitic Evolutionists' Understandings of Nature of Science

Alias	Em-per-ical	Scien-tific Meth-ods	Experi-ments	Prior expec-tations	Obser-vation	Ten-tative	The-ories & laws	nature of the-ories	Func-tions of the-ories	theory test-ing	Crea-tiveity	Infer-ence	theory-laden	social & cul-tural
Sauda	naïve		naïve		naïve	naïve	naïve	naïve			naïve	naïve	naïve	
Ali	naïve	naïve	naïve		naïve	In-formed	naïve	naïve	In-formed		naïve	naïve		naïve
Nadira	naïve	naïve	naïve	naïve	naïve	In-formed	naïve	naïve		naïve	naïve	In-formed	In-formed	In-formed
Samra	naïve				naïve	In-formed	naïve		In-formed		naïve	naïve	In-formed	naïve
Sana	naïve		naïve	In-formed	naïve	In--formed	naïve	In-formed		naïve	In-formed	naïve	naïve	naïve
Sulay-man	naïve	In-formed	In-formed		In-formed	In-formed	In-formed	naïve	naïve		naïve	naïve	naïve	naïve

Table 16
Religious Views of Highly Religious Accepters of Evolution

Alias	Moral Conseqences	Quran literal	Ideological	Ritualistic	R import	Experiential	Intellectual	Consequential	Religiosity average
Sauda	no	yes	high	high	high	high	medium	low	2.4
Ali	generational issues	no	high	medium	high	high	high	low	2.4
Nadira	a+	no	high	high	high	high	high	medium	2.8
Samra	no	yes	high	high	high	high	high	medium	2.8
Sana	r-	no	high	medium	high	high	high	low	2.4
Sulayman	a- if no God	yes	high	high	high	high	medium	medium	2.6

Note: Moral consequences of accepting or rejecting evolution, a+ = accepting evolution leads to positive moral consequences, a- = accepting evolution leads to negative moral consequences, r- = rejecting evolution leads to negative moral consequences.

Table 16 depicts religious views of the highly religious accepters of evolution identified in this study. All were high in the ideological dimension, which means that they hold beliefs that Hasan (2007) considered "orthodox" Islamic beliefs. All were high in the experiential dimension, which means that they had all had experiences that they interpreted as directly experiencing the divine. All thought that ritualistic practice of their religion was important, with four of the six scoring high in the ritualistic dimension and the remaining two scoring medium. The two who scored medium prayed on a daily basis, but did not always pray all five of the daily prayers, and read the Quran, but not regularly. These were the factors that depressed their scores for this dimension. Their scores in the intellectual dimension indicate that four considered themselves to know "a great deal" about their religion and two to know "some" about their religion.

Half of the highly religious theistic evolutionists identified in this study thought the Quran should be taken literally, word for word, while half did not. Two thought there were no moral consequences for either accepting or rejecting evolution. A third did not see any moral consequences, but he acknowledged that members of the older generation might. Of the remaining three, one thought that there could be negative moral consequences for accepting

evolution only if it led a person to stop believing in God, one thought that there could be negative moral consequences for rejecting evolution, and another that there could be positive moral consequences for accepting it.

In sum, the highly religious accepters of evolution identified in this study were diverse in terms of gender, age, class rank, ethnicity, and the type of Islam they practiced. They were also diverse in terms of GAENE scores, understanding of natural selection, and NOS understandings. They differed as to whether or not they thought there were moral consequences for accepting or rejecting evolution and whether or not they thought the Quran should be interpreted literally. They were similar in that none were converts to Islam and all considered their religion to be important to them. All were "orthodox" in their thinking about Islam and all had had personal religious experiences.

Chapter 5 – Discussion and Implications

The American Muslim undergraduates in this study exhibited three main patterns of reconciling their religious beliefs with scientific evidence in support of the theory of biological evolution. These patterns were used as a basis to place the respondents into three groups, theistic evolutionists, those with a belief in the special creation of humans, and those with a belief in the special creation of all species. The main difference between the three groups is whether they accept only microevolution or both macroevolution and microevolution, and for those who accept macroevolution whether it extends to human beings or not. The group labelled "theistic evolutionists" accepted both macroevolution and microevolution for all species. The group labelled "those with a belief in the special creation of humans" accepted microevolution for all species, including humans and macroevolution for all species except humans. The group labelled "those with a belief in the special creation of all species" accepted microevolution for all species and macroevolution for none. People in all three groups were willing to accept natural selection as the mechanism for those aspects of evolution that they accepted.

Most of the respondents in all three groups did not believe that there were any moral consequences for either accepting or rejecting evolution. Those who thought there might be moral consequences mentioned relatively minor consequences, such as having other people think you are "stupid" or that you have an incorrect creed. In no cases did participants consider that either accepting or rejecting evolution was necessarily incompatible with being able to practice Islam and none of the respondents thought that holding a particular view towards biological evolution would necessarily cause a person to leave Islam. Accepting evolution would only cause a person to leave Islam if it led a person to reject the idea that God is the ultimate Creator.

A person who holds a belief in God and also accepts evolution would still be considered a Muslim, even to those who do not themselves accept evolution.

The American Muslim undergraduates in this study had views on evolution which were impacted by their religious views, their attitudes towards science in general and evolution in particular, their understandings of evolution, and their understandings of NOS. For some evolution was a contentious issue, prompting a period of intense study and comparison of evidence on both sides. In some cases this was prompted by exposure to evolution itself. In other cases evolution was problematized for them by religious scholars they encountered at the mosque or Islamic center. Others did not find their encounters with evolution problematic. They were able to successfully negotiate these encounters with the help of an example from parents or a teacher, or simply because they did not see any contradiction between what they were learning and the verses of the Quran as they understood them.

BouJaoude and colleagues (2011) conducted qualitative research on a small sample consisting of seven professors and 20 secondary biology teachers in Lebanon. They suggested that religious affiliation might have an effect on acceptance of evolution, and they found differences between Sunni, Shia, Druze, and Christian respondents in their study, although they admitted that their sample was too small to allow for generalization. In the current study all three positions on evolution were found among Sunni, Shia, and Ahmadi respondents, suggesting that there is heterogeneity in evolution position among members of these groups. Further, BouJaoude and colleagues (2011) have suggested that literal interpretations of the creation in scripture are associated with individuals who reject evolution. Respondents in this study who held a belief in the special creation of all species did often have literal interpretations of the verses in the Quran that Adam was created from clay. However, the notion of what is literal and

what is metaphorical was not always straightforward. Some respondents thought that each verse of the Quran has both a literal and a metaphorical meaning, for example.

Words themselves have symbolic meanings. It is by human convention that a particular word represents a particular thing, concept, or idea. The signification of groups of words – phrases, sentences, paragraphs – are set by human convention as well. For the respondents in this study the actual signification they assigned to specific Quranic verses differed from person to person. Both people who interpreted the verses stating that Adam was created from clay in a sense similar to a ceramicist forming a statue and those who interpreted it as meaning that creation from clay referred to an early stage in the evolution of life believed that they were interpreting these verses literally. However the former interpretation was associated with rejection of evolution while the latter was not.

Which interpretation of the creation verses a particular respondent chose was impacted in part by the interpretations of particular religious scholars with whom the respondents came in contact. This is similar to what Asghar (2013) found in the Canadian context. In her study the views of some Muslim teachers were influenced by scholars' views. Some respondents were influenced by Sh. Yasir Qadhi, or Hassanain Rajabali, who they had heard either in person or on You Tube, or from other scholars who hold similar positions regarding evolution. These scholars insist on a literal interpretation of the verses in the Quran on the creation of Adam and also of hadith on Adam's creation. However, they can accept evolution for all other organisms because there is not such a detailed description of their creation in the Quran or hadith as there is for humans. Respondents influenced by these scholars held that evolution did occur for all other organisms, but that human beings did not evolve. Instead, they were formed in exactly the manner specified in literal interpretations of the Quran and hadith.

One hadith on the creation of Adam referenced by some Sunni respondents follows.

> Narrated Abu Huraira: The Prophet (ﷺ) said, "Allah created Adam, making him 60 cubits tall. When He created him, He said to him, 'Go and greet that group of angels, and listen to their reply, for it will be your greeting (salutation) and the greeting (salutations of your offspring.' So, Adam said (to the angels), 'As-Salamu Alaikum (i.e. Peace be upon you).' The angels said, 'As-salamu Alaika wa Rahmatu-l-lahi' (i.e. Peace and Allah's Mercy be upon you). Thus the angels added to Adam's salutation the expression, 'Wa Rahmatu-l-lahi,' Any person who will enter Paradise will resemble Adam (in appearance and figure). People have been decreasing in stature since Adam's creation.[17]

Some respondents interpreted this hadith as being in support of microevolution for humans because humans would have had to microevolve to decrease in stature.

Some Ahmadi respondents interpreted the verses on Adam being created from clay as referring to early stages in the formation of living organisms. They were influenced in this interpretation by the fourth Ahmadi khalifah, Mirza Tahrir Ahmad (1998), either by having read his book *Revelation, Rationality, Knowledge, and Truth* or by listening to videos online in which either he or scholars from the Ahmadiyyah Muslim community discussed this interpretation. Respondents influenced by interpretations that came from Ahmad (1998) were nearly all theistic evolutionists. The one respondent who reported having read the book but was not a theistic evolutionist based her belief in the special creation of all species on that part of Ahmad's (1998) argument that rejected the idea of randomness in the processes of formation of living organisms. The other Ahmadi respondents who were not theistic evolutionists did not reference Ahmad (1998) or his book and so were apparently unaware of his line of reasoning.

Many of the respondents who held a belief in the special creation of all species were influenced to reject macroevolution by creationist arguments. Creationist lines of argument that they referenced included the idea that if humans descended from apes (or monkeys) why are there still apes (or monkeys) in existence, that there are ancient fossils resembling organisms in

[17] From Sahih al Bukhari Vol. 4, Book #55, Hadith #543 retrieved from http://sunnah.com/bukhari/60

existence today, so this shows there is no evolution, and that there many holes in Darwin's theory of evolution that have yet to be resolved. Nearly all of these respondents were able to accommodate scientific evidence supporting evolution by accepting microevolution.

Two of the respondents who held a belief in the special creation of all species held a belief in evolution as a mechanism for speciation for non-human organisms, but only within kinds. One respondent was probably influenced by Christian creationists in adopting this belief, because she was a non-denominational Christian before converting to Islam and because she used the creationist term "kinds" in her description of her beliefs. The other seemed to have come up with this idea on her own because she was influenced by her mother who is a biology teacher to think that evolution makes sense, but she had trouble accommodating the notion that all organisms descended from a common ancestor with the dizzying variety of organisms she knew existed today. She neither referenced any creationist influences nor used any of their terminology or examples in explaining her position.

Many theistic evolutionists in this study reported that they accepted evolution because they found the scientific evidence in support of the theory of evolution convincing. Some accommodated their religious beliefs by interpreting the Quranic verses on the creation of Adam metaphorically. A few were helped in this accommodation by a special teacher who provided a positive example of how to negotiate the relationship between religion and science while accepting evolution. None of the non-Ahmadi theistic evolutionists in this study reported that they had a positive example from a Muslim religious scholar to help them negotiate this relationship.

One way of looking at the manner in which respondents chose their respective positions on evolution is to conceive of it as a means of reconciling their religious beliefs with scientific

evidence in support of current evolutionary theory. All but five of the participants in this study unequivocally stated that they believe that the Quran is the word of God. All but one of those who did equivocate affirmed the idea that revelation is a source of knowledge. These respondents take revelation into account when formulating their worldviews and consider it to be a source of knowledge. The respondents in this study considered scientific evidence as a source of knowledge as well. The positions that the respondents took on evolution can be seen as a means of reconciling their religious beliefs with scientific evidence.

Theistic evolutionists in this study accepted the scientific evidence while maintaining their religiosity. They had various methods of incorporating both into their worldview. One segregated scientific evidence and his religious views into different realms so that they would not conflict. Most integrated their understanding of science and their religious views. None of them saw a conflict between science and religion.

Some theistic evolutionists in this study rejected the idea of randomness altogether. Others claimed that God created through the process of evolution but did it in a way that it seemed to be random, even though it was not. In this way they were able to incorporate teleological notions into their conceptions of evolution. Other respondents did not find the idea of randomness problematic.

Respondents with a belief in the special creation of humans can accept evolution for all organisms except humans. In this manner they can incorporate the scientific evidence for evolution and their understanding of divine creation into their world views. Acceptance of human microevolution generally allows them to accommodate some scientific evidence for human evolution as well. Because the Quran provides more detail for the creation of humans than for other organisms, they find accepting evolution for all organisms except humans non-

problematic. Accepting evolution for all but humans allows them to incorporate both literal interpretations of the creation of human beings from the Quran and the scientific evidence for evolution into their world views. This generally allows them to avoid conflicts between the scientific evidence and their religious world views. For a few respondents, however, there was a conflict between the scientific explanation for the appearance of human beings and their understanding of the Quranic explanation.

Participants with a belief in the special creation of all species had various methods of accounting for both the scientific evidence and their understandings of creation as explained in the Quran. Nearly all accepted microevolution. This allowed them to take into account evolutionary changes that could be observed in a human lifetime, such as the development of antibiotic resistance in pathogenic bacteria. A few went further than simple microevolution to include speciation within closely related groups to account for the scientific evidence for evolution. For most these strategies allowed them to incorporate both the scientific evidence in support of evolution and their understandings of creation as described in the Quran into their world views without conflict. A few avoided conflict by holding independent functions for science and religion or by seeing them as in dialog. However, nearly half of the respondents with a belief in the special creation of all species did perceive a conflict between science and religion. For them, knowledge from religious sources, such as revelation, was stronger than scientists' explanations based empirical evidence. When these two came into conflict, they would choose the religion side over the science side.

One may wonder why a person would choose a religious explanation over a scientific one. David Long (2011) researched the intersection between evolution and religion for American undergraduate students in a Southern state. For Christian fundamentalist creationists

accepting evolution was unthinkable. It was more than simply including scientific explanations into their worldview. It entailed leaving their religious communities, because acceptance of evolution was completely unacceptable there. The social costs of losing one's community and social connections was too high for these students to ever consider accepting evolution as a viable option.

For the Muslim undergraduates in the current study, changing their position from rejecting to accepting evolution was not unthinkable. They considered it unlikely, but it was possible for them to entertain the idea. For these students the stakes were not as high for the Christian fundamentalists in Long's (2011) study. They would still consider themselves Muslims if they shifted their position, and their social networks would remain intact. The social consequences would be relatively minor ones, such as having others think that their position on evolution was "stupid."

It has been suggested that bringing in a more inclusive history of science could benefit non-mainstream students by helping them achieve in science (McKinley, 2007; Bianchini, Johnston, Oram, & Cavazos, 2003). In the current study four respondents, Hakim, Kohinoor, Habib, and Ayyoubou, specifically mentioned the role that the history of Islamic science played in helping them negotiate the relationship between religion and science. For example, Hakim described how his first encounter with the history of Islamic science helped him negotiate this relationship for himself.

> So, I don't think that there's any conflict between [science and religion], and my experience with that, how I developed that kind of mindset was I was 12 and I found a book on my dad's bookshelf that was called *Early Muslim Scientists*. That's when I first learned about the vast contributions that Islam had made to science. Then that gave me understanding of there aren't many borders to my faith in terms of what I can do and what I can learn.

These data lend support to the claim that bringing an inclusive history of science into the discussion could benefit non-mainstream students, specifically Muslim students.

Many respondents in this study had more difficulty in accommodating evolution of humans than of other organisms into their world views. Those who hold a belief in the special creation of humans exemplify this difficulty by rejecting evolution of humans while accepting it for all other species. However, this was true regardless of the respondents' stances on evolution. For example, Habib, a theistic evolutionist, paused when asked specifically about human evolution during administration of the GAENE. When I asked him why he paused, he stated the following.

> I'm not going to take a hardline definitive view, because, once again, is the creation idea, you know, the story. It's supposed to be taken literally. Is it supposed to be a parable? So on, so forth. That's what gave me pause, but I'll lean on agree. I'll lean on agree.

Hanif, who held a belief in the special creation of all species, indicated that he was less likely to accept human evolution than evolution of other species. When I asked him "Why do you feel differently about human beings than about other creatures?" he gave the following reply.

> Hanif: Because I believe the Quran is the word of God and I believe the story of Adam is literal, and not metaphorical or anything, so I believe that the story gives us a clear, and along with the hadith, the authentic hadith, hadith which I feel to be authentic that also refer to the creation of Adam. So, I believe Adam was created from clay and formed and shaped by Allah. So, these are the reasons why I would say human beings 100%. The other macroevolution I would say 95% on that, but it's not something I would, you know, would say you're stupid. You know, gee, I would say you're stupid for believing that.
>
> Khadija: Yeah. [laughs]
>
> Hanif: But if I got into a debate with someone about evolution, I couldn't say 100% I don't think that happened, but I'm pretty sure it didn't. So, I don't believe, like you said, like I said, reptiles turned into birds, but if someone's trying to prove it, oh, maybe they did have, and I'm not going to fight that tooth and nail.

Previous researchers found that Muslims worldwide (Hameed, 2008), Muslim undergraduates in the U. A. E. (Guessom, 2011), and mainstream students (Smith, 2010a) were less likely to accept human evolution than evolution of other species.

Quantitative studies in Turkey, a country with a population that is 99% Muslim, found a significant correlation between understanding and acceptance of evolution (Akol *et al*., 2012; Deniz *et al*., 2008; Peker *et al*., 2010). In the current study those who accepted macroevolution for all or most species were more likely to have either an excellent or a good understanding of evolution than those who rejected macroevolution for all species. This is seen in the fact that 68% of the theistic evolutionists and those with a belief in the special creation of humans had either an excellent or a good understanding natural selection according to the ACORNS measure but only 41% of those who held a view that all species were specially created.

Deniz and colleagues (2011) found a significant negative correlation between acceptance of evolution and religiosity. In the current study theistic evolutionists had an average religiosity score of 2.1, those with a belief in the special creation of humans had an average score of 2.3, and those with a belief in the special creation of all species had an average score of 2.6.

Deniz and colleagues (2008) found a small positive correlation between parents' educational level and acceptance of evolution. Peker and colleagues (2010) found a small positive correlation with mothers' but not fathers' level of education. In the current study, respondents were not asked about their parents' educational levels. However, a few respondents mentioned that their mothers had an influence on their acceptance of evolution. Angela mentioned how her mother, a school teacher, influenced her to accept evolution. Nadira explained how her mother was instrumental in helping her negotiate the relationship between religion and science so that she could accept evolution. There was no similar mention of fathers'

influence in the sample, although six respondents also mentioned that their parents influenced their views either in favor or against evolution without specifying if they meant either or both parents.

Peker and colleagues (2010) found that females were more likely to accept evolution than males. The opposite trend was seen in the current study where 58% of those holding the theistic evolutionist or special creation of humans positions were female and 73% of those who held the belief in the special creation of all species were female. This was out of an overall sample that was 63% female.

Peker and colleagues (2010) also found that seniors were more likely to accept evolution than freshmen. In the current study seven of 17 seniors held the theistic evolution position and six held that all species were specially created, while only four held the special creation of humans position. Two of 15 freshmen in the current study were theistic evolutionists, and four thought all species were specially created. The other nine held that humans were specially created. In the current study seniors were more likely to either accept or reject macroevolution for all species while freshmen were more likely to accept it for all but humans. One major difference between the current sample and the one researched by Peker and colleagues (2010) is that most of the respondents in the current study were first exposed to evolution in middle and high school while those in their study were more likely to have their first classroom encounter with evolution in college. Since they found a positive correlation between understanding and acceptance of evolution it is likely that the correlation they found for seniors was due to the fact that they had learned about evolution in college since entering in their freshman year.

Akol and colleagues (2012) found a positive correlation between acceptance of evolution and NOS understanding. In the current study informed and naïve views of different aspects fo NOS

were more or less evenly distributed among respondents holding the three different stances on evolution. The exception to this was tentative NOS, which was more likely to be informed for those who either accepted or rejected macroevolution for all species and less likely to be informed for those who rejected macroevolution only for humans. Tentative NOS was strikingly informed in the group of highly theistic accepters of evolution as only one in this group had a naïve view of this NOS aspect. However the other NOS views in this group were often naïve.

Limitations

There were a number of limitations in the various instruments used to collect data in this study. Respondents had differing interpretations of items in the interview and the GAENE due to differing stances on microevolution and macroevolution. Scoring VNOS-C surveys in a dichotomous manner produced some challenges when scoring respondents whose views, although well-considered, were at odds with those the developers of the instrument considered to be more informed. Modifications were made to the religiosity instrument for use in the current context, but this led to lower external validity for some items. A discussion of these limitations follows.

Interview question to elicit stances on evolution. An interview question adapted from Everhart and Hameed (2013) designed to elicit respondents' positions on evolution did not always result in the respondent choosing the option that was intended to correspond to their position. Although the majority of the respondents interpreted these responses as intended, a few did not. This was similar to the results obtained by Everhart and Hameed (2013) with Pakistani-American medical doctors. In their study a few participants did not choose the response that was intended to correspond to their position, although the majority did. So it is not surprising that participants in the current study had similar results. In the current study this

question was used to get the respondents talking about their positions. Follow-up questions were used to clear up any ambiguities in their responses. In this way a more complete understanding of the respondents' positions could be gained.

Everhart and Hameed (2013) did not make any distinction between macroevolution and microevolution in their study. In the current study, some of the respondents had differing views depending on whether macroevolution or microevolution was under consideration. For example some respondents with a belief in the special creation of all species chose option A: All species, including humans, have evolved over millions of years, but Allah guided the process. This response was intended to coincide with the theistic evolution position.

The question was adapted from one used by Harris for quantitative research polling. Ideally when conducting this type of research the survey questions should aim at only one construct. In this case these questions were not only double-barreled, but actually triple-barreled. Part of the question asked the respondents' stance on evolution. However, by not specifying whether this refers to macroevolution, microevolution, or both, this question asks the respondent to think of two constructs, not one construct, relating to evolution. Furthermore, the question gives a time frame of millions of years. This adds yet another construct to this question, that of young earth vs. old earth. These questions are triple-barreled in nature, therefore it should not be surprising that they resulted in varying interpretations by respondents in both the current study and Everhart and Hameed's (2013) study.

GAENE. The distinction between macroevolution and microevolution was not made by the developer of the GAENE, either. Therefore, the respondents had to decide on their own how to interpret the questions in the GAENE. If they interpreted the term "evolution" as referring to microevolution rather than macroevolution people who completely rejected macroevolution

could end up with relatively high GAENE scores by agreeing with statements such as "Evolutionary theory applies to all plants and animals, including humans." In the current study, four people who thought there was no macroevolution had GAENE scores in the 50s, which is at the upper end of the moderate acceptance range.

In some cases GAENE questions clashed with respondents' philosophical views regardless of their stance on evolution, and this depressed their scores. The statement "Evolution is a scientific fact" clashed with some respondents' more informed views of NOS. This is illustrated by the following exchange with Hakim.

> Khadija: Why did you, just out of curiosity, why did you strongly disagree with "Evolution is a scientific fact"?
>
> Hakim: Because scientific fact within itself is a, what's that called? I'm just going to use dichotomy. It's a dichotomy for science. Science is the gaining of knowledge and a fact is the absolution of knowledge, and nothing in science is absolute. So, therefore, a scientific fact is a dichomic term, like it can't be used.

Despite this question lowering his score, Hakim had a GAENE score of 58 at the upper end of the moderate acceptance range even though he rejects macroevolution and accepts only microevolution due to the issues mentioned in the preceding paragraph. By interviewing people qualitatively instead of quantitatively for this measure it was possible to determine that there is a complex interplay between respondents' acceptance or rejection of evolution, their feelings towards the word "evolution" itself, their understandings of the individual words in the questions, particularly whether they interpreted evolution to mean macroevolution, microevolution, or both, and their willingness to agree or disagree with the statements in the GAENE.

VNOS-C. The VNOS-C was designed as a qualitative instrument to elicit respondents' views of NOS (Lederman et al, 2002). In the present study the instrument provided an effective

platform for respondents to expound on their views of NOS. In addition, the first question asking respondents to compare science with religion and philosophy often yielded additional information about the respondents' views on the relationship between science and religion, a major focus of the current study.

Previous studies using VNOS-C as an instrument to measure NOS understandings of American undergraduate students have uncovered problems with the traditional administration of this instrument, namely giving the questions in a written format and interviewing only a subset of those who gave written responses (Rudge & Howe, 2013). If students' written responses are cursory, it is not clear whether they did not understand the question, did not care to put effort into answering the question, or hold naïve views on the subject matter of the question. Sometimes answers are ambiguous and difficult to interpret.

In the current study all of the respondents were interviewed to administer the VNOS-C so it was possible to ask follow-up questions for clarification of ambiguous answers. A few respondents complained about having to answer the questions or refused to provide examples to contextualize their answers, but most were motivated by the interview format to provide clear and complete answers. In addition, respondents generally gave their reasons for refusal to answer all or part of a VNOS-C question. The most common reasons were that they had no idea about the subject matter of the question or that they could not think of any examples. This was clear and unambiguous that they simply did not know, unlike a blank response on a written version of the VNOS.

One problem encountered with the VNOS-C in this study was that the scoring was dichotomous – either more informed or more naïve – but some of the respondents' answers were

mixtures of more informed and more naïve views. For example, in response to a question on the difference between theories and laws, Sulayman gave the following response.

> Scientific theory would, it's just, I guess could be a statement that may not be true, subject to change, but at the moment, it's what they have, and then a law would just like something that they're almost positive is true, and they could base their knowledge off of it almost any time. So, a law would be like the sky is blue, but a theory would be why is it blue.

This response is clearly more naïve because he conceived of theories as being more tenuous than they actually are. However he was one of only a few respondents who recognized that theories and laws serve different functions, and correctly identified theories as explanatory in nature. This response was scored as being more naïve on both the nature of theories their functions. However this type of scoring obscures the more informed element of this respondent's views.

The researcher as the instrument of study. Another problem I encountered with the VNOS-C was related to my dual role as both the collector and analyzer of the data. In interviewing the research participants I often came to respect their positions, many of which were carefully constructed as a result of their inquiries into the subjects of religion, science, and their intersections. As such, their answers on the VNOS-C corresponded to their own philosophies of science which they had constructed to make sense of scientific information they encountered in their classes and in their personal inquiries into the intersections of religion and science, particularly evolution. As I came to respect those views, I sometimes found it difficult to evaluate them on a scale of more informed to more naïve. This type of evaluation put me in the role of someone who could pass judgement on the philosophical positions of others. Instead I found myself wanting to say to them, with respect, I disagree with your position and this is why.

In other cases, I found myself sympathizing with their views. It seemed in a way unfair to characterize views as more naïve when it was clear that this is the way that the respondent was taught that science *should* be. The following exchange with Lena illustrates both of these points.

> Khadija: OK. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it's practiced. So which of those two do you think is the case?
>
> Lena: OK. I think that *true* science. There's so many variables of science to actually answer that question, but like true factual scientific information, I think it transcends cultural and national and all of those limitations I think that one would assume would stand in front of science, I don't think one has anything to do with the other. Now, if you were to say that.
>
> Khadija: Alright. So, can you give an example of, so you're saying it does transcend political, philosophical, cultural values, so can you give an example of that?
>
> Lena: That's what I was just thinking about.
>
> Khadija: OK.
>
> Lena: I think it depends on what kind of part, portion of science you're looking at. If you're looking at a more of a biological, you know, sort of like under a microscope kind of information, then I don't think that has anything to do with social or political or national. I don't think it has anything to do with that, because actual factual science, it has nothing to do with the wor-, with society. Now, if you were looking at specific theories based on cultural, or, you know, aspects, you know, for example. Oh, here's a good one! I was told in a previous training session that black babies are more prone to SIDS than Caucasians.
>
> Khadija: Wait, more prone to what?
>
> Lena: SIDS
>
> Khadija: Oh, OK.
>
> Lena: So, that has to be some sort of scientifical information that, you know, has to play into facts, but I don't see how, I don't see how that could be, you know, factual information, like based on scientifically, how did you reach that conclusion? That [sighs] the answer that I was given was that multiracial, not multiracial, people of color tend to lay their ba-, tend to, to families that, as opposed to Caucasians are less likely to, and I

don't see how that that could have been, how they could have reached that scientifical, like informa-. Like, oh! I think that that goes into the whole social thing, but it's not actual proven factual information. Like, scientifically, how did they come up with that answer? Because SIDS, like it's SIDS, you know, sudden infant death syndrome, I believe.

Khadija: Yeah.

Lena: And, you know, it comes from, you had to actually find a way, how, what is causing this death… but, you know, and there, what I gave back to her is, not necessarily is it proven that if you lay your child on its stomach, that, you know it, it will die. I did that for my sons until now. Now, well now he's not sleeping on his stomach.

Khadija: Right.

Lena: But for the entire, from birth until he left my bed, we did family bed, and he slept on his stomach. K, and, Alhamdulillah, nothing happened. I'm not white. Well, I'm multiracial, so I was never, anyways, I don't, some scientifical stuff, it does tie into social and cultural things, but I don't think that it's, I don't even, I don't think that has anything to do with science. I don't think that true science it would.

Khadija: Hmm. OK. So,

Lena: There are a lot of examples, I have in mind, but, you know.

Khadija: Alright. Alright. Let me just ask you some questions to clarify what you're saying. So, is, are you thinking that these social factors came into play in interpreting the data, or are you saying that it's a social factor whether you get SIDS or not based on your family practices?

Lena: I think that social practices have affected the scientific data, I guess you could call it. I don't think that, see, that's the qu-, that's where I'm conflicted, because I don't find that that is true science. I don't think that true science can be affected by social and cultural and political. I don't think it has anything to do with that, but, of course, what people construe as science and discoveries and advances in technology based on those things, the social, cultural, and political, they think that they do.

Khadija: They think what?

Lena: They think that they do.

Khadija: You think that they do. OK.

Lena: But I wouldn't call that true science. So, that's where I'm conflicted in that answer

Khadija: OK

Lena: to that question. I would say no. I would say that true science has no, has no cultural, social bounds to it. Oh, that would have some serious thought process to this one, ha!

According to the rubric, this response should be coded as more naïve, because the respondent thought that science transcended national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it's practiced, or at least she thought that it should not be affected by those things. In cases where these things clearly came into the picture, she wanted to insist that they should not.

The answer she gave was not naïve in the sense that it reflected her honest attempt to grapple with her conception of science as it should be with science as she has seen it in practice. It was a well-considered and philosophically coherent response. Yet, I coded it as more naïve according to the rubric provided with the VNOS-C instrument. It is possible that this view of socially and culturally embedded NOS negatively colored her view of evolutionary biologists, and that this in turn reinforced her rejection of macroevolution. Making that sort of analysis of her response seems reasonable. Labeling it "more naïve" somehow does not.

The research interviews made an impact both on myself as the researcher and on the research participants. Many participants had not thought through their views on the relationship between religion and science, or on biological evolution and how it relates to their religious beliefs about the manner in which Allah created human beings and other organisms. Going through the interview helped them to process their ideas and more clearly formulate their thoughts on these matters. Many of them expressed their gratitude at the end of the interview for the opportunity to explore these issues in depth.

As I progressed through this research inquiry I found that I was being transformed by it. I was deeply moved by the honesty and openness with which many respondents shared their views on sensitive topics such as their religious beliefs and practices, and their willingness to admit gaps in their knowledge about evolution in particular and science in general in order to honor the integrity of the data that they were providing to me. In listening to and then later analyzing their positions, I learned a great deal more than I anticipated as their philosophical positions enhanced and shaped my own. For example, examination of Cherif's discussion of instrumental causality helped me to better articulate what had previously been a not fully-formed idea in my own conceptions as a theistic evolutionist.

What I found most surprising about my own transformation was that I was able to come not only to understand, but also to respect the views of people whose stances on evolution were very different from mine. At the start of the project I thought that people who reject evolution must be somehow misinformed. What I came to understand instead was that they had examined the evidence and had come to a different conclusion than the one that I had reached.

Religiosity surveys. The religiosity surveys were adapted from Hassan (2007). They were useful for this study because they were designed to be used with Muslims and they provided a multi-dimensional examination of respondents' religiosity. Many measures of religiosity designed for Muslims use only one or a few scales (Abu-Raiya & Hill, 2014). Another consideration is external validity of instruments. Many have been used only on one study population (Abu-Raiya & Hill, 2014). Hassan's (2007) measure was used on 6300 participants in seven Muslim-majority countries. To supplement questions from Hassan's (2007) measure, I used questions from Pew surveys, because these also have strong external validity as they have been used with thousands of respondents worldwide.

Hassan's (2007) measure includes scales corresponding to ideological, ritualistic, experiential, and consequential dimensions of religiosity. His theoretical framework includes an intellectual dimension, but he did not measure this dimension in his study.

I supplemented Hassan's measures with questions from Pew surveys. To have some idea of the intellectual dimension of respondents' religiosity I used the question "How much would you say you know about the Muslim religion and its practices—a great deal, some, not very much or nothing at all?" One problem encountered with the question came from respondents' interpretation of "a great deal." Some respondents thought of this as being the amount of knowledge that a religious scholar would have, and so they chose another option. Others chose this option because they considered it to be the amount of knowledge a well-informed Muslim would have. A number of respondents said that their knowledge fell between "a great deal" and "some." To take into account respondents' modesty about their own religious knowledge, both respondents who chose "a great deal" and those who said that their knowledge fell between "a great deal" and "some" were considered to have a high level of religiosity in this dimension. As an example of difficulties with interpretation of this question, one respondent chose "a great deal" because she had attended an Islamic school for many years. Another Islamic school alumnus chose "some" to describe his knowledge of Islam. It is likely that both respondents had similar levels of knowledge about Islam, but they choose different responses to the question, probably due to factors such as possessing the virtue of humility or having confidence in one's knowledge, rather than how knowledgeable each actually was.

Although there are many problems inherent in using a single question to measure a complicated construct such as religious knowledge, it seemed that the alternative would be a much more cumbersome instrument, and I did not want to add a large number of questions to an

already lengthy interview protocol. For example, the Knowledge-Practice Measure of Islamic Religiosity has 100 multiple-choice items (Abu-Raiya & Hill, 2014).

Some of Hassan's (2007) measures of religiosity were altered for inclusion in the current study. The original measure of the experiential dimension contained five items, a general item, "feeling you were in the presence of Allah," and three negative items, including "a sense of being punished by Allah." The measure as originally written misses the experiential dimension for people who had positive experiences, so I added items on experiencing the rahmah or mercy and loving kindness of Allah and experiencing a feeling of being blessed by Allah. These additions resonated with the respondents. For example, when I read Sauda the question on having a feeling of being punished by Allah, she replied that she had, but hastened to add, "Yet, He's merciful, even I think that." Without the addition of the positive items, this aspect of the experiential dimension would have been missed for those of the respondents who did not go on to explain their responses as Sauda did. This would have given a false picture of the manner in which the American Muslim undergraduates in this study directly experience Allah. Another item in the experiential scale, "a sense of being saved by the Prophet" was problematic in terms of experience to the pilot testers. One of the pilot testers, Haroon, replied, "maybe" in response to that item. He explained, "Because I think he's gonna save us on the Day of Judgement, and that hasn't come yet." Clearly he interpreted this question intellectually and not experientially. The other pilot tester, Musa, did not understand the question and asked for clarification, "So, do you mean saved by his teachings, or that I put my hand in a candle and he stopped me from getting burnt?" He was not able to choose a response to this question. For these reasons that item was dropped from the scale used in the current study.

The experiential scale as amended for this study was intelligible to all of the participants and all of them were able to choose a response to all of the items. However, the added experiential scale questions used only in this study should not be considered valid beyond the participants in the current study, because they have not been tested with anyone other than American Muslim undergraduates.

Pedagogical Implications

From a teaching and learning standpoint none of the positions on evolution precluded a person from learning about the mechanisms of natural selection, because there were people with excellent and good understandings of this according to the ACORNS measure among those who held all three positions on evolution. Nearly all of the participants were able to accept microevolution and they were willing to agree that natural selection could be used to explain this process. For these reasons it might be beneficial to stress natural selection in terms of microevolutionary changes in the classroom. Once students have grasped the concept of natural selection in terms of microevolution, then the concept that microevolutionary changes eventually lead to macroevolution could be introduced. It would also be important to help students understand the distinction between microevolution and macroevolution, rather than simply using the more ambiguous term “evolution” as a catch-all. From a pragmatic standpoint many of the important practical applications of evolution, such as preventing antibiotic resistance in human pathogens or formulating flu vaccines, rely on understanding of microevolutionary changes, so stressing microevolution would probably not have serious negative practical consequences for people who go on to study further in biology.

From a practical standpoint the idea of starting with microevolution and natural selection stands on its head the traditional order in which this material is normally presented in the

classroom. For example, the NGSS require students to understand the evidence from the fossil record for macroevolutionary changes in middle school and the details of the mechanisms of natural selection in high school (NGSS Lead States, 2013). Therefore this recommendation is not practical at the present time for secondary education. However, it could be implemented in the context of a college biology course that would be expected to treat both the fossil evidence for evolution and the mechanisms of natural selection in a single course.

Many of the people in this study with a belief in the special creation of all species cited easily refutable creationist arguments in support of their positions. Most of the participants in the current study exhibited a respect for people of knowledge, including scientists. Most, even those with a belief in the special creation of all species, praised Charles Darwin for his intelligence and powers of observation. However, there were a few students with a belief in the special creation of all species who had some harsh criticisms of Darwin. These mirrored creationist arguments that he was an atheist with an agenda who promulgated his ideas to counteract the idea of God as Creator.

Addressing evidence that directly refutes Christian creationist arguments and their old-Earth variants promulgated by Harun Yahya could prevent some students from being swayed by these types of arguments. For example, explaining how some ancestral forms, such as lemurs, co-exist with descendent forms, such as monkeys in the present day could counteract arguments such as, “If humans are descended from apes, why are there still apes?” Teaching amendments to evolutionary theory, such as the idea of punctuated equilibrium, could counteract arguments that evolution does not happen because there are some extant species that do not appear to have changed appreciably in hundreds of millions of years when compared with their fossil counterparts. Helping students to understand theory-laden NOS could help counteract the idea

the Charles Darwin had an “agenda” in a way that other scientists do not. Helping students understand other NOS concepts, such as the nature of scientific theories, the logic of testing scientific theories, the validity of observationally based theories and disciplines, and the use of inference and theoretical entities in science might help counteract other creationist arguments on weaknesses in Darwin’s theory. Teaching the history of the development of evolutionary theory and the manner in which it has been critiqued from within the scientific community and how these criticisms have been dealt with based on scientific evidence could also be useful in countering these holes in the theory arguments. This need not entail even mentioning the creationist counterparts to these arguments, and I do not suggest bringing these into the science classroom. However, the teacher could have these in mind when designing lessons to arm students with information that could counteract these arguments when students encounter them outside of science class.

Several of the respondents mentioned how learning about the history of science practiced in the Muslim world helped them to view science as being compatible with their Islamic faith. Unfortunately this history is often omitted from presentations of the history of science in the classroom, even though some of this science was part of the foundations of Western modern science. This is a missed opportunity to facilitate cultural border crossings for Muslim students between Western modern science and Islam in the classroom setting. In the current context, thinkers from the Muslim world such as Abu Uthman al-Jahiz (781-869), whose work was familiar to European scientists, including Jean Baptiste Lamarck, could be included in the historical treatment of evolutionary thought commonly given as part of a unit on biological evolution.

Rana Dajani (2015) teaches evolution to Muslim undergraduates in Jordan. She encourages her students to become independent thinkers. Her objective is not to get them to

accept evolution but rather to learn to argue their position with evidence. Her view is that the idea that evolution is incompatible with religion was imported to the Middle East from the West. She points her students to the early history of the reception of Darwin's ideas among Muslims, including Hussein al-Jisr and Ahmad Medhat, who favorably received the idea of evolution in the 1880s. She also discusses proto-evolutionary ideas from earlier Muslim thinkers, such as al-Jahiz. She advocates an independence view of science and religion, stating, "Science allows us to question and discover how the world works and the Koran provides the moral guidelines for doing so" (Dajani, 2015, p. 409). Dajani's experiences lend further support to the idea that introducing Muslim students to the ideas of Muslim scientists could help them to reconcile scientific evidence concerning evolution with their religious views.

Exposing students to Muslim scientists who are currently working on evolution might also be beneficial. They could serve as role models for the general compatibility of Islam and science in general and Islam and evolution in particular. Researchers such as these can provide positive role models of practicing Muslims who not only accept evolution but actively work to push the boundaries of our knowledge on the subject.

Ehab Abouheif heads a productive research group at McGill University focusing on the evolution of ants (Verdone-Smith, 2015). He has numerous publications in prestigious research journals, including *Science* and *Proceedings of the National Academy of Sciences*. In an interview with *Forbes*, he stated, "There's a lot at stake here, because it's well beyond evolution. If it's not about the evidence, if you reject science, if you reject evolution as a science and you're not willing to listen to evidence, then that means that for all of science, when it comes into contact with sociological, political conflicts, then you won't believe it either" (Farell, 2012, para 7).

Fatimah Jackson (2015), who has also published in *Science*, conducts research at Howard University including on microevolutionary changes that lead to human diversity and human-plant co-evolution. A convert to Islam, she stated, "I studied evolution before I accepted Islam. It was no hindrance for me to become Muslim" (thedeeninstitute, 2013). Taking an independence view of the relationship between science and religion, she explained as follows.

> Remember, science, especially evolutionary science, is designed to tell you how things change, not why. Why comes from our Islam. You know, when we want to know why something happened we go to the Islam. (thedeeninstitute, 2013)

She reconciles the idea of God as the creator with scientific evidence as follows.

> Look at the similarities, the genetic similarities among all of the life that has been created. That is a sign of the signature of a single artist… you would never confuse a Monet painting with a VanGough. You would never confuse it, because every artist has a signature, has a style of presenting their creativity, and the style that we see is in the unity of the genetic message across all living species on this planet. (thedeeninstitute, 2013)

A few of the respondents mentioned a special teacher who helped them navigate the relationship between science and religion by serving as a positive example. As not all of these teachers were Muslim it would seem that the faith tradition of the person is not as important as the process of navigation itself. Teachers who are theistic evolutionists could potentially serve this role for their students. Alternatively, this role could be filled by suggesting outside readings, such as Dobzhansky's (1973) article, "Nothing in biology makes sense except in the light of evolution."

Nearly all of the participants in this study first learned about evolution in middle school or in high school. This highlights the importance of evolution education at these levels. It is after exposure to this material that students begin to formulate their own ideas on evolution. This supports Hermann's (2011) assertion that attention to concepts that are foundational to

evolution should be taught well in elementary and middle school to prepare students for better understanding of evolutionary theory in high school and college.

Directions for Further Research

Stephen J. Gould has recommended modeling an independence viewpoint for students, or as he put it, science and religion have "non-overlapping magisteria," which he explained by stating, "The lack of conflict between science and religion arises from a lack of overlap between their respective domains of professional expertise—science in the empirical constitution of the universe, and religion in the search for proper ethical values and the spiritual meaning of our lives."

In the current study the independence viewpoint was a minority viewpoint, and it was more often held by those who thought that all species were specially created than by theistic evolutionists. More than three quarters, or 79%, of the theistic evolutionists in this study held an integration view. This view was also held by 42% of those with a belief in the special creation of humans and 27% of those with a belief in the special creation of all species. Given that most of the theistic evolutionists in this study used integration, it might be more fruitful to model an integration viewpoint for students than an independence viewpoint. It might also be effective to model more than one method of negotiating the relationship between science and religion, because several respondents mentioned that methods other than the one they were using did not make sense to them. By modeling more than one method it would make it more likely that a student will have access to a method that would work for him or her. Research into using models other than independence is currently lacking.

Presentations of evolution in the science classroom are often accompanied by historical material featuring Charles Darwin and often also Erasmus Darwin and Jean Baptiste Lamarck.

However, students are not usually introduced to Islamic thinkers on evolution. Although Rana Dajani has successfully used the history of Islamic science in the Jordanian context, research on using this strategy in the American context is lacking. Research on introducing figures such as Abu Uthman al-Jahiz should be conducted to determine whether it has any effect on American Muslim students' understandings of evolution and NOS.

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Appendix A – Interview Questions

INTERVIEW QUESTIONS

Thank you for your willingness to participate in this study. The study is about relationships between your ideas about biological evolution, the nature of science, and your religious beliefs, so I will ask you questions about all of these.
[Give them the informed consent form, and ask them to read it.]
Remember that you have the option to refuse to answer any of the questions, and may answer some, all, or none of the questions if you wish, and you may terminate the interview at any time. Whether or not you participate will not affect your relationship with me or with Indiana University. Do you have any questions about the research before we begin?

[Show the following questions on laminated cards, and ask]

1a. Which of the following four statements is closest to your view?

A: All species, including humans, have evolved over millions of years, but Allah guided the process.
B: All species, including humans, have evolved over millions of years, and Allah played no part.
C: Allah created humans, but all other species have evolved over millions of years.
D: Allah created humans and all other species in the form they exist today.

[Once they have chosen a statement, ask follow-up questions:]

1b. Why did you choose that one? Why do you think that?

1c. Do you agree with the time frame given in the question? Do you think it took a longer amount of time, a shorter amount of time, or is the time in the question about right? Why do you think that?

1d. [If they choose "C" ask] Please explain to me why you don't think humans evolved. Why do you accept the idea that all creatures except humans evolved?

2a. Do you believe that the theory of evolution presents a conflict between science and religion? Explain in detail.

2b. Are there moral consequences for either accepting or rejecting evolution? Why do you think that is the case?

3. Does the theory of evolution clash with your own beliefs about the physical and biological world? Discuss in detail.

Next, I will ask you some questions about evolution.

4a. How would biologists explain how a living mosquito species resistant to DDT evolved from an ancestral mosquito species that lacked resistance to DDT?

4b. How would biologists explain how a species of flightless birds evolved from an ancestral bird species that could fly?

4c. How would biologists explain how some individuals of flightless birds originated within a population of bird species that could fly?

4d. How would biologists explain how a living rose species with thorns evolved from an ancestral rose species that lacked thorns?

4e. Dodder, a plant species, have haustoria. How would biologists explain how the dodder species with haustoria evolved from the ancestral species that lack haustoria?

4f. Do you have the same view? Would your answer differ from that of biologists? How so? How would you explain these?

4g. What do you think of the idea that the process of evolution emerges from natural selection of random changes in genetic material that lead to variation in populations? Do you have any issues with the idea that evolution emerges from random processes?

5. Where did you get your ideas about evolution? Is there any place other than in science classes that you have heard about evolution, for example, in a debate, in a speech by a religious scholar, from a speaker you heard, or from a You Tube video? Would you please explain the circumstances?

6. Have you heard of Harun Yahya? Richard Dawkins? Charles Darwin?

Now, I'm going to ask you some questions about religion.

7. In your opinion, do you think there is generally a conflict between science and religion, or do you not think so?

8. Do you think there is a natural conflict between being a devout religious person and living in a modern society, or don't you think so?

Appendix B – Religious Beliefs and Practices Survey

RELIGIOUS BELIEFS AND PRACTICES SURVEY

For each of the following questions, please mark the response that represents your views. If your ideas are not represented by the responses given, please write down or tell me your actual response.

1. How much would you say you know about the Muslim religion and its practices?
   - ☐ A great deal
   - ☐ Some
   - ☐ Not very much
   - ☐ Nothing at all

2a. Concerning daily salah or prayer, do you, in general,
   - ☐ pray more than 5 times a day
   - ☐ pray all five salah daily
   - ☐ make some of the five salah daily
   - ☐ occasionally make salah
   - ☐ only make Eid prayers
   - ☐ never pray

2b. Have you fasted during the last 12 months?
   - ☐ Yes
   - ☐ No

2c. Have you paid zakat or charity in the last 12 months?
   - ☐ Yes
   - ☐ No

3. On average, how often do you attend the mosque or Islamic center for salah and Jumah prayer?
   - ☐ More than once a week
   - ☐ once a week for Jumah prayer
   - ☐ once or twice a month, a few times a year
   - ☐ especially for the Eid
   - ☐ seldom
   - ☐ never

4. And outside of salah and Jumah prayer, do you take part in any other social or religious activities at the mosque or Islamic center?
   - ☐ Yes
   - ☐ No

5. How often do you read the Quran?
   - ☐ I read it regularly once a day or more
   - ☐ I read it regularly several times a week
   - ☐ I read it regularly once a week
   - ☐ I read it quite often but not at regular intervals
   - ☐ I read it once in a while
   - ☐ I read it only on special occasions
   - ☐ I never recite the Quran, or read it rarely

6. How does the Qur'an help you in making everyday decisions?
   - ☐ I hardly think of the Quran as I go about my daily life
   - ☐ I can't think of specific examples, nevertheless I feel sure that the Quran is still of help in my daily life
   - ☐ I can remember specific times when it has helped me in a very direct way in making decisions
   - ☐ I often consult the Quran to make specific decisions

7. Which comes closest to your view?
   - ☐ The Quran is the word of God
   - ☐ The Quran is a book written by men and is not the word of God

7a. IF YOU BELIEVE THE QURAN IS THE WORD OF GOD,
Would you say that
- ☐ The Quran is to be taken literally, word for word.
- ☐ Not everything in the Quran should be taken literally, word for word.

8. How much, if at all, does the way you live your life reflect the Hadith and Sunna, that is, the sayings and actions of the Prophet?
- ☐ a lot
- ☐ a little
- ☐ not too much
- ☐ not at all

9. Which of these two points of view is closer to your own?
- ☐ Islam should tolerate diverse interpretations of its teachings.
- ☐ There is only one true interpretation of the teachings of Islam.

Are each of the following important to you or not?	**Very important**	**Somewhat important**	**Not too important**	**Not at all important**
10. How important is religion in your life?				
11. How important is giving charity, or zakat?				
12. How important is fasting during Ramadan?				
13. How important is reading or listening to the Quran daily?				
14. How important is undertaking a pilgrimage to Mecca?				
14a. IF YOU HAVE ALREADY UNDERTAKEN THE PILGRIMAGE: How important was the pilgrimage?				

15. Do you believe in One God, Allah or not?
- ☐ I know Allah really exists and I have no doubts about it
- ☐ While I have doubts, I feel I do believe in Allah
- ☐ I find myself believing in Allah some of the time but not at other times
- ☐ I don't believe in a personal Allah, but do believe in a higher power of some kind

16. Do you believe in the Prophet Muhammad or not?
- ☐ I believe in Prophet Muhammad and I have no doubts about it
- ☐ While I have doubts, I feel I do believe in Prophet Muhammad
- ☐ I find myself believing in Prophet Muhammad some of the time but not at other times
- ☐ I don't believe Muhammad was a prophet

Do you believe in the following or not?	Completely true	Probably true	Not sure	Probably not true	Definitely not true	I don't know
17. Do you believe in the Day of Judgment?						
18. Do you believe in angels?						
19. Do you believe in the devil (Shaytan)?						
20. Do you believe that only those who believe in the Prophet Muhammad can go to Heaven?						
21. Do you believe in miracles?						

22. I believe that miracles can be explained by natural causes
    - ☐ Yes
    - ☐ No

Have you experienced any of the following or not?	Yes, I'm sure I have	Yes, I think I have	No
23. Have you experienced a feeling you were in the presence of Allah?			
24. Have you experienced a sense of feeling the rahmah (mercy, loving kindness) of Allah?			
25. Have you experienced a sense of being blessed by Allah?			
26. Have you experienced a sense of being afraid of Allah?			
27. Have you experienced a sense of being punished by Allah?			
28. Have you experienced sense of being tempted by the Devil (Shaytan)?			

29. Would you agree that a person who says there is no Allah is likely to hold dangerous political views?
    - ☐ Agree
    - ☐ Disagree
    - ☐ Uncertain

Appendix C – Views of Nature of Science Questionnaire Form C

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE

(VNOS-FORM C)

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?

   - If yes, explain why. Give an example to defend your position.

   - If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change: (a) Explain why theories change. (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom?

   What specific evidence **do you think** scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and use the **same set of data** to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected
   by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.

   - If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

    - If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

    - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix D – Demographic information

DEMOGRAPHIC INFORMATION

For the following questions, please put a check in the box that corresponds to your answer. **If your answer is not given, please write it in.**

Religion	
1. Do you think of yourself first as an American or first as a Muslim?	☐ American first ☐ Muslim first
2. Have you always been a Muslim, or not?	☐ Yes (Go to Question 3) ☐ No (Go to Question 4)
IF YOU HAVE ALWAYS BEEN A MUSLIM 3. How many generations of your family have lived as Muslims in the US? (Check all that apply.)	☐ Parents ☐ Grandparents ☐ Great-grandparents ☐ Great-great grandparents
IF YOU HAVE NOT ALWAYS BEEN A MUSLIM 4. a. What were you before?	
b. How old were you when you became a Muslim?	
5. Are you Shi'a, Sunni, or another tradition?	☐ Shi'a ☐ Sunni ☐ Another tradition (please specify)
6. Is your father Shi'a, Sunni, or another tradition?	☐ Shi'a ☐ Sunni ☐ Another tradition (please specify)
7. Is your mother Shi'a, Sunni, or another tradition?	☐ Shi'a ☐ Sunni ☐ Another tradition (please specify)
Education	
8. What is your current year in school?	☐☐ Freshman ☐☐ Sophomore ☐☐ Junior ☐☐ Senior

9. Please list the biology classes you have had. For each one, please tell what the level in school you had those classes. (i.e. High School Biology in Freshman year of HS; General Biology 101 Freshman year of college)	
10. Did any of these classes include evolution? a. If so, which ones?	☐ Yes ☐No
Personal Characteristics	
11. What is your sex?	☐ Male ☐ Female
12. What is your age?	☐
13. Are you of Hispanic origin or descent, such as Mexican, Puerto Rican, Cuban, or some other Spanish background?	☐ Hispanic ☐ Black Hispanic ☐ Not Hispanic
14. What is your race?	☐ White ☐ Black ☐ Asian ☐ Other (please specify)
15. In what country were you born?	☐ USA (Go to Question 16) ☐ Other (please specify) (Go to Question 17)
IF YOU *WERE* BORN IN U.S.: 16. a. In what country was your father born?	
b. In what country was your mother born?	
c. If both of your parents were born in the US, what is/are the country/countries of origin of the previous generations, grandmothers and grandfathers, etc.?	
IF YOU WERE NOT BORN IN THE U.S.A. 17. In what year did you come to live in the U.S.A.?	
18. Are you an American? (Americans include American citizens, permanent residents, and people who were brought to the U.S.A. as children by their parents.)	☐ Yes ☐ No

Appendix E – Generalized Acceptance of EvolutioN Evaluation

GENERALIZED ACCEPTANCE OF EVOLUTION EVALUATION (GAENE V.3)

For each of the following questions, please mark the response that comes closest to your opinion about that statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
1. Most living things have some very basic similarities.				
2. Everyone should understand evolution.				
3. Some parts of evolution theory could be true.				
4. It is important to let people know about how strong the evidence that supports evolution is.				
5. Evolutionary theory applies to all plants and animals, including humans.				
6. People who plan to become biologists need to understand evolution.				
7. I would be willing to argue in favor of evolution in a public forum such as a school club, church group, or meeting of public school parents.				
8. Simple organisms such as bacteria change over time.				
9. Nothing in biology makes sense without evolution.				
10. Understanding evolution helps me understand the other parts of biology.				
11. I would be willing to argue in favor of evolution in a small group of friends.				
12. Evolution is a good explanation of how humans first emerged on the earth.				
13. Evolution is a scientific fact.				
14. Evolution is a good explanation of how new species arise.				

Appendix F - Illustrative Examples of Responses to VNOS Items

Illustrative examples of responses to VNOS Items

NOS Aspect	More Naive Views	More Informed Views
Empirical NOS	Science is something that is straightforward and isn't a field of study that allows a lot of opinions, personal bias, or individual views—it is fact based. Science is concerned with facts. We use observed facts to prove that theories are true.	Much of the development of scientific knowledge depends on observation. . . . [But] I think what we observe is a function of convention. I don't believe that the goal of science is (or should be) the accumulation of observable facts. Rather . . . science involves abstraction, one step of abstraction after another.
The scientific method	Science deals with using an exact method. . . . That way we know we have the right answer. Science has a particular method of going about things, the scientific method.	When you are in sixth grade you learn that here is the scientific method and the first thing you do this, and the second thing you do that and so on . . . That's how we may say we do science, but [it is different from] . . . the way that we actually do science.
General structure and aim of experiments	An experiment is a sequence of steps performed to prove a proposed theory. Experiment is everything that involves the act of collecting data and not necessarily manipulation.	An experiment cannot prove a theory or a hypothesis. It just discredits or adds validity to them. An experiment is a controlled way to test and manipulate the objects of interest while keeping all other factors the same.

Role of prior expectations in experiments	You usually have some sort of idea about the outcome. But I think that to have a scientific and valid experiment you should not have any bias or ideas in advance.	To organize an experiment you need to know what is going to come out of it or it wouldn't really be a test method. I don't know how you would organize a test ... if you don't have a general idea about what you are looking for.
Validity of observationally based theories and disciplines	Science would not exist without scientific procedure which is solely based on experiments. . . . The development of knowledge can only be attained through precise experiments.	Experiments are not always crucial . . . Darwin's theory of evolution . . . cannot be directly tested experimentally. Yet, because of observed data ... it has become virtually the lynchpin of modern biology.
Tentative NOS	If you get the same result over and over and over, then you become sure that your theory is a proven law, a fact. Compared to philosophy and religion . . . science demands definitive . . . right and wrong answers.	Everything in science is subject to change with new evidence and interpretation of that evidence. We are never 100% sure about anything because . . . negative evidence will call a theory or law into question, and possibly cause a modification.
Difference and relationship between theories and laws	Laws started as theories and eventually became laws after repeated and proven demonstration. A scientific law is somewhat set in stone, proven to be true . . .A scientific theory is apt to change and be proven false at any time.	A scientific law describes quantitative relationships between phenomena such as universal attraction between objects. Scientific theories are made of concepts that are in accordance with common observation or go beyond and propose new explanatory models for the world.

Scientific theories Nature of	A theory is an untested idea, or an idea that is undergoing additional tests, Generally it hasn't been proved to the satisfaction of the scientific community.	In the vocabulary of a scientist the word theory is used differently than in the general population. It does not mean someone's idea that can't be proven. It is a concept that has considerable evidence behind it and has endured the attempts to disprove it.
Functions of	We learn scientific theories just so that scientists don't start all over from the beginning . . . they just can add to the old ideas.	Theories set a framework of general explanation upon which specific hypotheses are developed. Theories . . . also advance the pool of knowledge by stimulating hypotheses and research.
Logic of testing	Many theories can't be completely tested, e.g., the theory of evolution can't be tested unless you create your own world and then live for millions of years.	Most theories have things we cannot observe. So, we deduce consequences from them that could be tested. This indirect evidence allows us to see if the theory is valid.
Creative and imaginative NOS	A scientist only uses imagination in collecting data. . . . But there is no creativity after data collection because the scientist has to be objective.	Logic plays a large role in the scientific process, but imagination and creativity are essential for the formulation of novel ideas ... to explain why the results were observed.

Inference and theoretical entities	Scientists can see atoms with high-powered microscopes. They are very certain of the structure of atoms. You have to see something to be sure of it. There is . . . scientific certainty [about the concept of species]. While in the early days it was probably a matter of trial-and-error . . . nowadays genetic testing makes it possible to define a species precisely.	Evidence is indirect and relates to things that we don't see directly. You can't answer . . . whether scientists know what the atom looks like, because it is more of a construct. Species is . . . a human creation. It is a convenient framework for categorizing things. . . . It is a good system but I think the more they learn the more they realize that . . . we cannot draw the line between species or subspecies.
Theory-laden NOS	[Scientists reach different conclusions] because the scientists were not around when the dinosaurs became extinct, so no one witnessed what happened. . . . I think the only way to give a satisfactory answer to the extinction of the dinosaurs is to go back in time to witness what happened. Scientists are very objective because they have a set of procedures they use to solve their problems. Artists are more subjective, putting themselves into their work.	Both conclusions are possible because there may be different interpretations of the same data. Different scientists may come up with different explanations based on their own education and background or what they feel are inconsistencies in others ideas. Scientists are human. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think, and because of their prior knowledge.

Social and cultural embeddedness of science	Science is about the facts and could not be influenced by cultures and society. Atoms are atoms here in the U.S. and are still atoms in Russia Well, the society can sometimes not fund some scientific research. So, in that sense it influences science. But scientific knowledge is universal and does not change from one place to another.	Of course culture influence the ideas in science. It was more than a 100 years after Copernicus that his ideas were considered because religious beliefs of the church sort of favored the geocentric model. All factors in society and the culture influence the acceptance of scientific ideas. . . . Like the theory of evolution was not accepted in France and totally endorsed in Germany for basically national, social, and also cultural elements.

From Lederman et al. 2002.

Appendix G – ACORNS Scoring Rubrics

Key Concept (and Core Concept) 1: The presence and/or causes of variation among individuals

Scoring: A score of 1 indicates the presence of a key concept in the response. A score of 0 indicates the lack of a key concept in the response.

Score	Description	Key words	Example 1	Example 2
1	**Mutation** the random change of genetic information; may produce different phenotypes from parent's traits	mutation/mutated gene/ change of gene/genetic information/DNA/genome genetic defect/error/ deformity/anomaly/make-up/etc. random change/randomly/by chance/etc.	The long tarsi enabled the prosimian to survive longer, so the ones with the long tarsi **mutation** survived longer.	Biologists would…Next they would need to show that as time goes on, each generation of prosimian is slightly different than the last and that **these changes in DNA** eventually cause a major change in structure of the prosimian.
1	**Variation** diversity of genotypic or phenotypic Attributes; each individual genotype or phenotype is different	variation in genetics a few/some species/organism/ had X gene/trait genetic difference/variation gene pool	Animals may have adapted to their environment or **different genes** are replicated.	The species of pro simian probably all had short tarsi at one point in history. There must have been some genetic variation so that some of the species had slightly longer tarsi. The environment must have changed and therefore the species with the longer tarsi were better equiped and they survived and reproduced more efficiently therefore increasing the number of prosimian with long tarsi.
1	**Recombination** mixed characters, cross breeding, genetic recombination	hybrid cross breeding/pollination/fertilized/ allele, dominant/recessive gene interacted/mated different species	Through selective breeding, prosimians could **choose to breed with others** that have longer than average tarsi. After time, only longer tarsi would exist.	Bees and other animals spread pollen to fertilize seeds. Therefore, pollen (or a similar substance) from a tree with winged seeds could have crossed with the elm without winged seeds. A new species of elm tree which produced winged seeds eventually emerged.
1	**Particular genotype** special genes are associated with particular traits	the/this/that gene/trait gene for X function	the ancestral prosimian species with short tails may have used the tails in mating rituals. This could mean that the females picked **the males with the longer tails** and as each generation after that the same process would occur. The choosing of **this genetic trait** made each generation of the species have longer and longer tails.	the ancestral prosimian species with short tails may have used the tails in mating rituals. This could mean that the females picked the males with the longer tails and as each generation after that the same process would occur. The choosing of this genetic trait made each generation of the species have longer and longer tails.

Draft

Key Concept (and Core Concept) 2: The heritability of variation

Scoring:
A score of 1 indicates the presence of a key concept in the response. A score of 0 indicates the lack of a key concept in the response.

Score	Description	Key words	Example 1	Example 2
1	**passing gene** the transmission of the gene; possibility of "passing" the gene	pass/passed/ to next/future/offspring was/were/got passed can pass/be able to pass/ can be passed/be able to be passed	Once again this long tarsi was favourable to this anuimal in some way. This favourability gave this organism a better chance to survive and mate and **pass on its genes**.	This means that at one point in time, the elm species that did not produce winged seeds had random plants that mutated and did produce winged seeds. These plants that produced the winged seeds showed better survival rates than those without the winged seeds and **passed this trait on to their offspring**.
1	**produce same O** procreate and resemble offspring; procreate O with same trait/gene	produce/create/reproduce O with gene produce/create/reproduce same/resemble O the offspring who have same gene/trait	Prosimian reproduced and a trait among some of the offspring was long tarsi. This prosimian was benefitted in its life by his tarsi being longer than average, when they reproduced **they produced offspring with long tarsi** and because they survived easier the trait evolved.	That the seeds that were furthest from the tree (after falling) would have the best chance of survival. If the seeds are further, they will not lack water or sunlight that may be blocked or used by the mature tree. Those seeds with projections that affected their falls would grow and **produce more seeds with possibly similar shapes**, leading to evolution of wings.
1	**continue gene** continuity of the gene or genetic material or associated trait	continue/keep gene to next/future generation	The prosimian with a long tarsi might have originally been a mutated prosimian and it was a mutation that was beneficial to the prosimian species that had short tarsis. **The species with long tarsi continued to share this gene generation after generation**, eventually leading into its own species.	The winged seeds probably formed from a gene mutation that led to an edge in competition for resources. **The trait was favorable and continued** through the process of natural selection.
1	**inheritable** inherence of the gene or genetic information	inherent/inheritable/inherited/	Natural selection would be the theory used to describe this product of evolution. Basically its survival of the fittest. Some offspring were born with certain genetic anomalies, and due to the fact that they survived Long enough to reproduce, their offspring **inherited** those genes, and after generations the entire population had the long tarsi.	Seeds that contained a wing-like mutation dispersed more, and produced viable offspring, the dispersal advantage of winged seeds lead to the a successful **inheritable mutation**.

Key Concept 3: Competition

Scoring:
A score of 1 indicates the presence of a key concept in the response. A score of 0 indicates the lack of a key concept in the response.

Score	Description	Key words	Example 1	Example 2
1	**competition** Competition, Vying for resources	Compete, Competition, out-competed	The ancient prosimian which had short tarsi underwent a minor mutation which allowed them to grow long tarsi. This advantage allowed them to **outcompete** those prosimians with short tarsi. Eventually, only the prosimians with long tarsi existed	Through evolution, ancestral elm species that reproduced in a windy climate would occasionally produce a seed better suited for dispersal with aid of the wind. These seeds were carried to areas with less **competition** and were able to reproduce more readily eventually creating a species of elm with winged seeds
1	**battle** Battle, struggle for X	Battle, struggle	The species that did not have pulegone developed a need for it in the environment that would help them better survive. A mutated gene occurred in those lacking pulegone to make some species have pulegone. The latter had more success in survival and reproduction thus won out the **battle** of evolution.	According to the findings of Charles Darwin and the evolution of life, species adapt over time and all species of life have descended over time from common ancestors. So you could trace this specific species of snail back to its ancestors and find that its ancestors are non-poisonous. The poisonous snail may have evolved over time due to a constant predator killing them off. So, overtime "Natural Selection" evolved poisonous snails so that the predator would recognize the snail as poisonous and not attack it. As more individuals of each species, in this case the snails, are born than can possibly survive, consequently, there is a frequent recurring **struggle for existence**. Therefore, if it evolves into something that can help it survive then the snails will have a better chance of living. And through inheritance, any species can grow into its new and modified form.

Key Concept 4: Hyperfecundity or the overproduction of offspring

Note:
This aspect of evolutionary change is very rarely invoked by students.

Scoring:
A score of 1 indicates the presence of a key concept in the response. A score of 0 indicates the lack of a key concept in the response.

Score	Description	Key words	Example 1	Example 2
1	**More individuals are typically born than can survive; overproduction of offspring; hyperfecundity of nature**	over populated; more are born than can survive, too many offspring	According to the findings of Charles Darwin and the evolution of life species adapt over time and all species of life have descended over time from common ancestors. So you could trace this specific species of snail back to its ancestors and find that its ancestors are nonpoisonous. The poisonous snail may have evolved over time due to a constant predator killing them off. So overtime Natural Selection evolved poisonous snails so that the predator would recognize the snail as poisonous and not attack it. **As more individuals of each species in this case the snails are born than can possibly survive consequently** there is a frequent recurring struggle for existence. Therefore if it evolves into something that can help it survive then the snails will have a better chance of living. And through inheritance any species can grow into its new and modified form.	The rose species that has thorns over populated and was the keystone species of the environment. Once the roses lost their thorns due to genetic drift and speciation the roses were in environmental equilibrium with the rest of their population living in commensalism.

Key Concept 5: Resource limitation

Note:
We interpret predator-prey discussions to be related to food as a limiting resource.

Scoring:
A score of 1 indicates the presence of a key concept in the response. A score of 0 indicates the lack of a key concept in the response.

Score	Description	Key words	Example 1	Example 2
1	**related to survival** kill or be killed	predator/predation prey/preyed be eaten/killed hunt/hunted	It is only safe to assume that snails have multiple **predators** in the wild. Those snails who are lacking the poison would have no defense mechanism to attack these **predators** and would eventually go extinct. If even just one snail were equipped with poison in their system the trait would be favorable because of its ability to attack **predators** and the trait would be passed from generation to generation once again using the survival of the fittest theory.	The snail was originally non-poisonous millions of years ago. These snails were most likely **hunted by another species as their food source**. To combat this, the snail began to develop a defense mechanism, that being the poison. The poison, over time, developed even more and because of evolution, creating the poisonous species of snail we see today.
1	**related to reproduction** help reproduction possibility	pollinator/pollination insect (it means pollinator)	All plants need seed dispersal to live and each species needs a particular niche to survive. The elm perhaps inhabiting a windy area and lacking flowers eventually produced winded seeds to disperse their seeds. Because the wind could carry them and the elm does not have flowers to attract **pollinators** this adaptation improved the fitness of the plant.	They would explain this by saying that the pluegone made the pants have some sort of advantage to **attract insects for pollination or to ward off insects that may prey upon them**. It could have also come to be from the need to find a better way to make energy or work in a more efficent way and save more energy.
1	**Related to resources** Needed for life	air/space/sunlight/soil type/rainfall/water (plant) food/feeding opportunity/water/nutrient/habitats (animal) resource	Seed dispersal is the reason why winged seeds were selected. This allows for seed to move far away from the parent which allows for more or less access to **resources**. The hope is to have more access **to resources**.	It might have become necessary for the seeds to travel longer distances maybe because of an increased tree size and subsequent **need for more spacing between the trees for root space and nutrition**.

Key Concept (and Core Concept) 6: Differential survival of individuals

Scoring:
A score of 1 indicates the presence of a key concept. A score of 0 indicates the lack of a key concept.

Score	Description	Key words	Example 1	Example 2
1	**improved survival/reproduction** differential survival/reproduction	better/more/greater/higher/etc survival/reproduction(rate) (than other) better/more/greater/etc chance to survive/reproduce (than other) survive better/longer (than other) reproduce/create more offspring (than other) become more frequent/abundant	Biologists would say that the prosimian with the short tarsi underwent genetic mutations resulting in prosimians with long tarsi. The long tarsi prosimians were better adapted to their environment, meaning **they were able to survive better than the short tarsi prosimians**. This assumes that the prosimians containing genetic information for short tarsi died out. Although the genetic information could still be held by the long tarsi prosimians.	Through evolution, ancestral elm species that reproduced in a windy climate would occasionally produce a seed better suited for dispersal with aid of the wind. **These seeds** were carried to areas with less competition and **were able to reproduce more readily** eventually creating a species of elm with winged seeds.
1	**increased survival/reproduction** more survival/reproduction reproductive rate change	increase/expand survival/reproduction (rate) increase/expand chance to survive/reproduce increase/expand fitness	Through evolutionary gradual change from a short tarsi to a long tarsi. The environment the prosimian with short tarsi lived in might have changed (temperature, feeding opportunities, more predators, etc.) and a long tarsi might have proven more effective in the new environment, possibly increasing the animals speed or dexterity **and therefore increases its chance to survive**.	At some point in time it became advantageous for the elm tree to produce a winged seed to **increase its reproductive capabilities**. Therefore, it evolved to form winged seeds that are capable of traveleing a longer distance than non-winged seeds.
1	**more fit to survive** in a better condition to survive/reproduce than previously	more/better fit to survive/reproduce more/better suited to survive/reproduce more suitable to survive/reproduce	Prosimian animals that **had longer tarsi were probably more fit to survive their environments**. They went on to produce offspring with long tarsi.	A genetic mutation that took place in the specie. The poison makes the snail less vulnerable to prey and therefor **more fit** for survival in certain environments, so the **poisonous offspring survived** and generated the new specie.
1	**advantage survival/reproduction** advantage of condition/trait/feature for survival/reproduction	advantage of survival/reproduction (rate) advantageous to survive/reproduce beneficial survival/reproduction reproductive/survival advantage	The prosimian likely gained some sort of **survival** advantage from the long tarsi over the short tarsi, thus the prosimian with the long tarsi survived at a greater rate than the short tarsi.	The pulegone must give an evolutionary advantage that would give labiates with it an **advantage in reproduction**.

Key Concept (and Core Concept) 6 (continued):

Score	Description	Key words	Example 1	Example 2
1	**help survival/reproduction** help species survive/reproduce	help/aid/allow/enhance/etc particular species to survive/reproduce help/aid/allow/enhance/etc survival/reproduction rate help/aid/allow/enhance/etc to grow	A biologist would explain that the long tarsi **helped** the prosimian survive better. Furthermore, the long tarsi was more of an advantage than the short tarsi because those with short tarsi had a lower survival rate. This detail allows one to assume that the long tarsi **help** the prosimian in their environment.	A random mutation produced winged seeds from non winged seeds. This allowed for greater dispersal and was more benefical to the species, allowing for the species to have a greater area of places to live. This would help the species of winged seeds survive over the non-winged seeds with poor dispersal.
1	**some survive/others die** **only particular "species" survive/reproduce** differential survival/reproduction	O survived/reproduced **while** other O died off Only/this/that/the O with gene/trait survived/died off others died off so it survived predator kill only one species O without gene/trait die off (extinct)	Some ancestral prosimians had long tarsi and some had short tarsi. Over time, the ones with longer tarsi were better suited to survival in their environment so they survived to reproduce **while** the prosimians with shorter tarsi died out.	Over time, the seeds that had a bit of a wing thrived while the seeds that did not have any bit of wings died off. This caused the smaller wing seeds to create the plants, which would then create more winged seed plants. Since the plans with winged seeds survived longer, the seeds grew to all have winged seeds because they were able to survive.
1	**selected** natural selection	This/that/the trait/gene/species was selected/favored Natural selection favored/selected those trait/gene/species	They may talk about the biological benefits that allowed the longer tarsis to be selected for over many generations because of natural selection.	They may talk about the biological benefits that allowed the longer tarsis to be selected for over many generations because of natural selection.
1	**sexual selection** sexual selection	females chose those species with gene/trait The/this/that species is more attractive to the female	this was due to sexual selection. The female animals preferred the long tarsi and therefore mated with the animals with the longer tarsi and therefore that was the trait was carried on	Through out thousands of years prosimian started to develop long tarsi. When reproducing the female saw the long tarsi as a better, more valuable trait so she started to pick males with long tarsi. Eventually long tarsi became more dominant.

Key Concept 7: Generational changes in the distribution or frequency of variation

Scoring:
A score of 1 indicates the presence of a key concept. A score of 0 indicates the lack of a key concept.

Score	Description	Key words	Example 1	Example 2
1	**Until unit changed**	until…all O became own/new species until…all O had X trait/mutation/gene until…O without X trait was extinct until… O became common/normal	Again nearly the same question. The plant with winged seeds would have a huge advantage in its ability to disperse with winged seeds. So it may have outcompeted those with nonwinged seeds that could not disperse as readily and **therefore became minority in population until there were no more wingless seed plants**.	The winged formation of the seeds allows those seeds to spread farther and therefore more seeds can sprout because they are farther apart and not crowded out by each other. More trees with the winged seeds survive to reproduce until all the trees of that species have winged seeds.
1	**over time.. it become new species**	over time/eventually/ultimately… O became own/new species over time/eventually/ultimately… two Os were separated over time/eventually/ultimately… O had trait/mutation/gene	The ancestral elm could have started producing seeds in a protective case as they fell from the ground eventually any seed encased in an irregularly shaped case would have a strange flight pattern and fallen further from the tree. Thus elms with a more irregular shaped seed would spread and reproduce better. **As this trait increased the dispersal of the plant the trait became more exaggerated and eventually the tree drifted genetically enough to be a new species.**	The scientists would most likely relate this to Darwin's theory of natural selection. The idea that different species of a common organism may have derived from a common ancestor. The population of that of that ancestral species may have become split up and over time the isolated population begins to adapt to its environment by developing characteristics and traits that will ensure its survival in that type of environment.
1	**Become prominent or common**	trait/gene/mutation/O with X trait become common/mail/dominant/prevalent	A random mutation occured and that snail was able to reproduce and **its genes became common throughout the population.**	The poisonous gene probably first occurred as a random genetic mutation. Poisonous snails were unlikely to be eaten. As the snails that possessed this trait were able to live longer, and reproduce more than those without it, the gene became more and more common until it appeared in every individual.
1	**Frequency change**	trait/gene/mutation/O with X trait became more and more trait/gene/mutation/O with X trait accumulate allelic frequency change/alter	This phenomenon could be explained through the theory of evolution. Specifically in addition to being able to avoid predation the development of being poisonous was likely a genetic mutation in previous generations. After it was determined that poisonous snails are more fit for survival within their niche **more and more poisonous snails became populated.**	Assuming that pulegone is a triat that the species exhibits, if the species is favored for having pulegone it will then pass that trait onto the next generation and by natural selection it will accumulate.

Essentialism

Scoring:
A score of 1 indicates the presence of a cognitive bias in the response. A score of 0 indicates the lack of a cognitive bias in the response.

Score	Description	Example 1	Example 2	Example 3
1	Response explains change at a level higher than the individual (e.g. the entire species changes, reifying the species; highlighted in **bold**) and fails to mention within species variability (e.g. some individuals have a specific trait while others do not)	*A biologist would explain this by saying that this species of elm had a mutation that was advantageous and saw that it was more effecting in seed dispersal which caused it to continue into this line of species.*	*Predation is a major selective pressure acting on animals. Their was most likely a gene mutation that caused the snails to become poisonous and as a result it allows them to be able to defend themselves more efficiently.*	*It underwent a mutation the resulted in a long tarsi which increased the prosimian's fitness.*
0	Response explains change at a level higher than the individual but mentions within species variability (variability highlighted in **bold**).	*Winged seeds developed from selective pressures. Random mutation created an elm tree species with winged seeds. Natural selection occurred to the ancestral elm trees that produced winged seeds. The **winged seeds produced more offspring than the elm trees that did not produce winged seeds**. The improved fitness of the elm trees with winged seeds produced more offspring, eventually forcing the ancestral elm tree into extinction.*	*For some reason, the plant needed pulegone to survive and eventually the plant evolved to contain pulegone. The plants with pulegone survived better and reproduced to produce plants with pulegone.*	*Long ago, one of the ancestral snail species developed poison and was unique to the other snail species. In the environment where the snail species inhabited, the poison showed to be beneficial to the snail because it prevented the snail from being predated on. **This allowed the poisonous snail to better survive and outlive the non poisonous snails, and were better able to pass on this trait to more offspring.***
0	Response does not explain change at a level higher than the individual.	*The condition of being poisonous was beneficial to the individual and those individuals that were poisonous were likely to survive and reproduce than those individuals that were not poisonous.*	*At some point, an ancestral prosimian had a genetic mutation that caused it to have a longer tarsi than others. This allowed it and its descendants to survive and reproduce better than ones with shorter tarsis. Over time, through breeding long tarsis with long tarsis, the tarsi became the length it is now.*	*Elm trees which produced seeds with more around the edge that could catch the wind could spread their seeds further, thus having less competition with other elms. Natural selection led to the expansion to create the wings over several generations. The winged seeds were an advantage, thus allowing those trees to produce more offspring.*

Intentionality

Scoring:
A score of 1 indicates the presence of a cognitive bias in the response. A score of 0 indicates the lack of a cognitive bias in the response.

Score	Description	Example 1	Example 2	Example 3
1	Explanation contains mental verb; agent of mental verb is evolving species or nature; mental verb causes evolutionary change. (Intentionality language highlighted in **bold**)	since plants ever evolved, they were **looking** for a way to pollinate and disperse, and they **couldn't find a way** to help with that so with natural selection coming in handy, it produced winged seeds, to be easy for the plant to disprese and spread to different areas.	The Pulegone was **chosen** by natural selection to be better. The Labiatae mutated the pulegone.	One explanation could be that the long tarsi was **desired** more by the species and thus they mated with the prosimian with the longest tarsi. This can cause the short tasi promisian to become less fit in the population and the offspring being born would exhibit the long tarsi.
0	Explanation contains mental verb and agent is the evolving species or nature, but the mental verb does not cause the evolutionary change. (Intentionality language highlighted in **bold**)	a mutation causing seeds that caught more wind led to better seed dispersal and natural selection **favored** them because they reproduced more than seeds without wings.	i have no idea what a tarsi is... I would guess that the ones with the short tarsis **selected** each other until they converged to short tarsis.	this was due to sexual selection. The female animals **preferred** the long tarsi and therefore mated with the animals with the longer tarsi and therefore that was the trait was carried on
0	Explanation contains mental verb, but agent of verb is not the evolving species or nature.	The winged seeds could have evolved from a process to which over time mutations created a phenotype of the seed with larger leaf like structures off of the seed. This seed would be more sucessful at dispersal and create more offspring which would in turn produce more winged like seed bearing trees. Over time this would result in the elm we **know** today.	Biologists would say that the external forces such as predators have caused a need for the snail to come up with some form of defense mechanism, in this case poison. This way the predators will **learn** that eating the snails will harm them, causing them to find new prey.	I don't **know** what a pulegone is. But, I would **think** that uncontrollable environmental elements affected the labiatae plants and in response a pulegone developed.
0	Explanation does not contain a mental verb.	A mutation occured in the seeds of a tree and the seeds were able to disperse themselves better because of the wings.(dispersal is everything) This allowed this tree to pass on the gene for winged seeds better than other trees seeds so the trees evolved to include winged seeds.	A genetic mutation in a select number of individual snails were poisonous and were able to survive and reproduce. They passed this mutation onto their offspring, who thrived as well.	The presence of long tarsi derives from a random mutation that increased the survival and reproduction rate of the individual. Individuals with this trait leave more offspring and those offspring leave more offspring, resulting in the eventual evolution of a new species.

Teleology

Scoring:
A score of 1 indicates the presence of a cognitive bias in the response. A score of 0 indicates the lack of a cognitive bias in the response.

Score	Description	Example 1	Example 2	Example 3
1	Response contains teleological language (highlighted in **bold**) without mentioning preexisting variation in the "needed" trait; need causes trait to occur	Elm species probably weren't having very much success reproducing in their ancestral form so they **needed** a new way to reproduce.	the snail **adopted** the poison as a defense mechanism **to ensure** their survival.	The animal lived in a habitat that **required** longer tarsi for survival, so over time the animal evolved longer tarsi.
0	Response contains teleological language but mentions variation (highlighted in **bold**) preexisting to, but unrelated to, the "need."	The possibility of winged seeds comes from a mutation in the ancestor elm that resulted in winged seeds. These **mutants had better fitness**, more than likely reproducing more efficiently, and this a population was created	a mutation caused the feature of having poison. Through predation, **the non poisonous snails were eaten and the poisonous snails survive** because they have the poisonous defense mechanism. These poisonous snails have survived through natural selection.	A mutation causing long tarsi occurred many years ago and **the mutant individuals were more or equally successful** than those with short tarsi so the long gene was passed on and eventually formed a new species.
0	Response does not contain teleological language.	winged seeds aid in dispersal increasing fecundity and fitness and the pressures of natural selection worked and this character to influence evolution of a new winged-seed species	A gene coding for a poisonous chemical became more prevalent in the population after, presumably, more non-poisonous counterparts were preyed upon before they could reproduce.	An ancestral prosimian species with a short tarsi more likely had trouble reaching food in tall trees. Those with the shortested tarsis had more trouble competing for resources and eventually died out, leaving only long tarsi individuals.
0	Response does not contain teleological language.	winged seeds aid in dispersal increasing fecundity and fitness and the pressures of natural selection worked and this character to influence evolution of a new winged-seed species	A gene coding for a poisonous chemical became more prevalent in the population after, presumably, more non-poisonous counterparts were preyed upon before they could reproduce.	An ancestral prosimian species with a short tarsi more likely had trouble reaching food in tall trees. Those with the shortested tarsis had more trouble competing for resources and eventually died out, leaving only long tarsi individuals.

Pressure

Scoring:

A score of 1 indicates the presence of a misconception in the response. A score of 0 indicates the lack of a misconception in the response.

Score	Description	Key words	Example 1	Example 2
0	Pressure results in differential survival (e.g., natural selection loop), resulting in evolution of the species	○ Pressure results in differential survival of a trait/organism(s) ○ May include increase in frequency ○ Typically includes examples	The term **pressure** mean that in the intense competition for fitness, plant that could disperse more seeds will have higher fitness, thus the **pressure** will be apply on that favorable trait, increasing the number of organism with that trait.	Selective **pressures** are factors in the faces of which a species must be able to thrive…If a characteristic is exhibited which mitigates the effect of selective **pressure(s)** without unduly affecting the ability of the plant to thrive in other ways, then repetitive mating overtime will increase the prevalence of the genes or the alleles involved in its creation. At the same time, the species lacking this characteristic may not withstand the selective pressure(s) facing it and may not thrive in the same numbers and/or in the same environment.
0	Specific Process (e.g. natural selection, evolution)	○ Includes only a process without explaining or connecting it.	**Pressures** of natural selection	Evolution, **pressures** of natural selection
1	Pressures are abiotic/biotic factors or interactions (e.g., predation, competition, food, water, habitat, climate). Answers include no mention of how they interact with evolutionary processes.	○ List of example pressure types ○ No connection to direct change ○ No connection to evolutionary processes ○ AKA "the lazy answer"	**pressures** refer to things such as wind, rainfall, temperature that are results of nature	Selectve **pressures** are things like wind, temperature, water quanity, etc.

Score	Description	Key words	Example 1	Example 2
1	Pressure causes a mutation in an individual(s) (increase/decrease in variation), resulting in evolution of organism/species.	○ Pressure causes a mutation or a change ○ May include increased fitness, differential survival, etc. but not necessary	**Pressures**, meaning forces that cause a change in the genes of an organism because of predation, weather, desication, food, and water. These changes occur for survival.	**pressure** means the force that promotes changes in a species to be better suited to survive and produce viable fertile offspring
1	Pressure (directly) causes/results in evolution or change in the organism/species. Answers may or may not include examples of pressures.	○ Pressure = change ○ Lacks evolutionary process ○ May include examples, but not necessary	**Pressures** meaning that nature makes the plant evolve into a newly derived characteristics.	There are different **pressures** in nature like wind, temperature, and rainfall that push evolution in a certain direction
1	Lack of pressure (directly) causes/results in evolution or change in the organism/species. Answers may or may not include examples of pressures.	○ Lack of pressure = change ○ Lacks evolutionary process ○ May include examples but not necessary	By **pressure**, I mean that the method of the ancestral plant dispersing its seeds was being acted upon by some outside force or event, preventing its continuation.	If it is no longer a required trait to have winged seeds then nature evolves by altering the production those forms of seeds and uses the energy in other ways.
1	Pressure (1) causes a need to adapt and/or (2) is cause to adapt, resulting in evolution or organism/species.	○ Pressure creates a need (or lack of need) ○ Need may result in direct change or adapt ○ May include examples but not necessary	by **pressures** i mean the things in nature that you need to adapt and survive from, like predation and food	By **pressures** I mean any outside forces that would affect the trees ability to reproduce and survive. Based on these pressures the tree may have to adapt to better survive.

Draft

Adapt

Scoring:

A score of 1 indicates the presence of a misconception in the response. A score of 0 indicates the lack of a misconception in the response.

Score	Description	Key words	Example 1	Example 2
0	A heritable trait that increases the survival and reproduction of an organism compared with individuals without the trait, in a specific environment.	○ Relative to other individuals ○ Heritability ○ Increased survival/reproduction	How a species evolves and develops trait that benefits a species and is able to be passed on from generation to generation within that environment	The term "**adapted**" that I used in my response to question one was used to show the change in the snail from non poisonous to poisonous. The term meant to show how the species population was changed when a mutated gene that allowed snails to become poisonous which allowed them to live longer and breed with many mates to spread the mutated gene, which allowed for survival.
0	Adapt means to be better at surviving or better suited for a particular environment.	○ Not relative to other individuals or species ○ Means to be better suited or more suit ○ Refers to environment	better at surviving possible changes in their environment	By saying that the species is better **adapted**, I mean that they are more fit for their environment and more likely to survive.
1	Organisms adapt to be able to live in the environment.	○ Refers to fit with the environment ○ Also may include intentionality	**adapt**- to be able to live in the environment that is currently present	to survive the current ecosystem it lives in.
1	The organism must/has to/needs to adapt in order to survive. Adapting is a requirement (do or die).	○ Must adapt in order to survive ○ Due to a pressure or constraint in the environment	**Adapted** is a term referring to evolution and natural selection. If the elm plants do not adapt, or evolve to their natural environment then their population will not disperse and will eventually die out.	It needed to form a defense mechanism by a mutation for survival.
1	Adapt means there is a direct change in the organism/species.	○ Intentional adaptation ○ Direct change occurs	Modification-the seed was modified from its original wingless form to a more suitable, survivable form.	in this context, **adapted** means to make changes to or adjust to the environment to be better suited to live in said environment. this is what could have happened genetically with the most recent labiatae species

Need

Scoring:

A score of 1 indicates the presence of a misconception in the response. A score of 0 indicates the lack of a misconception in the response.

Score	Description	Key words	Example 1	Example 2
0	Need is a filler word for 1 or more correct evolutionary concepts (elements of natural selection). Response is not necessarily completely correct.	○ Differential survival/reproduction ○ Acting on variation/mutation (not producing) ○ Heritability of traits	Here, the term '**need**' is used loosely, as something 'favored' by natural selection that allowed the plant to reproduce more than its neighbors.	This plant had a genetic mutation that allowed for these flying seeds and they successfully grew into new plants.
1	Need is equivalent to pressures in the environment.	○ Need = pressure to change ○ Pressure creates a need ○ May result in change or adaptation	By **need** I mean that the species was surviving well as they were, until something new was introduced, making them have to change to survive. It fits into my explanation because the pressure creates a **need** in the species to change to survive so they can reproduce and be fit in their environment.	What I mean by the term "**needed**" is that this snail had pressures put upon it (like predation), and these pressures forced the snail to evolve into a poisonous snail.
1	Need is equivalent to the need to survive/have offspring/increase fitness.	○ Need = survival ○ Does not include a process or mechanism ○ Does not incorporate correct evolutionary concepts	'**Needed**' meaning, in order to survive and reproduce.	I mean that the snail evolved to survive so it could reproduce viable offspring.
1	Need results in the development of a trait or adaption, in response to a situation.	○ Need = trait development ○ Typically includes the situation the organism is responding to	The plant had to come up with a plan to attract animals to itself because it was too plain and didn't stand out compared to other plants out there.	**needed** it to avoid predation and become more able to attack prey
1	Lack of need results in change/evolution of the organism/species.	○ Lack of need = change ○ Does not include process	It is not necessary to produce poison if predators are lacking, so the **need** is also nonexistent.	
1	Need results in the direct change/evolution of the organism/species.	○ Need = change ○ Does not include process ○ Key words: had to, desired, wanted, required, necessary, in order to survive	Requirement in order to better survive	**Needed** in this context means required. If the snail did not have this trait, it might not have survived.

Must

Scoring:

A score of 1 indicates the presence of a misconception in the response. A score of 0 indicates the lack of a misconception in the response.

Score	Description	Key words	Example 1	Example 2
0	Used to indicate the occurrence of a beneficial event, but does not indicate any necessity or desire for that event.	○ Random occurrence, results were beneficial ○ Not a necessity	"there was" not as a means of necessity, but just as a fact. The trees don't NEED the winged seeds to survive, they just dispersed and survived better because of them	I am implying that there is a very likely chance that the short tarsi hindered their existence.
0	Used to refer to a response to competition or predation.	○ Competition for resources ○ Defense against predation ○ Response to a stimulus	The seeds would have to compete with the tree because if they drop straight to the ground, they would have to compete with the trees roots that are already there and taking in nutrients and water.	I mean that it is undoubtable that the snails had some encounter with predators. It explains the reason for them developing the ability to produce poison.
1	Used to refer to the need to fulfill a basic requirement of life (take in nutrients, etc.). Use does not indicate a preference or desire.	○ Basic requirements (may say need, compelled) ○ Does not indicate desire	By "**must**" I mean the tree is compelled by physical necessity to adapt to its surroundings.	**Must**-To be compelled, as by a physical necessity or requirement
1	Used to indicate a force/pressure/requirement that makes any change necessary for survival.	○ Pressure or forces cause a change ○ In order to survive ○ Requirement for survival	By saying 'had to' I mean that the ancestral species was forced to find another method of dispersing its seeds to continue it species.	Most plants need insects to pollinate them. In doing so they attract with flashy colors, scents and other characteristics to whirl in the insect. In order for a plant to survive and continue to reproduce they adapt new mechanism. This is a **must** because it is essential to their survival.
1	Use to refer to a necessity or preference for change (need or desire).	○ Necessity or preference for change ○ Needs, desires ○ In order to survive	**must** refers to desire the need for that to happen.	**must** implies necessity to be better suited to survive

Use and disuse

Scoring:

A score of 1 indicates the presence of a misconception in the response. A score of 0 indicates the lack of a misconception in the response.

Score	Description	Key words	Example 1	Example 2
1	Species use a particular trait. The word 'use' can be substituted for 'run', 'swim.' Sometimes 'use' can be connected with 'need'	use(s) traits the use of trait run/swim/walk/fly more and more trait was used	The species **used the tarsi more and more** as time when on causing them to become longer to suit the needs of the prosimian.	The species of ancestral penguins likely encountered arctic temperatures and conditions and **began to walk more and fly less** because of the frigid temperatures and difficulty flying. As the need to swim to retreive food became pressing the penguins may have began to use their wings for swimming.
1	Species did not use a particular trait. The word 'did not use' can be substituted for 'did not run', 'did not swim.' Sometimes 'did not use' can be connected with 'did not need'	did not use traits lack of use have no use no longer use was not used no longer being used use less stopped/ceased using	The penguin could have developed alternative ways to travel and **did not use his wings as much**. Therefore, he lost his wings throughout the course of evolution.	This could have many factors affecting this. If the environment or land mass was different millions of years ago it may have caused penguins to need to be able to fly to get there food. As time went on the land and ecology changes and the penguins no longer needed their wings to survive. **The less that they used them the more they were no longer used to fly.**
1	Energy should be allocated in other trait instead of particular trait which is not helpful.	better use of energy invest more resources saved by not having trait in other trait resource allocated to trait could be used elsewhere	Without the need to fly to be successful, **resources allocated to wings could be used elsewhere**, increasing reproductive success	If thorns are costly to produce, which seems likely, there would also be selection for thornlessness, since **those individuals would be able to invest more resources (that they came by not making thorns) in offspring.**

Draft

Energy

Scoring:

A score of 1 indicates the presence of a misconception in the response. A score of 0 indicates the lack of a misconception in the response.

Score	Description	Key words	Example 1	Example 2
1	Sustaining particular is waste of energy so species should save energy Often, this idea relates to 'need': in order to save energy.	save energy it is waste of energy it takes energy to have trait in order to save energy	The new species of penguins did not gain advantage from functional wings therefore it **would be a waste of energy to continue to use them.**	The rose with thorns could have been in a situation where there no predators around so over time it would eventually lose its thorns to **save energy.**
1	Sustaining particular is costly expensive so species should stop using the traits.	costly in terms of energy reduced trait is less energetically expensive trait is a cost due to energetic cost it was less costly to not develop	**Thorns are energetically more expensive** to produce than no thorns so energy would be conserved with no thorns .	A biologist could state that **thorns incur a cost in order to produce for the rose** and if the rose is in a particular environment in which it does not need that kind of protection then it would devolve to lose that extra cost of thorn production.
1	Energy should be allocated in other trait instead of particular trait which is not helpful.	better use of energy invest more resources saved by not having trait in other trait resource allocated to trait could be used elsewhere	Without the need to fly to be successful, **resources allocated to wings could be used elsewhere**, increasing reproductive success	If thorns are costly to produce, which seems likely, there would also be selection for thornlessness, since **those individuals would be able to invest more resources (that they came by not making thorns) in offspring.**

From Nehm et al, 2010

Appendix H – Large Tables

Table 5
Theistic Evolutionists – Relationship Between Science and Religion, Evolution Understanding, Evolution Acceptance, Religiosity, and Demographic Information

Pseudonym	Science & Religion	ACORNS	GAENE	Religiosity	Gender	Age	Class	Group	Race	Convert	US born
Aida	integration	Good	51	1.6	f	18	Sophomore	Ahmadi	Mixed	no	yes
Rabia	integration	Fair	60	2	f	35	Senior	Muslim	White	Yes - non-denominational Christian	yes
Angela	dialog	Excellent	51	2	f	34	Junior	Sunni	White	Yes - culturally Christian	yes
Cherif	integration	Excellent	65	1.8	m	22	Senior	Ahmadi	White	Yes - non-religious	no
Mustafa	integration	Excellent	54	2.2	m	21	Senior	Sunni	White	no	yes
Sauda	integration	Poor	58	2.4	f	43	Freshman	Sunni	Asian	no	no
James	integration	Excellent	65	1.2	m	20	Junior	Muslim	White	Yes - raised Christian	yes
Habib	integration	Excellent	56	1.8	m	21	Junior	Sunni	White	Yes - Baptist/Buddhist	yes
Halima	integration	Fair	66	1.8	f	19	Sophomore	Spiritual	Asian	no	yes
Abbas	independence	Good	69	2.2	m	22	Senior	Sunni	Asian	no	yes
Kohinoor	dialog	Good	55	2.2	f	18	Sophomore	Shia	White	no	yes
Naima	integration	Good	67	2.2	f	20	Junior	Ahmadi	Asian	no	yes
Ali	integration	Fair	53	2.4	m	25	Senior	Shia	Asian	no	yes
Nadira	dialog	Good	54	2.8	f	21	Senior	Ahmadi	Asian	no	yes
Nasir	integration	Excellent	58	2	m	19	Freshman	Ahmadi	White	no	yes
Samra	integration	Fair	57	2.8	f	18	Sophomore	Muslim	White	no	yes
Sana	integration	Good	63	2.4	f	22	Senior	Ahmadi	Asian	no	yes
Sulayman	integration	Fair	36	2.6	m	21	Sophomore	Sunni	African-American	no	yes
Afifah	integration	Excellent	61	1.8	f	18	Sophomore	Sunni	White	No	no

Note: ACORNS scores indicate understanding of evolution, GAENE scores indicate acceptance of evolution,

Table 6

Those With a Belief in the Special Creation of Humans – Relationship Between Science and Religion, Evolution Understanding, Evolution Acceptance, Religiosity, and Demographic Information

Pseudonym	Science & Religion	Acorns	GAENE	Religiosity	Gender	Age	Class	Group	Race	Convert	US born
Adam	dialog	Fair	58	2.6	m	18	Freshman	Shia	White	no	yes
Hasina	no conflict	Fair	50	2.2	f	18	Freshman	Sunni	Asian	no	yes
Jason	integration	Fair	50	2.4	m	19	Freshman	Shia	White	no	yes
Aisha	integration	Excellent	51	2	f	19	Sophomore	Sunni	White	no	yes
Amber	integration	Fair	40	1.8	f	22	Junior	Sunni	Mixed	no	yes
Basel	integration	Excellent	54	2.2	m	21	Senior	Sunni	White	no	yes
Salim	conflict	Excellent	41	1.8	m	19	Freshman	Ahmadi	Asian	no	yes
Ayyoubou	dialog	Poor	36	2.8	m	24	Freshman	Sunni	White	no	no
Salma	conflict	Poor	56	2.6	f	28	Sophomore	Sunni	White	no	no
Nabila	conflict	Excellent	48	2.4	f	18	Freshman	Sunni	Asian	no	no
Fatimah	integration	Good	43	2.4	f	24	Junior	Shia	Asian	no	no
Nafisa	independence	Excellent	53	1.8	f	22	Senior	Ahmadi	Asian	no	yes
Rafiq	integration	Good	58	2.4	m	21	Senior	Sunni	White	no	no
Mariam	integration	Good	47	2.6	f	21	Senior	Sunni	White	no	yes
Asiya	independence	Excellent	62	2	f	20	Junior	Sunni	Asian	no	yes
Salahuddin	integration	Excellent	55	2.4	m	20	Sophomore	Sunni	White	no	no
Yusuf	conflict	Excellent	41	2.2	m	19	Freshman	Sunni	Asian	No	yes
Najila	no conflict	Excellent	30	2	f	18	Freshman	Sunni	White	No	yes
Yasmine	dialog	Good	51	2.4	f	18	Freshman	Sunni	White	no	no

Note: ACORNS scores indicate understanding of evolution, GAENE scores indicate acceptance of evolution.

Table 7

Those With a Belief in the Special Creation of All Species– Relationship Between Science and Religion, Evolution Understanding, Evolution Acceptance, Religiosity, and Demographic Information

Pseudonym	Science&Religion	ACORNS	GAENE	Religiosity	Gender	Age	Year in school	Group	Race	Convert	US born
Bilal	independence	Fair	34	2.2	m	22	Junior	Sunni	A-A	no	no
Brittany	conflict	Fair	39	2.6	f	34	Junior	Sunni	A-A	Yes - Baptist	yes
Zaki	integration	Excellent	36	2.6	m	27	Sophomore	Sunni	White	no	yes
Amatullah	conflict	Good	41	2.4	f	20	Sophomore	Ahmadi	Asian	no	yes
Carlene	independence	Excellent	59	2.6	f	22	Sophomore	Sunni	Mixed	Yes - non-denom Christian	yes
Hadiyah	integration	Fair	43	2.6	f	34	Junior	Sunni	White	Yes - no religion	yes
Abeer	conflict	Fair	49	2	f	24	Junior	Sunni	White	no	no
Kareema	conflict	Good	36	2.6	f	22	Senior	Muslim	A-A	No	yes
Hakim	dialog	Fair	58	2.2	m	23	Senior	Sunni	A-A	no	yes
Hanif	integration	Fair	31	3	m	36	Sophomore	Sunni	Mixed	Yes - Catholic/ Atheist	yes
Rahima	dialog	Fair	51	3	f	22	Senior	Ahmadi	Asian	no	no
Lena	conflict	Fair	31	3	f	28	Freshman	Salafi	Mixed	no	yes
Nusaybah	no conflict	Fair	45	2.8	f	18	Freshman	Sunni	A-A	Yes - Baptist	yes
Hamid	independence	Fair	35	2.6	m	20	Senior	Sunni	White	no	yes
Masoud	no conflict	Poor	45	2.2	m	24	Senior	Sunni	A-A	no	no
Parvaneh	integration	Good	54	2.6	f	22	Senior	Shia	White	no	yes
Lubna	conflict	Good	45	2.2	f	18	Sophomore	Sunni	White	No	yes
Sayyida	conflict	Fair	33	3	f	18	Freshman	Shia	White	no	yes
Jannah	conflict	Fair	40	2.6	f	45	Junior	Muslim	White	Yes - Christian	yes
Umm Salama	integration	Good	46	2.6	f	39	Junior	Sunni	Mixed	Yes - Atheist	yes
Akilah	conflict	Excellent	53	3	f	18	Freshman	Sunni	White	No	Yes
Latifa	integration	Excellent	46	1.8	f	20	Sophomore	Ahmadi	Mixed	no	yes

Note: ACORNS scores indicate understanding of evolution, GAENE scores indicate acceptance of evolution, A-A denotes African-American

Table 8
Theistic Evolutionists – Elements of Religiosity

Pseudonym	Science & Religion	Moral Consequence	Quran literal	Ideological	Ritualistic	R import	Experiential	Intellectual	Consequential	Religiosity
Aida	integration	no	no	medium	medium	medium	low	medium	low	1.6
Rabia	integration	no	no	medium	medium	medium	medium	high	low	2
Angela	dialog	no	yes	high	medium	high	medium	medium	low	2
Cherif	integration	no	no	low	high	medium	low	high	low	1.8
Mustafa	integration	no	I don't know	high	high	high	medium	medium	low	2.2
Sauda	integration	no	yes	high	high	high	high	medium	low	2.4
James	integration	no	no	low	low	medium	low	medium	low	1.2
Habib	integration	no	no	medium	medium	medium	low	high	low	1.8
Halima	integration	no	no	medium	low	medium	medium	high	low	1.8
Abbas	independence	no	no	high	medium	high	high	medium	low	2.2
Kohinoor	dialog	no, but social a-	no	high	medium	medium	medium	high	low	2.2
Naima	integration	a+ r-	no	high	medium	low	medium	high	low	2.2
Ali	integration	generational issues	no	high	medium	high	high	high	low	2.4
Nadira	dialog	a+	no	high	high	high	high	high	medium	2.8
Nasir	integration	a+	yes	medium	medium	medium	medium	high	low	2
Samra	integration	no	yes	high	high	high	high	high	medium	2.8
Sana	integration	r-	no	high	medium	high	high	high	low	2.4
Sulayman	integration	a- if no God	yes	high	high	high	high	medium	medium	2.6
Afifah	integration	no	yes	medium	medium	medium	low	high	low	1.8

Note: Moral consequences of accepting or rejecting evolution, a+ = accepting evolution leads to positive moral consequences, a- = accepting evolution leads to negative moral consequences, r- = rejecting evolution leads to negative moral consequences.

Table 9

Those With a Belief in the Special Creation of Humans – Elements of Religiosity

Pseudonym	Science & Religion	Moral Consequences	Quran literal	Ideological	Ritualistic	Ritualistic importance	Experiential	Intellectual	Consequential	Religiosity
Adam	dialog	no	no	high	high	high	high	high	low	2.6
Hasina	no conflict	no	no	medium	medium	high	medium	high	medium	2.2
Jason	integration	a- or a+	yes	high	medium	high	high	high	low	2.4
Aisha	integration	idk	no	medium	medium	high	medium	medium	medium	2
Amber	integration	no	no	medium	medium	medium	medium	medium	low	1.8
Basel	integration	no	no	high	medium	medium	high	medium	low	2.2
Salim	conflict	no, but social + or -	no	low	high	high	low	high	low	1.8
Ayyoubou	dialog	no	no	high	high	high	high	medium	high	2.8
Salma	conflict	a-	yes	high	high	high	high	medium	medium	2.6
Nabila	conflict	a- if no God	no	high	medium	high	high	medium	medium	2.4
Fatimah	integration	a- for Muslims but not in general	no	medium	high	high	medium	high	medium	2.4
Nafisa	independence	no	no	medium	high	high	low	medium	low	1.8
Rafiq	integration	a- if no God	yes	high	high	high	high	medium	low	2.4
Mariam	integration	a-		high	high	high	high	high	low	2.6
Asiya	independence	no	no	medium	medium	high	high	medium	low	2
Salahuddin	integration	a-	yes	high	high	high	medium	high	low	2.4
Yusuf	conflict	a-	no	medium	medium	high	medium	medium	high	2.2
Najila	no conflict	moral no, r-social yes	idk	medium	medium	high	high	medium	low	2
Yasmine	dialog	no	yes	high	high	high	high	medium	low	2.4

Note: Moral consequences of accepting or rejecting evolution, a+ = accepting evolution leads to positive moral consequences, a- = accepting evolution leads to negative moral consequences, r- = rejecting evolution leads to negative moral consequences.

Table 10

Those With a Belief in the Special Creation of All Species – Elements of Religiosity

Pseudonym	Science & Religion	Moral Conseqences	Quran literal	Ideological	Ritualistic	Ritualistic Importance	Experiential	Intellectual	Consequential	Religiosity
Bilal	independence	no	no	high	medium	high	medium	medium	medium	2.2
Brittany	conflict	no	yes	high	high	high	medium	high	medium	2.6
Zaki	integration	a- if no God	yes	high	high	high	medium	high	medium	2.6
Amatullah	conflict	no	no	medium	high	high	medium	high	medium	2.4
Carlene	independence	a-	both	high	medium	high	high	medium	high	2.6
Hadiyah	integration	a-	yes	high	medium	high	high	medium	high	2.6
Abeer	conflict	no (a- if humans evolved)	no	high	low	high	medium	medium	medium	2
Kareema	conflict	no personal, yes societal	no	high	medium	high	high	medium	high	2.6
Hakim	dialog	no	both	high	medium	medium	medium	medium	medium	2.2
Hanif	integration	a-	yes	high	high	high	high	high	high	3
Rahima	dialog	no	no	high	high	high	high	high	high	3
Lena	conflict	a-	yes	high	high	high	high	high	high	3
Nusaybah	no conflict	idk	no	high	high	high	high	medium	high	2.8
Hamid	independence	no	no	medium	high	high	medium	high	high	2.6
Masoud	no conflict	no	yes	medium	high	high	medium	medium	medium	2.2
Parvaneh	integration	no	no	high	high	medium	medium	high	medium	2.6
Lubna	conflict	no	yes	high	medium	medium	medium	medium	medium	2.2
Sayyida	conflict	a+ for Muslims	yes	high	high	high	high	high	high	3
Jannah	conflict	no	idk	high	high	high	medium	high	medium	2.6
Umm Salama	integration	a+ if no God	no	high	medium	high	high	high	medium	2.6
Akilah	conflict	a- if no God	yes	high	high	high	high	high	high	3
Latifa	integration	no	no	medium	medium	low	medium	medium	low	1.8

Note: Moral consequences of accepting or rejecting evolution, a+ = accepting evolution leads to positive moral consequences, a- = accepting evolution leads to negative moral consequences, r- = rejecting evolution leads to negative moral consequences.

Table 11

Theistic Evolutionists – Views of Nature of Science

Pseudo-nym	Emperical	Scientific Methods	Structure and Aim of Experi-ments	Role of Prior Expect-ations	Obser-vation	Tentative	Theories & Laws	Nature of Theories	Functions of Theories	Theory Testing	Creativity	Inference	Theory-Laden	Social & Cultural
Aida	naïve	naïve	naïve			naïve		informed	naïve	naïve	naïve	naïve	informed	naïve
Rabia	naïve	naïve	naïve		naïve	naïve	naïve	naïve		naïve	informed			naïve
Angela	informed		informed	informed	naïve	informed	naïve	naïve	informed	naïve	naïve	naïve	naïve	informed
Cherif	naïve		naïve		naïve	informed	informed	naïve	informed		informed	naïve	naïve	informed
Mustafa	informed		informed		naïve	informed	naïve	naïve			informed	informed	informed	
Sauda	naïve		naïve		naïve	naïve	naïve	naïve			naïve	naïve	naïve	
James		naïve	informed		naïve	informed	naïve	informed	informed		informed	naïve	informed	informed
Habib	naïve		naïve		naïve	informed	naïve				informed	naïve	naïve	informed
Halima	naïve	naïve	informed		naïve	informed	informed	informed	naïve	informed	naïve	informed		naïve
Abbas	naïve		naïve		naïve	informed	naïve	naïve	naïve		informed	naïve	informed	informed
Kohinoor	naïve		informed	informed	naïve	informed	naïve	naïve			informed	informed	informed	informed
Naima	naïve		naïve			naïve	naïve	naïve		naïve	naïve	naïve	naïve	naïve
Ali	naïve	naïve	naïve		naïve	informed	naïve	naïve	informed		naïve	naïve		naïve
Nadira	naïve	naïve	naïve	naïve	naïve	informed	naïve	naïve		naïve	naïve	informed	informed	informed
Nasir	naïve	naïve	naïve	naïve	naïve	informed	naïve	informed	naïve		naïve	naïve	naïve	naïve
Samra	naïve				naïve	informed	naïve		informed		naïve	naïve	informed	naïve
Sana	naïve		naïve	informed	naïve	informed	naïve	informed		naïve	informed	naïve	naïve	naïve
Sulayman	naïve	informed	informed		informed	informed	informed	naïve	naïve		naïve	naïve	naïve	naïve
Afifah	naïve	informed	naïve		informed	informed	naïve	naïve			naïve	naïve	informed	naïve

Table 12
Those With a Belief in the Special Creation of Humans – Views of Nature of Science

Pseudonym	Emperical	Scientific Methods	Structure and Aim of Experi-ments	Role of Prior Expect-ations	Obser-vation	Tentative	Theories & Laws	Nature of Theories	Functions of Theories	Theory Testing	Creativity	Inference	Theory-laden	Social & Cultural
Adam			naïve	informed	naïve	informed	naïve	naïve	naïve			naïve	informed	informed
Hasina	naïve		naïve		naïve	naïve	naïve	naïve		naïve	naïve	naïve	informed	naïve
Jason				informed	naïve	informed				naïve	naïve		naïve	informed
Aisha	naïve		informed		naïve		naïve	naïve		naïve	naïve	naïve	naïve	naïve
Amber	naïve		naïve		naïve		naïve	informed			naïve	naïve	naïve	informed
Basel	naïve		naïve		naïve	naïve	naïve	naïve	naïve		naïve	naïve	naïve	informed
Salim	naïve				naïve	informed	naïve	naïve		informed	informed	naïve	naïve	naïve
Ayyoubou	naïve				naïve	naïve	naïve				informed	naïve		naïve
Salma	naïve		naïve		naïve	naïve		naïve			naïve	naïve	naïve	
Nabila			naïve		naïve	informed	naïve	naïve			naïve	naïve	naïve	naïve
Fatimah	naïve		naïve		naïve	naïve	naïve	naïve	informed		naïve	naïve	naïve	naïve
Nafisa	naïve		naïve		naïve	naïve	naïve	naïve	naïve		informed	naïve	informed	naïve
Rafiq	naïve		naïve	naïve	naïve	informed	naïve		naïve		naïve	naïve	naïve	naïve
Mariam	naïve	naïve	naïve		naïve	naïve	informed	informed		naïve	naïve	naïve	informed	naïve
Asiya	naïve		informed	informed	naïve	informed	naïve				informed	naïve	naïve	naïve
Salahuddin	naïve		naïve	informed	naïve	naïve	naïve	informed			naïve	naïve	informed	informed
Yusuf	naïve		naïve		naïve	naïve	naïve	naïve			naïve	naïve	naïve	naïve
Najila	naïve	naïve	naïve		naïve	naïve	naïve	naïve	naïve		naïve	naïve	informed	naïve
Yasmine	informed	informed			informed	informed	informed	informed		informed	informed	informed	informed	informed

Table 13

Those With a Belief in the Special Creation of All Species – Views of Nature of Science

Pseudonym	Emperical	Scientific Methods	Structure and Aim of Experi-ments	Role of Prior Expect-ations	Obser-vation	Tentative	Theories & Laws	Nature of Theories	Functions of Theories	Theory Testing	Creativity	Inference	Theory-laden	Social & Cultural
Bilal	naïve		informed	informed	informed	informed	naïve	naïve			naïve	informed	naïve	naïve
Brittany	naïve	naïve	naïve		naïve	informed	naïve	naïve	naïve	naïve	informed	naïve	informed	naïve
Zaki	naïve		naïve		naïve	informed			naïve		informed	naïve	informed	informed
Amatullah	naïve		naïve		naïve	naïve	naïve	naïve		naïve	naïve	naïve	naïve	naïve
Carlene	naïve	naïve	informed		naïve	informed	naïve	naïve	naïve	naïve	naïve	naïve	naïve	informed
Hadiyah	naïve		informed		naïve	informed	naïve	naïve			naïve	naïve	naïve	informed
Abeer	naïve		naïve		naïve	informed	naïve	naïve	naïve		naïve	naïve	naïve	naïve
Kareema	naïve		naïve		naïve	naïve	naïve	informed	informed	naïve	naïve	informed	naïve	naïve
Hakim	informed				naïve	informed	naïve	informed	naïve		informed	naïve	naïve	informed
Hanif	naïve	naïve	informed		naïve	informed	naïve	naïve	informed	naïve	informed	naïve	informed	informed
Rahima	naïve	naïve	naïve		naïve	informed	naïve	naïve			informed	naïve	informed	informed
Lena	naïve			naïve		naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve
Nusaybah	naïve	naïve	naïve		naïve						naïve			
Hamid	naïve				informed	informed	naïve	informed		naïve	naïve	naïve	naïve	informed
Masoud	naïve		naïve		naïve				naïve		informed	naïve	naïve	informed
Parvaneh			naïve		naïve	naïve		informed		naïve	informed	informed	naïve	informed
Lubna	naïve		naïve		naïve	naïve	naïve	naïve		naïve	naïve	naïve	naïve	naïve
Sayyida	naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve	naïve	informed	naïve
Jannah	naïve		naïve		naïve	informed	naïve	naïve		naïve	naïve	naïve	naïve	informed
Umm Salama	naïve	naïve	naïve	naïve	informed	informed	naïve	naïve	naïve		informed	naïve	informed	informed
Akilah	naïve				naïve	informed	naïve	naïve			naïve	naïve	naïve	naïve
Latifa	naïve		informed			informed	naïve	naïve	informed		naïve	naïve	informed	naïve

Khadija Engelbrecht Fouad
Curriculum Vitae

Education and Certifications

Ph.D. Curriculum and Instruction for Science Education
Minor History and Philosophy of Science
Indiana University, Bloomington, IN. May, 2016.

Certification in Secondary Science
Southeast Missouri State University, Cape Girardeau, MO. 1997

Ph.D. candidate Microbiology
Minor biochemistry
Purdue University, W. Lafayette, IN. 1994

M. A. Microbiology
Indiana University, Bloomington, IN. 1989

B. A. Biology
Minor African and African-American Studies
Earlham College, Richmond, IN. 1981

Certifications
Kentucky State Secondary Biology and Chemistry, 1998-2013 and current.
Missouri Teacher's Certificate for Biology and General Science 1997-2000.
College Board AP Biology and Chemistry
Adult and Child CPR and First Aid

Teaching Experience

Universal Muslim Academy
Teacher, 2014-current**.**
Cincinnati, OH
- 4^{th} and 5^{th} grade

Indiana University
Associate Instructor, School of Education, 2010-2014**.**
Bloomington, IN
- Classroom Management, Secondary Science Field Experience – teacher of record
- Early Field Experience for Math and Science, , Introduction to Inquiry, Secondary Science Methods, Methods of Teaching Secondary and Middle School Science

St. Catharine College

Lecturer, 2008-2009.
St. Catharine, KY

- Summer sessions in chemistry for non-majors and pre-nursing students

Nur Islamic School of Louisville

Teacher, 2008 – 2010**.**
Louisville, KY

- Middle school and elementary science, elementary social studies, language arts, and Islamic studies

Administrator, 2008 – 2010**.**

- Teacher development, school improvement

Islamic School of Louisville

Teacher, 2007-2008**.**
Louisville, KY

- Middle school and elementary science, middle school social studies and language arts

Administrator, 2007**.**

- Teacher development

Jeffersontown High School

Science Teacher, 2006 to 2007**.**
Louisville, KY

- Freshmen Biology, Study Hall

Iroquois High School

Science Teacher, 1999 to 2006**.**
Louisville, KY

- College Board Advanced Placement Biology, Honors Biology, Biology, Repeater Biology, Anatomy and Physiology, Environmental Biology, Integrated Science, College Board Advanced Placement Chemistry, Honors Chemistry, Chemistry, and Physics

Science Department Chair, 2002-2006**.**

- Teacher development, equipment and supply management, curriculum development

Western High School

Science Teacher, 1998 to 1999**.**
Louisville, KY

- Integrated Science, Chemistry, Honors Physics

Jefferson County Public Schools and Louisville Islamic Schools

Quick Recall Coach, 1998-2006, 2008-2010
Louisville, KY

- Public schools
- Islamic schools

Couch High School

Science teacher, 1997 to 1998
Myrtle, MO

- Biology, Exploratory Biology, Advanced Biology, Anatomy and Physiology, Chemistry, Physical Science
- Served on Health, Library, and Educational Climate committees
- Math and Science Club sponsor

Charleston High School

Student Teacher, Spring, 1997**.**
Charlestown, MO

- General Biology, Sophomore Biology, Advanced Biology

Project Upward Bound

Instructor and Tutor of Natural Sciences, 1995-96**.**
Cape Girardeau, MO

- Biology, Anatomy and Physiology, Chemistry, Physics

Southeast Missouri State University

Assistant Professor, Biology Department, 1994-1995**.**
Cape Girardeau, MO

- Microbiology Lecture, Microbiology Laboratory, Readings in Biology, Biological Research

Purdue University

Teaching Assistant, Biology Department, 1989 to 1994**.**
West Lafayette, IN

- Development, Structure, and Function Lecture
- Laboratory in Microbiology and Laboratory in Developmental Biology
- Biology of Animals
- Diversity, Ecology, and Behavior Laboratory

Indiana University

Associate Instructor, Biology Department, 1984 to 1986**.**
Bloomington, IN

- Microbiology Laboratory
- Introductory Biology Laboratory, Biological Science for Elementary Teachers Laboratory, Biology of the Prokaryotes Laboratory, and Developmental Biology Laboratory

Professional Development

Islamic School of Louisville and Nur Islamic School of Louisville

Professional Development and Volunteer, 1999 to present**.**
Louisville, KY

- Inquiry learning, Nature of science, Science demonstrations, Lesson planning, Long-range planning, Aligning lessons with standards

Al-Rahmah School and Lexington Universal Academy

Professional development, 2014**.**
Distance learning

- Inquiry learning, Nature of science, History of science, Lesson planning

Publications

Fouad, K. E., Wiebke, H. L., & Akerson, V. L. (2015). Using history of science to teach the nature of science to elementary students. *Science & Education, 24*, 1103-1140. DOI: 10.1007/s11191-015-9783-5

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Fouad, K. E. & G. D. Hegeman. 1993. Microbial spoilage of tofu (soybean curd). *Journal of Food Protection, 56,* 157-164.

Presentations

Fouad, K. E. (2016, April). *American Muslim undergraduates' views on evolution.* Poster presented at NARST - A worldwide organization for improving science teaching and learning International Conference, Baltimore, MD.

Fouad, K. E. (2016, April). *Views of Muslim undergraduate rejecters of evolution – implications for teaching evolution to Muslim students.* Paper presented at American Educational Research Association, Washington, DC.

Fouad, K. E. (2016, April). *Belief in the special creation of humans as a means to reconcile scientific evidence with religious belief.* Paper presented at Midwest American Academy of Religion Conference, Muncie, IN.

Fouad, K. E. (2015, April). *Compatibility of science and religion in the modern world in the context of biological evolution*. Presented at Midwest Association for Middle East and Islamic Studies Conference, Louisville, KY.

Fouad, K. E. (2015, April). *American Muslim undergraduate students' views on evolution*. Presented at Midwest American Academy of Religion Conference, Ada, OH.

Fouad, K. E. (2015, February). *American Muslim undergraduates' views on evolution*. Presented at Curriculum and Instruction Research and Creative Activity Symposium, Indiana University, Bloomington, IN.

Fouad, K. E. (2015, February). *OK! Nobody wants two minutes! You're not going to get anyone with an hour! Using the pilot study to improve interview instruments*. Presented at Science Education Research Symposium, Indiana University, Bloomington, IN.

Avsar Erumit, B. & Fouad, K. E. (2014, February). *The effect of learner-directed scientific investigations on students' questionings and their nature of science views*. Paper presented at the Hoosier Association of Science Teachers, Inc. Conference, Indianapolis, IN.

Fouad, K. E. (2014, February). *Muslim students' and teachers' views on evolution: A review*. Poster presented at Curriculum and Instruction Research and Creative Activity Symposium, Indiana University, Bloomington, IN.

Fouad, K. E. (2014, March). *Muslim students' and teachers' views on evolution: A review*. Poster presented at NARST - A worldwide organization for improving science teaching and learning International Conference, Pittsburgh, PA.

Avsar Erumit, B. & Fouad, K. E. (2014, April). *Science inquiry workshop*. Paper presented at 15th Annual Islamic Society of North America Education Forum, Rosemont, IL.

Fouad, K. E. (2014, April). *Biological evolution: Wading into the controversy — Strategies for teaching Muslim students and Islamizing lessons*. Paper presented at 15th Annual Islamic Society of North America Education Forum, Rosemont, IL.

Fouad, K. E. (2013, June). *Using history of science to teach nature of science – Extending its use to include elementary students.* Paper presented at the 12th biennial International History, Philosophy, and Science Teaching conference, Pittsburgh, PA.

Fouad, K. E. (2013, April). *Making history come alive to Islamize science lessons*. Paper presented at 15th Annual Islamic Society of North America Education Forum, Rosemont, IL.

Fouad, K. E. (2013, February). *Eureka! Make history of science come alive to make nature of science connections*, Hoosier Association of Science Teachers, Inc. Conference, Indianapolis, IN.

Buck, G., Avsar Erumit, B., Harris, T. A., Erumit, S., Fouad, K. E., & Mills, M. (2013, February*). Is There an App for That? Scientific Inquiry Enhanced by Smartphones and Electronic Tablets*, Hoosier Association of Science Teachers, Inc. Conference, Indianapolis, IN.

Fouad, K. E. (2013, February). *An instrument to elucidate teaching orientations towards nature of science – Preliminary findings*. Presented at Science Education Research Symposium, Indiana University, Bloomington, IN.

Fouad, K. E., Wiebke, H., & Akerson, V. L. (2012, March). *Using the history of science to teach the nature of science to elementary students*. NARST - A worldwide organization for improving science teaching and learning International Conference, Indianapolis, IN.

Fouad, K. E., Wiebke, H., & Akerson, V. L. (2012, February). *Using the history of science to teach the nature of science to elementary students.* Paper presented at Curriculum and Instruction Research and Creative Activity Symposium, Indiana University, Bloomington, IN.

Fouad, K. E. (2007, August). *Effective science teaching with an Islamic perspective: Creating creative lesson plans*. Workshop presented at Lexington Universal Academy Staff Development Conference, Lexington, KY.

Dunn, T., Kaelin, N., & Fouad, K. E. (2004, July). *Effective data-driven management system guides instruction and learning*. Presented at High Schools That Work Staff Development Conference, Atlanta, GA.

Simpson, J., Addington, T., Fouad, K. E, & Overman, S. R. (1995, April). Identification of bacterial genera in solid waste composting at mesophilic and thermophilic temperatures. Presented by Jennifer Simpson and Tiffani Addington at the Student Research Conference, Southeast Missouri State University, Cape Girardeau, MO.

Fouad, K. E. (1989). *Tofu and its place in developing nations*. Presentation and panel discussion on High Technology Food Sciences for Developing Nations at conference on Technology Transfer to Developing Nations, Association of Muslim Scientists and Engineers, Purdue University, West Lafayette, IN.

Honors

Jhumki Basu Scholar Award 2015
Faculty Doctoral Fellowship Indiana University, 2010-2014
E. Wayne Gross Fellowship Indiana University, 2012, 2014
Daisy Jones Fellowship, Indiana University 2012-2014
Southeast Missouri State University Dean's List, 1996-1997
Floyd Fellowship, Indiana University 1985-1986.
Hoosier Scholarship, 1977-1981.
Earlham Alumni Scholarship, 1977-81
National Merit Scholar, 1977

Grants

School to Community Grant, 1999-2001.
Southeast Missouri State University Grants and Research Funding Committee grant, 1995-96.
Purdue Research Foundation summer grant, 1990, 1992, 1993.

Professional Affiliations

American Educational Research Association, member 2015 to present.
National Association for Research in Science Teaching, member 2010 to present.
National Science Teachers Association, member 1997 to present.
History of Science Society, member 2012 to present
American Academy of Religion, member 2010 to present
National Education Association, member 1998 to 2008, delegate, 2006.
Kentucky Education Association, member 1998 to 2008, delegate 2004, 2005, 2007.
Jefferson County Teachers Association, member 1998 to 2007.
Louisville Area Chemistry Alliance, member, 1999 to 2010.
Biology Alliance, member, 2005 to 2010.
Missouri State Teachers Association, member, 1997 to 1998.

Activities

Science & Education reviewer, 2015 to present.
Midwestern Regional Comparative and International Education Society conference planning committee, 2014
Salt River Water Watch volunteer, 2000 to 2010.
Boy Scouts of America volunteer, 1999 to 2010.
Graduate Student Representative, Purdue University, 1991-92.
Muslim Women's Study Group Vice-president, Purdue, 1992-1993.
Women's Center Coordinator, Earlham College, 1980-81.
WECI college radio station disc jockey, Richmond, 1977-81.
Women's Track and Field Team shot put, Earlham College 1980-81.