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Selection Perception: Views on the Theory of Evolution Among Residents of Moshi, Tanzania

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SIT Study Abroad

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Abstract

The theory of evolution is a major tenet of biological science and has many practical applications, particularly in agriculture, medicine, and conservation. Nevertheless, there is significant opposition to the theory and its incorporation into school curricula, largely on religious grounds. This disconnect between public opinion and scientific opinion has been studied at length in the US and to some extent in other industrialized nations, but little is known about the issue in other communities around the world. This paper will use the town of Moshi, Tanzania as a case study in community views and knowledge about the theory of evolution. Information will be primarily gathered from questionnaires and interviews with participants from a range of age groups and education levels. The analysis will look for overall trends and correlations between demographic info and responses to questions on evolutionary topics.

Keywords

evolution, Moshi, community views, religion, education

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Introduction

The theory of evolution by natural selection was formulated by British scientist Charles Darwin in his famous 1959 book, *On the Origin of Species.* In the 1940s, Darwin's evidence was combined with Mendel's genetics experiments to form the "Modern Synthesis" (MS). This synthesis has 3 major tenets: 1) There is variation in heritable traits among individuals in a population, 2) competition arises because of limited resources, causing the individuals with the most adaptive traits to have a greater chance of survival and reproduction, and 3) the genes contributing to greater fitness are passed on to the next generation, which changes the frequencies of traits in the population over successive generations (Starr et al. 2011). There are several lines of evidence that support the theory. First, the fossil record shows the transition of ancestral organisms through intermediate forms to modern organisms. Second, biogeography shows that more closely related species are generally found in spatially adjacent areas, while geographical barriers tend to promote the generation of new species. Third, comparative anatomy shows that closely related species share similar features that provide differing functions through slight modifications to the ancestral form. Fourth, for thousands of years, humans have selectively bred desirable traits in organisms to create new species of domesticated plants and animals, artificially modelling the process of selection in nature. Lastly, recent advances in molecular genetics and epigenetics have increased the robustness and complexity of evolutionary theory in what has now been called the "Extended Evolutionary Synthesis" (Pigliucci 2009).

The theory of evolution is supported by a majority of scientists and is seen as a major unifying theme in biology by notable scientific bodies including the National Research Council, American Association for the Advancement of Science, and the National Academy of Sciences (National Academy of Sciences 1998). Despite the widespread consensus in the scientific community and whole departments of evolutionary biology in many universities, there is still significant opposition to the theory of evolution among the broader public, largely attributable to religious opposition (Masci 2017). It is a common misconception that evolution and religion have always been at odds. In reality, many prominent religious philosophers theorized on evolution before Darwin, including St. Augustine of Hippo and Thomas Aquinas (Bowler 2009). After Darwin, "With but few exceptions the leading Christian thinkers in Great Britain and America came to terms quite readily with Darwinism and evolution"(Alexander 2014). The religion-evolution dichotomy is largely a product of the politicization of the issue starting in the 20th century US, making national news in the Scopes Monkey Trial (Bowler 2009). The term

"Creationism" came about during this era of debate to describe a spectrum of beliefs in opposition to evolutionary theory that have a basis in religion (Brosseau and Silberstein 2015).

The two most widespread religions in the world are Christianity and Islam, accounting for a combined 55.2% of people (Hackett and Stonawski 2017). This is important because cross-comparative studies of religion in the US have shown that Christians and Muslims are much more likely to oppose the theory of evolution than members of the other major religions (Hinduism, Buddhism, Judaism, and Unaffiliated) (Masci 2017). The reason for this conflict can largely be traced to the creation myths of the two religions. The Christian creation myth relates that God made the world in six days, creating in sequence: light and darkness; sky; land, seas, and plants; sun, moon, and stars; aquatic and aerial animals; and land animals and humans (Gen. 1:1-30 GNT). The literal interpretation of Genesis thus conflicts with evolutionary theory in several ways. First, if all life on earth was created in the span of four days then it can't have evolved over billions of years and no new species can arise after the initial creation. This includes "all kinds of animal life: domestic and wild" (Gen. 1:25) contradicting the idea that humans created new domesticated species by artificially selecting desirable traits in their wild ancestors. In Islam, it is also believed that the world was created in six "days"; however, these days are generally interpreted as six ambiguous eras and the divine acts of creation are not laid out in chronological order (Huda 2018). God (Allah) is said to have created all life from water (Sura An-Noor 24:45), with humans specially created as God's vicegerents on Earth (Surah al-An'am, 6:165). While many articles argue that Islam is less in conflict with evolutionary theory than Christianity, many Muslims still oppose it because they believe it challenges God's role in human creation and the diversification of life on Earth.

This evolution-creationism controversy deserves attention because evolutionary theory not only provides a basis for the rest of biology, but it has also had important practical applications. For example, evolutionary biology has helped conserve endangered species by highlighting the importance of preserving not just population numbers, but the evolutionary potential of the population in the form of genetic diversity. It has also helped slow the overuse of antibiotics and pesticides by explaining the evolution of resistance in pathogen and pest populations (National Academy of Sciences 1998, Caldwell et al. 2004). However, the potential for future applications depends on wider acceptance of this field of science, prompting investigations into the specific causes of opposition.

Due to the prevalence of Christian fundamentalists, politicization by conservatives, and discourse about separation of church and state, the most vocal creationists are from the United States and creationist ideas are more widespread in the US than almost every other industrialized country (Owen 2006). Consequently, perceptions on evolution have been studied most extensively in the US and to some extent in Europe to provide a contrast because Europeans believe in evolution more than Americans on average (Owen 2006). Led by the Pew Research Center, this research has revealed that an average of 33% of Americans believe humans have evolved due to natural processes (See Appendix IV). Belief in evolution declines with age and religiosity (with the lowest level among Evangelical Protestants, Mormons, and Jehovah's Witnesses); it increases with level of education, science knowledge, and political liberalism (Funk and Rainie 2015). Beyond these demographic trends, several studies describe how high school and college students may dismiss evolutionary theory due to a misunderstanding of the nature of science and scientific evidence (Hokayem and BouJaoude 2008, Dagher and Boujaoude 2005, Sinatra et al. 2003, Woods and Scharmann 2001).

In contrast, there is a dearth of research on the belief in evolutionary theory in other regions of the world. One published survey was conducted in Latin America, which found that among 18 countries and one territory, the belief that "humans have always existed in their present form" ranged from a low of 20% in Uruguay to a high of 56% in the Dominican Republic (See Appendix IV) (Bell and Sahgal 2014). In these countries, Catholics on average believed in human evolution more than Protestants. Another questionnaire was conducted among Muslims in a total of 22 Muslim-majority countries across Eastern Europe, Asia, Tunisia, and Morocco (See Appendix IV). This study found that the belief that humans have always existed in their present form ranged from a low of 16% in Kazakhstan to a high of 67% in Iraq (Bell 2013). The only other research done on the topic in African countries comes from South Africa. With a strong Calvinist tradition, this country historically had an official anti-evolution curriculum and still supports a large creationist community (Retief 2008). One poll found that 43% of South Africans believe that "God created life in its present form" (New Scientist 2009). Qualitatively, Pentecostal churches throughout Africa openly oppose the theory of evolution and it has been suggested that high levels of religiosity and belief that the theory of evolution is a Western import have hindered its adoption in Africa (Pelz 2018). This research gap is ironic given that the continent has supported such a plethora of scientific research on human evolution because the most widely accepted model of human origins is the "Out of Africa Theory" (Liu et al. 2006). This theory

posits that anatomically modern *Homo sapiens* evolved in Africa and then dispersed to the other continents; it is supported by the genetic tracing of the matrilineal and patrilinear most recent common ancestors of all humans, or "Mitochondrial Eve" and "Y-Chromosomal Adam", to East Africa (Gibbons 1997). And yet, little is known about how Africans themselves think about Eve, Adam, and human evolution.

This issue is particularly interesting to examine in Tanzania for several reasons. First, Tanzania hosts Olduvai Gorge, called the "Cradle of Mankind" because of the famous archeological discoveries of early hominins in this area (Ngorongoro Conservation Area Authority). Common English-language biology (Starr et al. 2011, 455) and paleoanthropology (Larsen 2016, 242-303) textbooks mention this famous site when explaining human evolution. Second, the previously discussed literature suggests a strong link between religious and evolutionary beliefs and Tanzania is a very religious country, with 61.4% identifying as Christian, 35.2% Muslim, and only 1.4% unaffiliated (Hackett 2015). Sending children to religious schools has also been increasingly popular in the last decade (Dilger 2013). This trend may impact the teaching of scientific concepts thought to conflict with religious teachings.

Preliminary talks with graduates and professors from Mweka College of African Wildlife Management revealed that students learn basic evolutionary concepts in primary school history, but they are taught only the simplistic and somewhat misleading idea that humans evolved from monkeys. In addition, an interview with a man from Old Moshi during the pilot period revealed a lack of knowledge about even the existence of extinct animals like dinosaurs. As a consequence, his beliefs about living things contrasted quite starkly with those of the Mweka professors. Lastly, the results from only 5 pilot questionnaires among Moshi residents revealed a wide diversity of ideas and divergence from the consensus of the scientific community.

This objective of this study is to determine the degree of knowledge and perceptions about the theory of evolution by natural selection among residents of Moshi, Tanzania. More specifically, the study will investigate 1) whether there is a correlation between belief in evolution and religion, age, or education, 2) whether beliefs are consistent between humans and other living things, 3) the differences between evolutionary beliefs in Moshi and other locations that have been previously studied 4) the frameworks that people use to understand some of the common applications of evolutionary theory, and 5) the level of familiarity that people have with the various lines of evidence for evolution. Based on comparative data discussed above and results from the pilot work, the corresponding hypotheses are that 1) belief in evolution by natural

selection will be lowest among Protestant Christians, the elderly, and the least educated, 2) there will be less support for the idea that humans evolved compared with the idea that other living things evolved, 3) average belief in evolution by natural selection will be lower in Moshi than the average in the US, Western Europe, Latin America, and Muslim-Majority countries, 4) the majority of people do not think of the impacts of pesticides and antibiotics in an evolutionary framework, and 5) the majority of people are unfamiliar with the evidence for evolution. The following sections of this paper will cover the study's methods, results, discussion, conclusion, bibliography, and appendices.

Methods

Study Area

This study was conducted in Moshi, a town in the Kilimanjaro region of Tanzania with a population of about 202,000 people and an area of 58 km^2 (Moshi Municipal Council). The region supports coffee, maize, and bean agriculture, manufacturing industries, and cultural and natural tourism. It is a good candidate town for this study because it has both aspects of an urban area (i.e. markets, colleges) and rural area (i.e. farms), which was expected to increase the diversity of opinions gathered. In addition, Tanzanians throughout northern Tanzania send their children to schools in the Kilimanjaro region and Moshi in particular because of its many highly reputable private schools (C. Hearch, personal communication, 2017). This means that students in Moshi schools are more likely to come from a diversity of areas and there will be more residents of Moshi with post-primary education levels.

See Appendix I for all locations visited in this study. Moshi Urban district is outlined in green, red pins are villages/towns, and blue icons are schools/buildings. Old Moshi, Machame, and Mweka are villages on the edge of Mt. Kilimanjaro. They each contain several sub-villages. Rau and Majengo are villages within Moshi Urban. Moshi town in central Moshi Urban is the most urbanized area that includes a bus station, restaurants, banks, and hotels. Mweka College of African Wildlife Management is a vocational training college that awards certificates, bachelor's degrees, and graduate degrees in either wildlife management or wildlife tourism. It was included in the study because of its emphasis on biology education. Udzungwa Mountains College Trust awards certificates in tourism. It was chosen as a representative of a technical school between secondary level and bachelor's degree level. Nsoo Secondary School is a private co-educational, primarily boarding school owned by the Catholic Diocese and located in Mweka village. In 2017,

124 students sat the Ordinary (O)-level national exams, attaining a ranking of 527/5851 (SaaHiiHii 2017c). Majengo Secondary School is a private co-educational school in Moshi Urban with. In 2017, 394 students sat the O-level exams, attaining a ranking of 672/5851 and 849 students sat the Advanced (A)-level exams, attaining a ranking of 530/830 (SaaHiiHii 2017a). Old Moshi Secondary School is an all-boys public school in Moshi Urban. In 2017, 94 students sat the O-level exams, attaining a ranking of 656/5851, and 259 students sat the A-level exams, attaining a ranking of 264/830 (SaaHiiHii 2017b). These three schools were purposely chosen as a representation of the three common types of secondary schools found in Moshi – religious, private, and public.

Experimental Design

The largest component of this study was the distribution of questionnaires consisting of 18 questions written in both English and Kiswahili (See Appendix II). Apart from basic demographic information, the questions were based on input from the pilot work, personal experience, and Pew Research Center surveys on the same topic. The lattermost was important to allow for cross-locational comparisons in the analysis. Questionnaires were distributed in four areas of Moshi: 1) Old Moshi (n=50), 2) Machame (n=27), 3) Mweka (n=26), and 4) Moshi Urban – Town Center, Rau, and Majengo (n=58) for a total sample size of 161. This created a 36% urban, 64% rural distribution, designed to approximate the nationwide statistics of 32% urban and 68% rural. In order to partially prevent the bias of excluding illiterate people, 12 questionnaires were completed verbally. Participants were chosen in a nonrandom manner based on availability to participate and intentional effort to get a spread of genders and ages.

In addition, interviews were conducted with key informants in order to gather more specific information about the teaching of evolution and interacting religious views. These consisted of two Lutheran pastors in Old Moshi, Rasta in Moshi town, Muslim Mullah in Rau, introductory biology lecturer at Mweka College of African Wildlife Management, lecturer at Udzungwa Mountains College Trust, and five secondary school history and/or biology teachers at Nsoo Secondary School (n=2), Old Moshi Secondary School (n=2), and Majengo Secondary School (n=1).

Supplemental information about the educational materials on evolution present in Tanzania was gathered in-person visits to Arusha's National Natural History (German Boma) Museum (NNHM) and Ngorongo's Olduvai Gorge Museum (OGM); secondhand research was also

gathered on the Dar es Salaam National Museum (DSNM). School curricula and textbooks in biology or history were also viewed when possible.

To get a comparative sample of views from foreign students and workers in Tanzania, questionnaires were distributed to SIT students (n=14) and KiliHub workers (n=2) for a total sample of size of 16. This sample was not designed to be representative of non-Tanzanians or of Americans. Rather, it was included to provide a snapshot of the contrasting views between Tanzanian residents and the foreigners they may be working or interacting with. The sample is skewed towards people studying biology, which makes sense given that many foreign workers in Tanzania come to study biological topics in the country's famous protected areas.

All data were collected between April 11, 2018 and April 27, 2018.

Data Analysis

Notes from the interviews were either directly typed into Word or typed later from handwritten notes. Data from the questionnaires were inputted into an Excel spreadsheet. Formulas were used to count frequencies and percentages for all letter choices. Any edits made to original data for the purposes of standardization or increased accuracy were recorded in the "Notes" column. Statistical tests were conducted with SAS ® University Edition software. Chi-square tests were conducted to test the significance of relationships between two categorical variables. Quantitative variables were created by coding for aggregate variables of letter-to-score values, as delineated in the Results section. Pearson's correlations were used to test the significance of relationships between two quantitative variables, and ANOVA was used for relationships between one or more categorical variables and a quantitative variable.

Ethics

All questionnaires and interviews were conducted anonymously and with full consent. The introductory paragraph of the questionnaire included a statement of consent and anonymity (See Appendix II). Interviewees were also given a consent form to read and sign (or if they were illiterate, they were read the contents of the form). For secondary school students under the age of 18, the headmaster signed the consent form as proxy.

This study was sensitive to the differing views held by members of the communities in which it was conducted in that my own views were not shared unless specifically questioned about them. In responding, I always used statements of personal belief and not fact. When appropriate,

participants were also reassured that the questionnaires were intended to reflect beliefs and not correctness of knowledge. Interviewees were given the chance to ask me any questions they had for me at the end of the interview. The study aims to enhance these communities by increasing awareness of the diversity of beliefs about evolution and by improving education about this important scientific topic.

Results

Demographics

The gender distribution was 62% Men and 38% Women. The religious distribution was 53% Protestant, 39% Roman Catholic, 6.8% Muslim, 1.8% Unaffiliated, Irreligious & Other. The most common occupations were student (42%), farmer (14%), businessperson (12%). Figures 1 and 2 show the age and education distributions of participants.

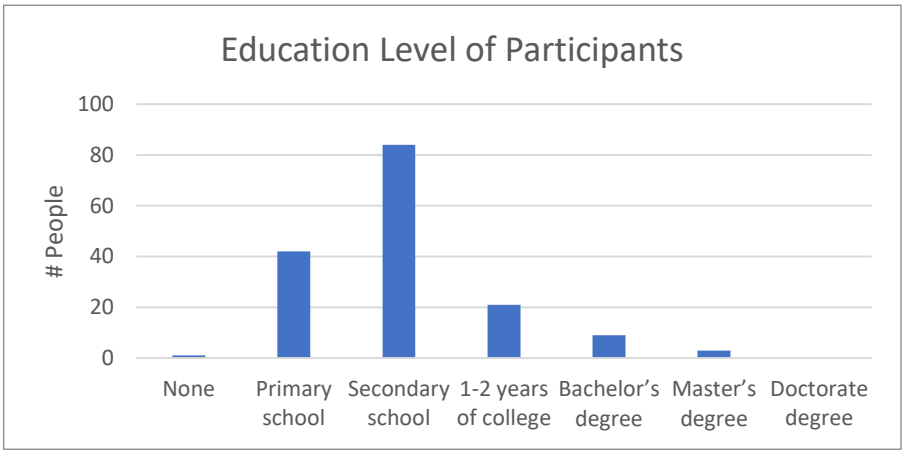

Figure 1: Education level distribution of participants

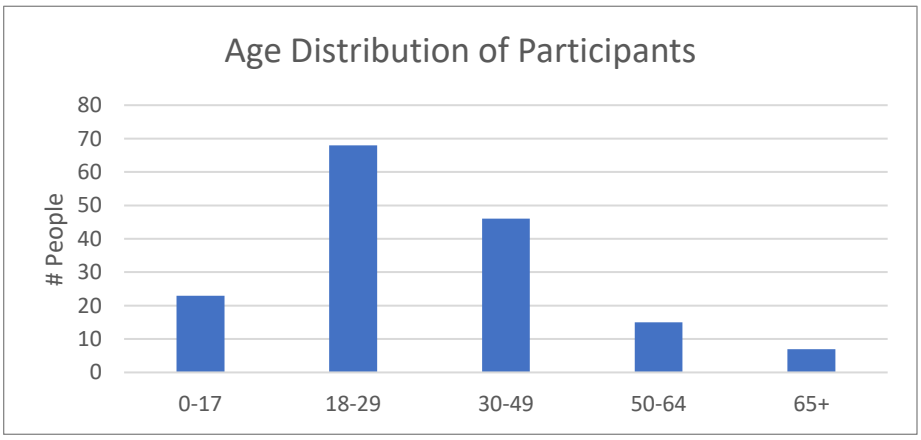

Figure 2: Age distribution of participants

Hypothesis 1

Evolutionary belief ('SumEvo') was operationally defined as the sum of the ranked values for questions 7,8,9, 13, and 14, related to human evolution, plant/animal evolution, human ancestors, adaptation, and the gradualness of creation (See Appendix III for individual frequency distributions). Based on a Pearson's correlation between age and evolutionary belief, the study failed to reject the null hypothesis that there is no association between age and evolutionary belief (p=0.74, Figure 3). Based on a one-way ANOVA on evolutionary belief and religion, the study also failed to reject the null hypothesis that there is no association between religion and evolutionary belief (p=0.80, Figure 4). The education factor of Hypothesis 1 was tested in three different ways: education level, type of educational institution attended (public vs. private), and language preference (English vs. Kiswahili) because English tends to be used more often in the upper levels of the Tanzanian educational system. One-way ANOVAs revealed a significant effect of education level on evolutionary belief (F=3.48, p=0.0054, Figure 5), but no effect of education type (p=0.23) or language (p=0.66).

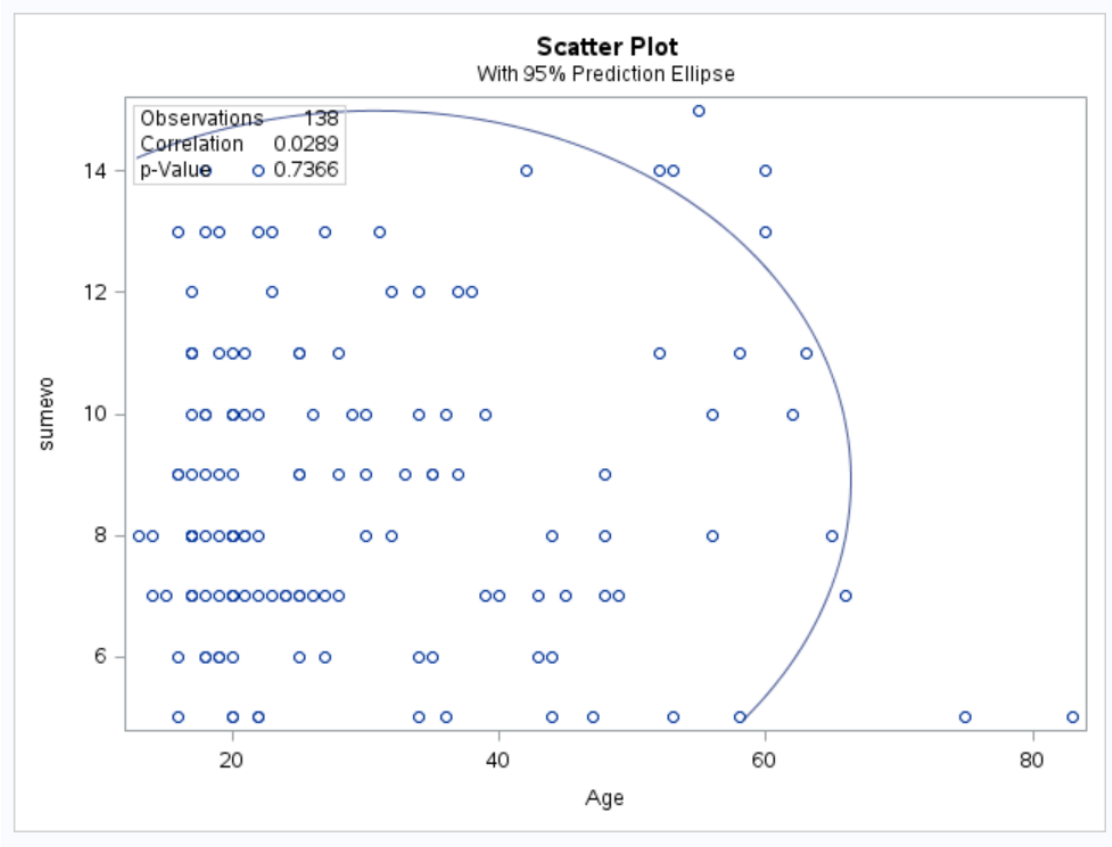

Figure 3: Scatter plot of evolutionary belief by age

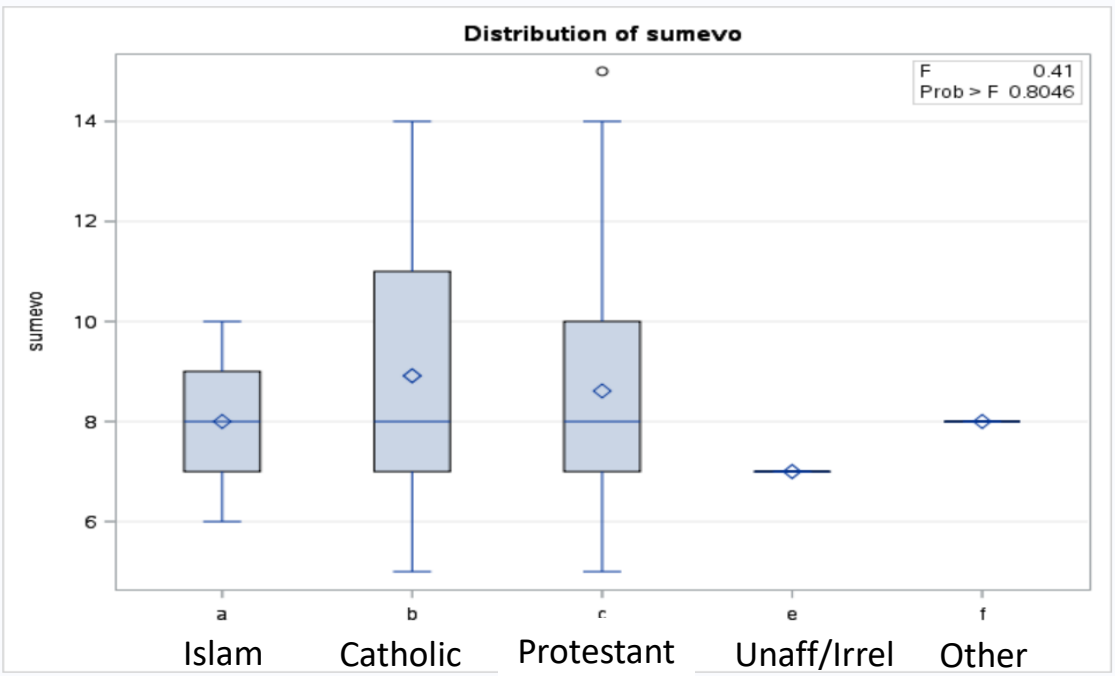

Figure 4: Box-and-whisker plot (diamond = mean, line = mean, box = upper and lower quartiles) of evolutionary belief by religion

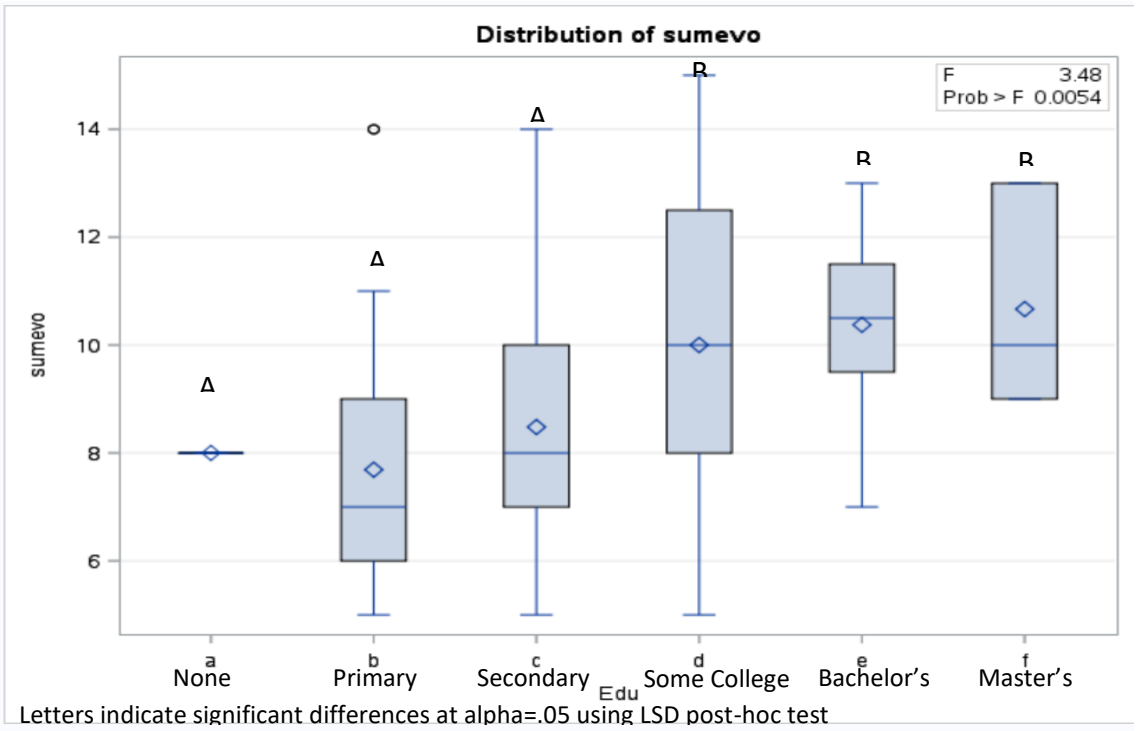

Figure 5: Box-and-whisker plot of evolutionary belief by education level showing results of ANOVA with LSD post-hoc analysis

Hypothesis 2

The study failed to reject the null hypothesis that there is no significant difference between belief in the evolution of humans and belief in the evolution of plants and animals**.** The first way this hypothesis was tested was by determining if there were any differences between the average responses to each of the three identical answer choices for questions 7 and 8 on the evolution of humans and of plants and animals, respectively. Chi-square tests revealed no significant differences for all three comparisons ($p>0.05$, Figure 6a). Secondly, a chi-square test revealed a significant association between a participant's response to question 7 and to question 8 ($p<0.0001$, Figure 6b).

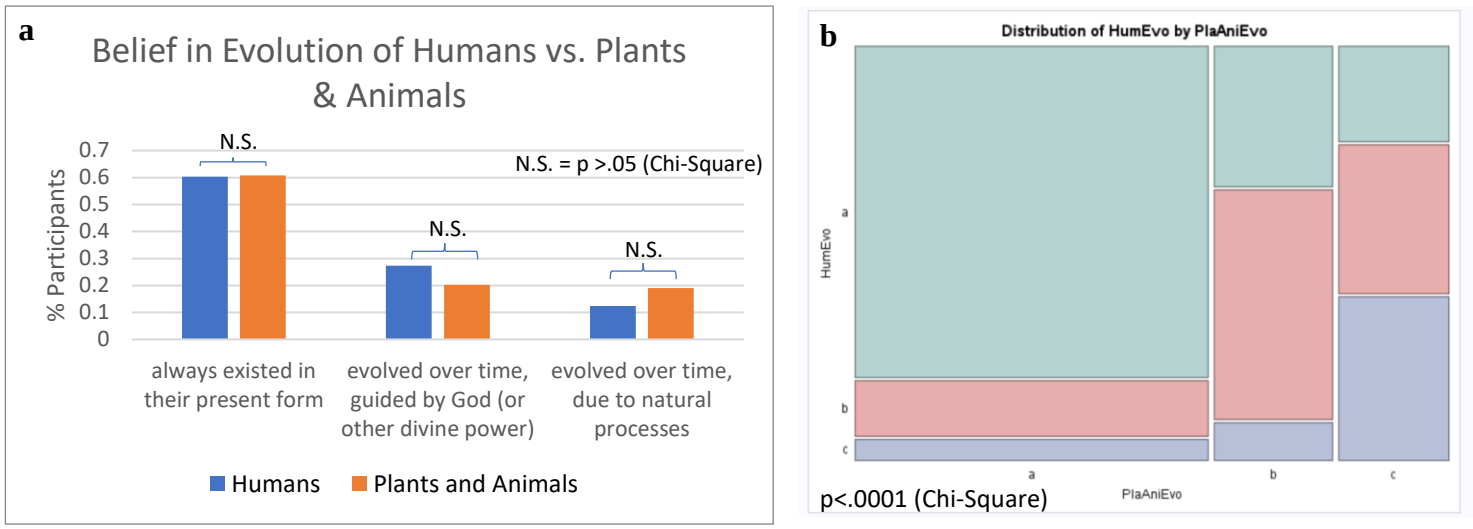

Figure 6: Comparison of belief in evolution of humans vs. plants and animals through bar graph of average responses (a) and mosaic plot of association between answer choices (b)

Hypothesis 3:

All cross-country comparative data was from Pew Research Center surveys on beliefs about humans having "evolved over time" or "always existed in their present form". The former response was identical to this study's question 7, response a; the latter response was considered a combination of responses b and c. While some of the Pew surveys included a "Don't Know" option, the data is still the most comparable available. The mean of all countries within each region was calculated for Europe (n=32), Latin America (n=19), and Muslim-majority countries (n=22). Total participant samples sizes for Europe, Latin America, Muslim-Majority countries, and the US were 31390, 27326, 29934, and 35071, respectively. Chi-square tests of equal proportions supported the alternative hypothesis that the belief that humans evolved over time is

lower in Moshi than all other regions and the corresponding belief that humans have always existed in their present form is higher (p= 0.02 - <0.0001, Figure 7). The US survey also contained the more detailed data breaking down "evolved over time" into "due to natural processes" versus "guided by a supreme being". This study used almost identical terminology, only changing the latter option to "guided by God or other divine power", as advised during the pilot period to be more understandable to participants in Moshi. Chi-square tests revealed that compared with Moshi, significantly more Americans believe that "humans have evolved over time due to natural processes", significantly fewer believe that "humans have always existed in their present form", and an equal proportion believe that "humans have evolved over time guided by God or other divine power" (p<0.0001, Figure 8). This study's comparative sample of foreigners in Tanzania provides a supplement to Hypothesis 3 in that it also looks at the impact of different backgrounds. Despite a large difference in sample size, there was noticeably less variation in responses in the foreign sample compared with the Moshi sample, with six questions answered unanimously and the rest with one answer chosen by 80% or more participants. A comparison of the five questions used to quantify evolutionary belief (see Hypothesis 1) revealed that significantly higher percentages of the foreign participants chose the pro-evolution response for all five questions (chi-square p=0.0019 - <0.0001, Figure 9).

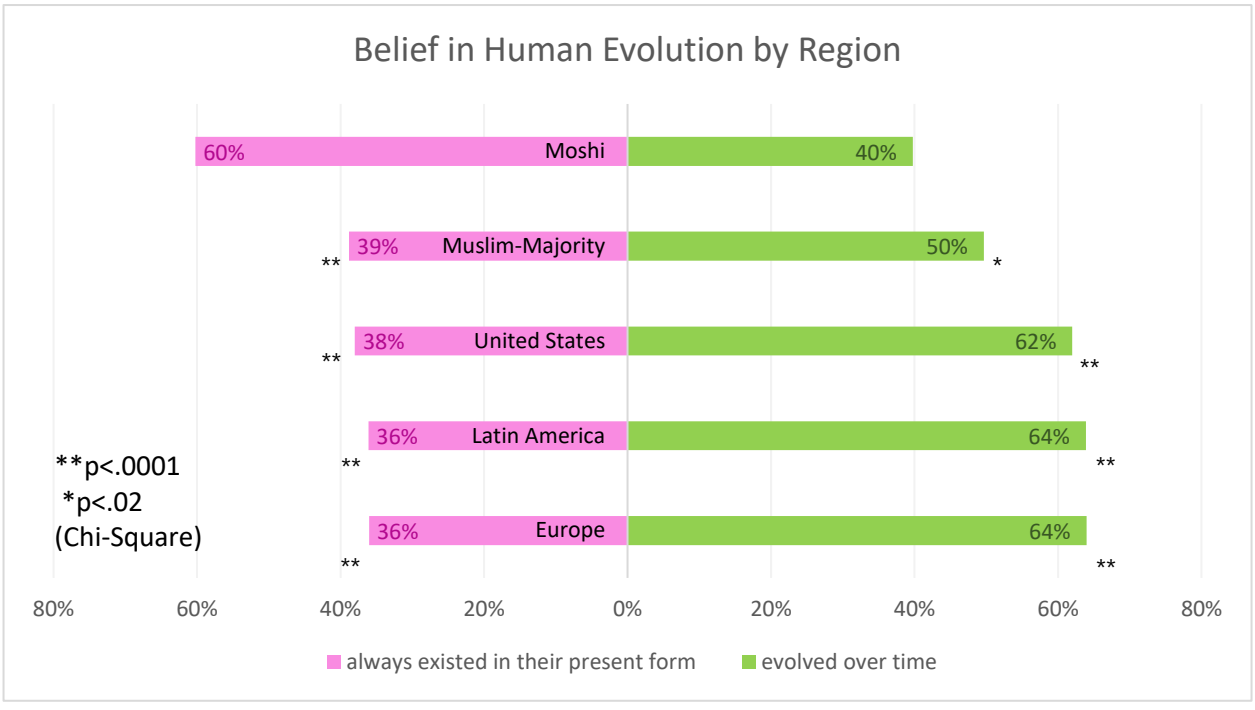

Figure 7: Cross-regional comparison of the belief in human evolution

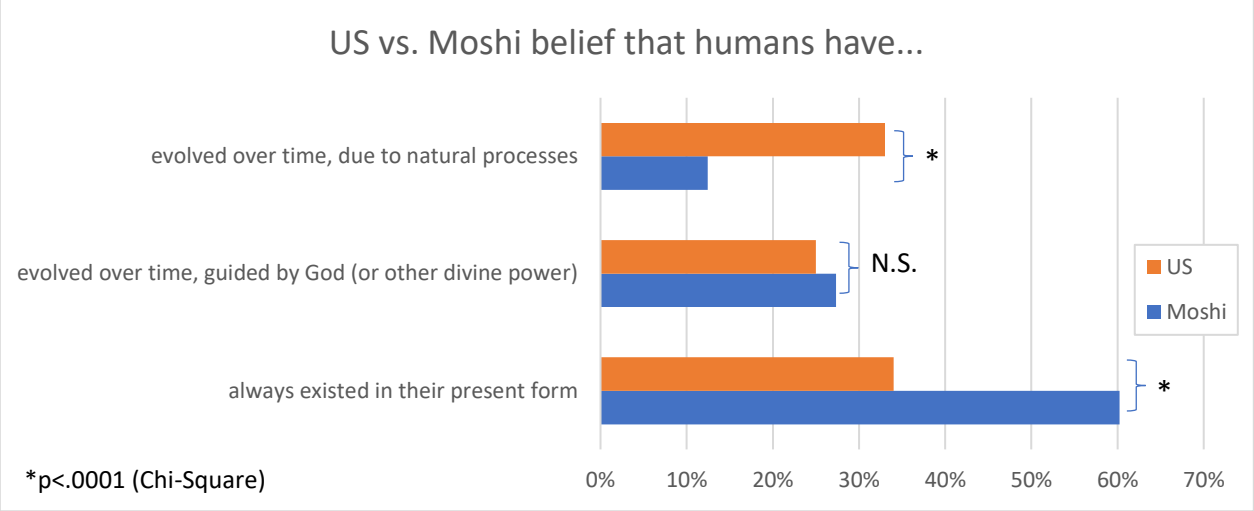

Figure 8: Bar graph comparing belief in human evolution between US and Moshi

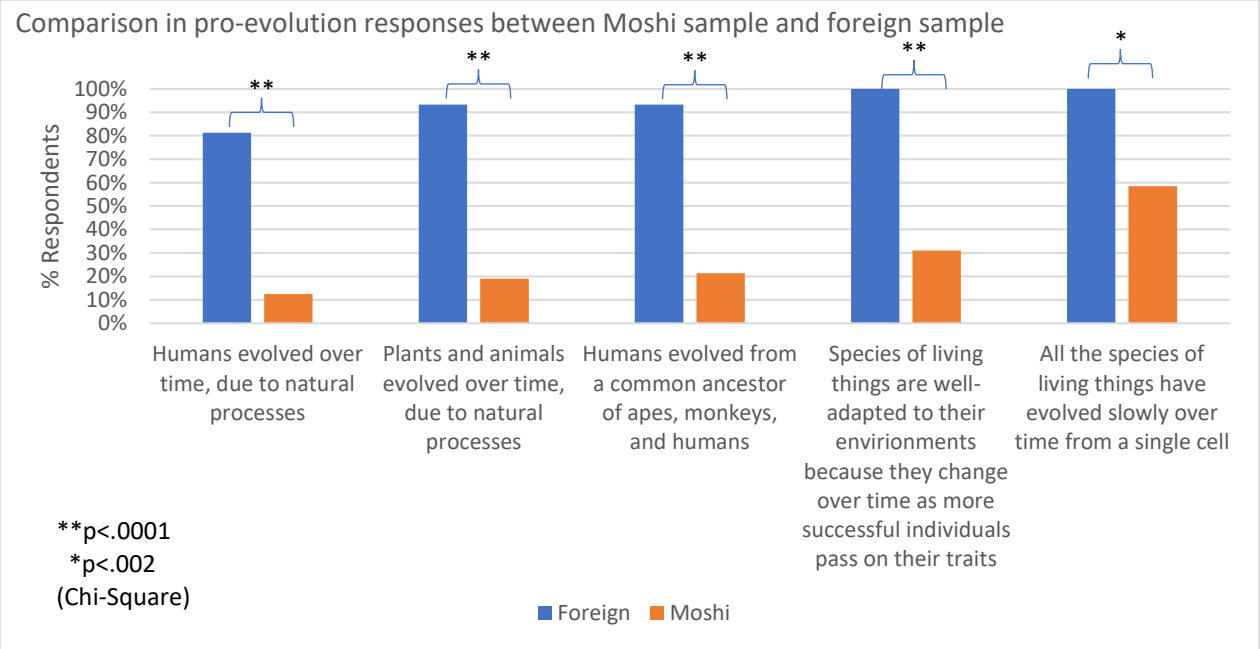

Figure 9: Bar graph comparing responses from 5 questions on evolution between foreign and Moshi sample

Hypothesis 4

A statistically equal proportion identified the use of pesticides over multiple seasons as "less effective because pest populations evolve resistance" compared with identifying them as either equally or more effective (p=0.90, Figure 10a). Similarly, a statistically equal proportion identified the practice of monocropping as "harmful because it increases the chance of pest and weed outbreaks" as opposed to beneficial (p=0.48). However, a significantly smaller proportion

identified natural selection as the mechanism for pathogen resistance as opposed to other answers ($p<0.0001$, Figure 10b). The majority (59%) identified behavioral avoidance as the mechanism, followed by decreased drug potency (22%).

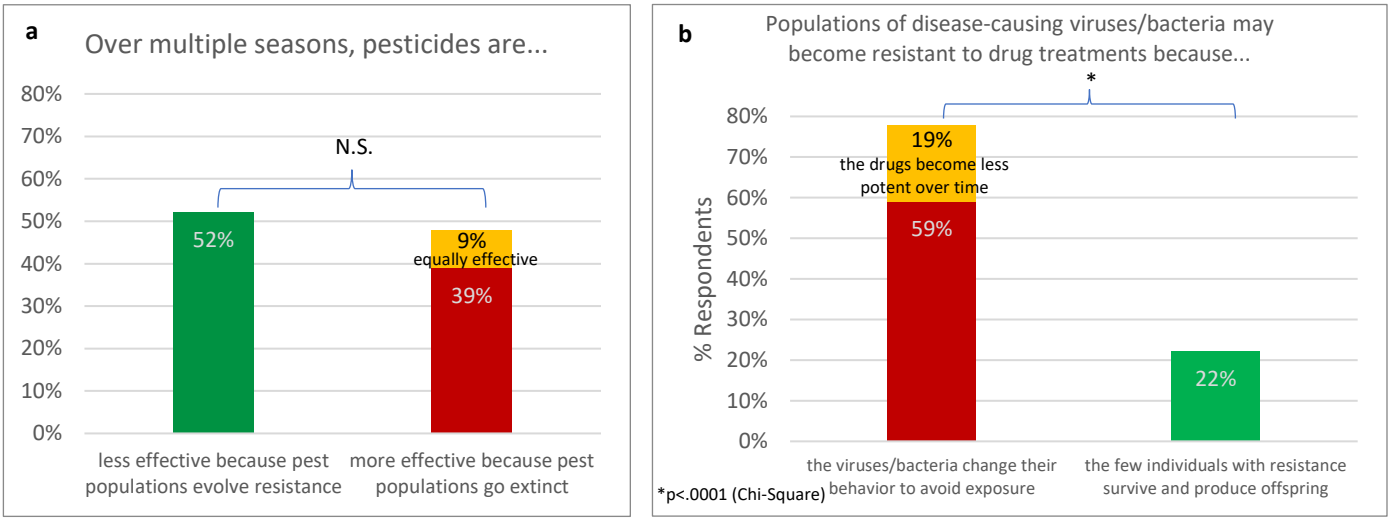

Figure 10: Bar graphs comparing identification of evolution as mechanism for resistance vs. other answers in the case of pest populations (a) and pathogen populations (b)

Hypothesis 5

The answers to questions 10, 12, 13, and 15 relating to Earth's age, the definition of natural selection, adaptation to the environment, and artificial selection were used to partially assess the hypothesis that the majority of people have not been exposed to or do not understand the various lines of evidence for natural selection (See Appendix III for individual frequency distributions). For two out of four of the questions, the majority, and for one question the plurality, of participants chose the scientifically accurate answer (Figure 11). However, the overall proportion of participants who choose a non-accurate answer was 43%, 47%, 64%, and 69% for questions 12, 10, 15, and 13, respectively. Science Knowledge ("SciKnow") was operationally defined as the sum of the ranked values for answers to these four questions. A weak, but significant correlation was found between science knowledge and evolutionary belief (Pearson's $r=0.23$, $p=0.009$). Schools were identified as a major vehicle for exposure to evidence for evolution. Key informant interviews revealed that due to government-required syllabus content, all secondary schools teach both the theory of divine creation and the theory of evolution by natural selection in relation to the origins of humankind and of life on Earth. All three schools used standard Tanzania Institute of Education biology and history textbooks to teach these topics,

supplemented by other textbooks, including *Oxford Student's Book* for various forms and *Campbell Biology*. Despite this seemingly universal exposure, the interviews also revealed that only 1/7 teachers believed in evolution by natural selection, while 3/7 teachers believed in evolution in the classroom, but creationism outside the classroom, and 3/7 teachers believed in creationism alone. An Old Moshi biology teacher commented, "I would suggest removing this topic of evolution from the syllabus because we were created by God. The topic of evolution is challenging the power of God." Teachers also commonly demonstrated a lack of knowledge on evolutionary topics; examples include using Lamarckism to refute the theory of evolution, conducting a pseudo-scientific experiment, confusing phenotypic plasticity with genetic change, and failing to recall any of the evidences for evolution. Lastly, museums were identified as another potential site of exposure to evolutionary evidence. Olduvai Gorge and its accompanying museum is Tanzania's most famous site of evolutionary evidence. At least 3 of the 5 schools in the sample routinely take their students on a trip to Olduvai. Question 11 was also used to assess knowledge about Olduvai and the results showed that 49% correctly identified it as an "archeological site with fossils of hominids". However, contrary to what might be expected, chi-square tests of equal proportions found that choosing this response was not associated with a reduced belief that humans have "not evolved from any other living thing" ($p=0.71$) or have "always existed in their present form" (Chi-Square $p=0.24$). In addition to OGM, two other Tanzanian museums with exhibits on evolution include NNHM and DSNM. OGM was completely renovated in October of last year, aimed at increasing the "number of tourists and researchers visiting the country" (Juma 2017). The exhibit rooms are organized chronologically into four time periods, with each room displaying paintings, artifacts, and fossils, along with explanations for all items (See Appendix V a-c for examples). Up-to-date human evolution research is discussed on signage; for example, the hypothesis that humans transitioned from being hunted to being hunters (Hart and Sussman 2008). In contrast, NNHM's exhibit on human evolution includes no physical evidence, only pictures and one hominid diorama with a low level of detail (See Appendix V d). It also presents the outdated linear model of human evolution, rather than the now widely accepted overlapping line/branching tree model (as in Appendix V c and e). DSNM does a good job prominently displaying the physical evidences of the Laetoli footprints and "Zinj" fossil skull, along with a large branching tree display of human origins. However, the exhibit is quite small and therefore does not contain much information on the whole (Baum and Baum 2011).

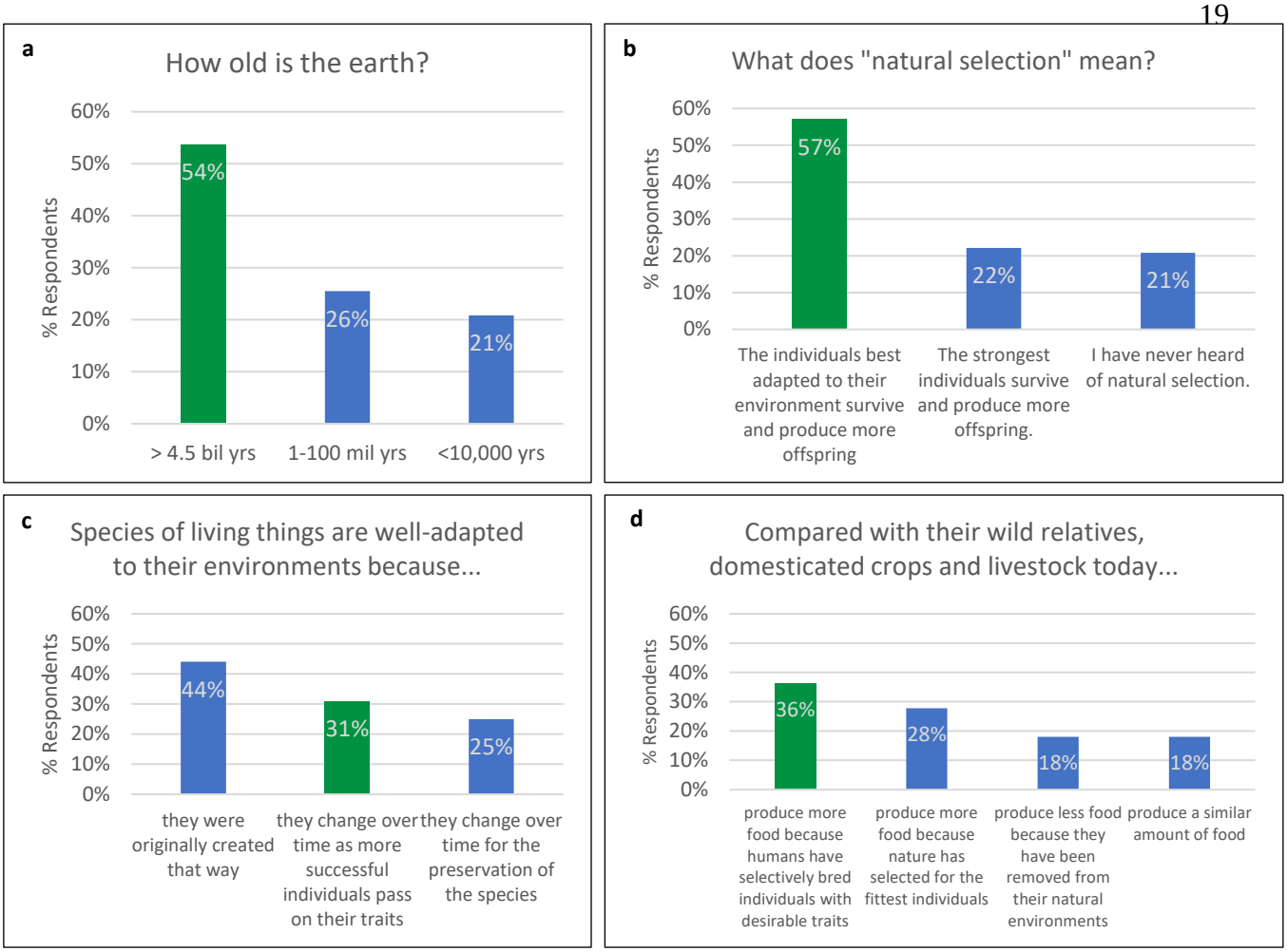

Figure 11: Bar graphs showing answers to questions 10 (a), 12 (b), 13 (c), and 15 (d), with scientifically accurate answers in green

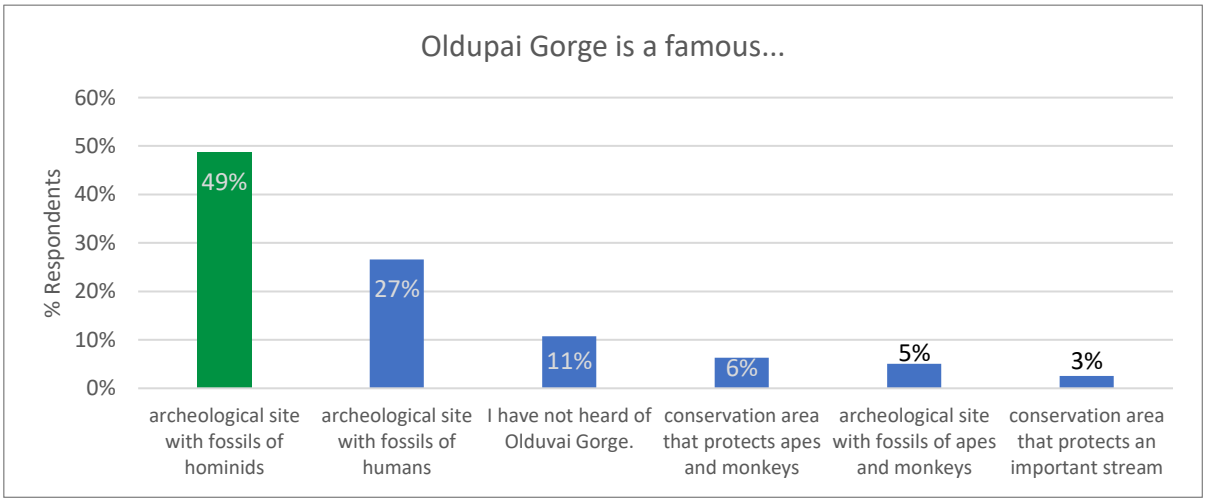

Figure 12: Bar graph showing responses to question 11, with accurate answer in green

Discussion

Hypothesis 1

Age was expected to be negatively correlated with evolutionary belief, as has been found in other countries. This study did not find support for this expectation, which may indicate a high degree of consistency in these beliefs across generations. However, a larger sample size would be needed to allow for statistical isolation of confounding variables, such as location and education. Type of religion probably did not impact evolutionary belief because of a high degree of consistency between the beliefs of Muslims, Catholics, and Protestants (98.2% of the sample) on this topic. This assertion is supported by the fact that the two Lutheran pastors and Muslim Mullah gave almost identical answers to the posed interview questions. Even the Rasta man, who was staunchly anti-Christian and had many contrasting beliefs on other matters, was still similar in opposing the theory of evolution. Although private school education tends to be higher quality than public school, and thus might be expected to impact evolutionary belief, this trend was likely not found because of the prevalence of private religious schools. For example, a teacher at the private Catholic school in this study explained that while each student can choose what to believe when they study the origins of life, "This is a church school so we tell them to abide more with special creation. We have never had a student who believes that the other theories of origin of life are true." Lastly, the only demographic variable found to impact evolutionary belief was education level, with significantly higher levels of belief among those with 1-2 years of college and above. This may be because those students who are able or who choose to pursue post-secondary studies tend to take a more critical look at scientific evidence or because students gain exposure to a greater diversity of thought on these topics in college. Socioeconomic status and family background may also be confounding factors in terms of the impact of education level.

Hypothesis 2

It was expected that participants would show a greater acceptance of evolution in the case of plants/animals rather than humans, but the results of the questionnaire found that there was no significant difference. This may be because humans, plants, and animals are all discussed in the Christian and Islamic texts as being created by God within the six days of creation. However, the failure to find a significant difference may also reflect too small a sample size. Anecdotal evidence from the interviews revealed that while it was most common to not believe in the evolution of any

organism, several interviewees were more supportive of the evolution of bacteria, plants, and animals (particularly very small animals like flies).

Hypothesis 3

As predicted, this study's Moshi sample had significantly lower average levels of belief in the theory of evolution than all other comparative samples. This is not surprising for the US and Europe because of lower average levels of religiosity and higher average levels of education. The finding is more surprising in Latin America, where only 8% identify as religiously unaffiliated (Bell and Sahgal 2014). One possible explanation is that there is a much higher percentage of Catholics versus Protestants in Latin America, which is the opposite trend in Moshi. Although in Moshi, there was not found to be a difference in belief between Catholics and Protestants, this trend has been found in the Pew Research Center surveys discussed previously. Another factor may be that Latin America is much more urbanized than Moshi, with 80% of its population living in cities (Atlantic Council 2014). The fact that Muslims in Muslim-majority countries also showed higher average belief in evolution also requires explanation, especially given the modern rise in Islamic fundamentalism (Hiro 2013). It may be that in these countries, the trend found in the US, in which Muslims tend to believe in evolution more than Evangelical Protestants, accounts for the difference. The Muslim Mullah interviewed in this study continually emphasized that "Islamic belief and science go together". While this assertion failed to manifest in the form of a belief in evolution for that interviewee, it is possible that this sentiment has been used by other Muslims to reconcile religion and evolution. For all of these potential factors, further study would be needed to determine their influence.

Hypothesis 4

The results overall revealed moderate levels of understanding of pathogen resistance and low levels of understanding of pesticide resistance. Interview questions related to these topics suggested that participants were much more likely to believe that viruses/bacteria could change over time compared with plants/animals. However, some participants who described the development of resistance through natural selection still did not support evolution. These apparently contradictory beliefs may align with a statement from the Christian Ministries International: "Thus the pesticide resistance 'icon' of evolution actually gives no support to molecules-to-man evolution whatsoever. It is however right in line with the Bible's account of

origins, beautifully consistent with an originally ‘very good’ creation (Genesis 1:31) now in ‘bondage to decay’ (Romans 8:19–22) as a consequence of the Fall (Genesis 3). We’re not seeing improvement in the genes, we see brokenness, for that is what mutations do—they break genes, not create brand new ones” (Cathpoole 2009). Further study is needed to determine if this is how participants in the study viewed the development of resistance.

Hypothesis 5

The results of this study are somewhat inconclusive as to whether most participants were unfamiliar with the evidence for evolution. There was a wide diversity of responses to questions testing relevant science knowledge, and multiple participants voiced unfamiliarity with the idea of “species”, “fossils”, and “extinct animals”. On the other hand, all the secondary schools include the theory of evolution by natural selection in their curriculums and a majority of respondents correctly identified Olduvai Gorge as a site of hominid fossils. In terms of the potential for museums to be a site for exposure to evidence, this study’s comparative analysis clearly shows that OGM is the most up-to-date, engaging museum. However, the museum is geared towards tourists and the barriers to visiting for most Tanzanians include its greater distance from population centers and high entrance fee of $35 (compared with $3 for DSNM and 5$ for NNHM). Furthermore, this study also found no relationship between possession of accurate knowledge and belief in evolution, and low levels of belief in evolution among teachers and students who are recently exposed to evidence for evolution. Both of these findings suggest that it is the context of exposure to evidence and not the exposure itself that makes a difference. This conclusion is supported by several pieces of anecdotal evidence from interviews. For example, several interviewees were familiar with the famous fossil finding “Zinj” (OH 5). This finding is interpreted by modern scientists as belonging to a hominid species ancestral to modern humans, thus supporting the theory of evolution. In contrast, one interviewee said, “Zinj was a monkey, not related to humans,” while another said, “Lucy might have been Eve and Zinj might have been Adam. They were modern humans, just in the past.” Both responses demonstrate that these interviewees fit Zinj into their existing creationist frameworks – without the context of an evolutionary interpretation, this potential source of evolutionary evidence was ineffectual. Lastly, the interviews conducted for this study revealed that while many participants had some exposure to evolutionary evidence, a set of common misconceptions and misinterpretations prevented the kind of scientific familiarity that was being tested in this hypothesis.

Most Common Objections and Misconceptions

As alluded to in the former section's discussion of Hypothesis 5, there were many objections to and misconceptions surrounding the theory of evolution that were raised repeatedly by participants. In an effort to provide a greater understanding of the views of these participants and support the dissemination of information addressing them, the following list is an aggregation of the most common objections and misconceptions.

- Evolution claims that humans evolved from monkeys/apes. If humans evolved from monkeys/apes, why do monkeys/apes still exist today? Why haven't monkeys/apes evolved into humans?
- If humans evolved in the past, then they should be evolving in the future, and this has not happened.
- Fossils of species purportedly ancestral to modern humans are really just modern humans affected by different environmental or developmental conditions. If modern human were exposed to the same conditions, they would be the same as these ancient humans.
- Purportedly newly evolved species are really just newly discovered species.
- Physiological or behavioral change in response to immediate environmental factors, and not genetic change through natural selection, can account for the adaptation of organisms to their environments.
- Racial differences in humans are analogous to differences between ancestral and modern organisms, and are thus not different species at all.
- If evolutionary adaptation was responsible for racial differences, then a black family that moves to Europe should become white.
- Faith and science cannot coexist in the question of evolution. Evolution is a threat to religion.
- Humans have only made improvements to existing domesticated species, rather than creating new species.
- Evolution says that traits that are not useful to survival should disappear, but we see evidence of these traits (ex. the appendix, the left hand).

Biases and Limitations

Ideally, the study would have included primary school children, but due to logistical difficulties with acquiring parental consent, this group could not be included. An educator at Olduvai Gorge was also contacted to provide further insight on this source of evolutionary knowledge, but acceptable permissions to allow for an interview could not be obtained.

It was impossible to use a random sampling design in this study. Because of limited time and resources, people could not be chosen at random from a directory of people or map of residences; directories and maps were not easily attainable and only a small percentage of people in a given location were available and interested in participating at a given time. A representative sample was also hard to get because the age structure of the area meant there was a small percentage of elderly people and men were more often available than women. In terms of education, no participants with doctorate degrees were found, even though they are presumably present in the area. The sample size was also smaller than planned because when questionnaires were left at KiliHub and Mweka, only a fraction of the intended number were returned completed.

Another challenge was translation between English and Kiswahili. For the written questionnaire, I had three Kiswahili speakers contribute to the Kiswahili translation, but certain words or concepts are not easily translated from one language to another. For example, there was a clear lack of understanding by many participants of the translations for “Protestant” and “hominid”. Due to these issues, examples of Protestant sects and a hominid were included in the second printing of the questionnaire. Responses to the religion question were modified for respondents from the first printing with input from my translator. For interviews conducted in English, there was also a language barrier limiting the depth of possible conversations.

In some cases my translator suggested answers to people after asking them one of my questions. For verbal completions of the questionnaire, he sometimes paraphrased the response options. Both of these likely prompted people to give biased answers. Participants completing questionnaires were also sometimes influenced by nearby people in the form of discussion between multiple participants or input from non-participants. Participant error also meant some questionnaires were incomplete or unreadable.

The study questions invariably contained biases due to my particular background. The biases that became clear over the course of the study included: hominids like *Homo habilis* being different species than *Homo sapiens* (Q11), knowing what a fossil is (Q11), knowing what a species is (Q13, Q14), domesticated crops/livestock having wild ancestors (Q15), pathogens

having the ability to develop resistance (Q16), and evolution being the only explanation for pests developing resistance (Q17). There was also some confusion about the education level question for current students in terms of marking their current level or highest completed level. In the case of secondary school students, answers were standardized in the dataset, but this could not be done for college students due to different types of degrees. Another issue that arose during data analysis was that occupations were written-in answers and may have been misread or mistranslated in some cases. The grouping of answers into occupation categories was also somewhat arbitrary and unclear in some cases.

The last challenge was that participants would often ask me about my own religious and scientific beliefs. In each case I attempted to assess the extent to which the interviewee would be offended by or interested in my evolutionary and atheistic beliefs. However, occasionally my translator would preempt my judgement of the situation by offering his own interpretation of my beliefs, which created some awkwardness in a few cases.

Conclusion

"Nothing in biology makes sense except in the light of evolution" is now an oft-quoted phrase by evolutionists criticizing creationism. What is sometimes forgotten is that this phrase actually comes from an essay written by a prominent evolutionary biologist and committed Eastern Orthodox Christian who argues for a version of theistic evolution that reconciles the belief in God with the belief in evolution. In the essay he explains, "It is wrong to hold creation and evolution as mutually exclusive alternatives…the Creation is realized in this world by means of evolution" (Dobzhansky 1973). In fact, this view is currently supported by many prominent religious figures. For example, Pope Francis said, "…creation continued for centuries and centuries, millennia and millennia…the scientist must be motivated by the confidence that nature hides, in her evolutionary mechanisms, potentialities for intelligence and freedom to discover and realize…" (Pope Francis 2014). The General Assembly of the Presbyterian Church and Central Conference of American Rabbis have also released statements denying a conflict between faith and evolution. This contrasts with the Udzungwa Mountains College Trust interviewee's assertion that "you can't believe in evolution and also believe in God", a sentiment echoed by several other interviewees. As one anti-evolution secondary school teacher put it, "The topic of evolution is challenging the power of God." As a consequence of this dichotomous view, people with strong religious backgrounds (as is true for most of the study's participants) often make the choice to disavow the

theory of evolution. While this study did find a significant impact of education, residents of Moshi, Tanzania show overall low levels of belief in evolution, largely due to conflicting religious beliefs. With the recognition that generalizing to a larger scale will always increase the margin of error, it is nevertheless productive to tentatively consider the results of this study on the nationwide scale. Given that the average views collected in this study likely represent a conservative approximation for the views of Tanzanians as a whole (because of the disproportionately high number of students and urban residents included in the sample), the study's findings suggest a potential barrier to the country's progress in both applied biology and biological research.

Recommendations for Future Study and Practical Measures

This study indicates that while most secondary school students are exposed to the evidences for evolution as part of the standard syllabus instruction, this has not proven to be an effective means for encouraging belief in evolution. This may be because some teaching materials are written by or draw heavily from Western textbooks that do not take into account the different pre-existing knowledges and backgrounds of students in other regions. In addition, students are less likely to believe in evolution if their teachers do not agree with or do not understand the topic themselves. It therefore might be helpful to distribute teaching materials that both break down the evolution-creation dichotomy and address the major objections to evolution discussed in this study. Examples of similar materials in the US created to teach evolution in a Christian context may serve as useful guides for these materials (FASTly: Faith and Science Teaching , Haarsma and Haarsma 2007, Skehan and Nelson 2000). The materials should also include hands-on, engaging lesson plans because research has shown that "active learning is even more important for controversial topics" (Jensen and Association 2008). This content might also be included in the widely distributed Tanzania Institute of Education textbooks. In order to increase cross-cultural exposure, it may be beneficial to hold an international conference of teachers on topics related to the origins and diversification of life with a focus on the non-confrontational discussion of the whole spectrum of beliefs. It is also important to consider that written materials alone may be inadequate to teach a topic like evolution that faces substantial resistance from students. Museums represent a good opportunity for visual experiences with evolutionary evidence. To this end, Tanzania could make it cheaper for Tanzanians to visit Olduvai Gorge, invest in updating the exhibits at the National Natural History Museum, and sponsor the creation of new natural history

museums in towns like Moshi. In terms of future studies, it would be instructive to repeat this study in different regions of Tanzania to increase both the size and representativeness of the sample, to study the specific ways of teaching evolution that are most successful in Tanzania, and to better isolate the specific factors that influence evolutionary belief. These might include but are not limited to socioeconomic status, frequency of religious worship, sect of Christianity/Islam, contact with foreigners, beliefs of teachers, and number of visits to relevant museums.

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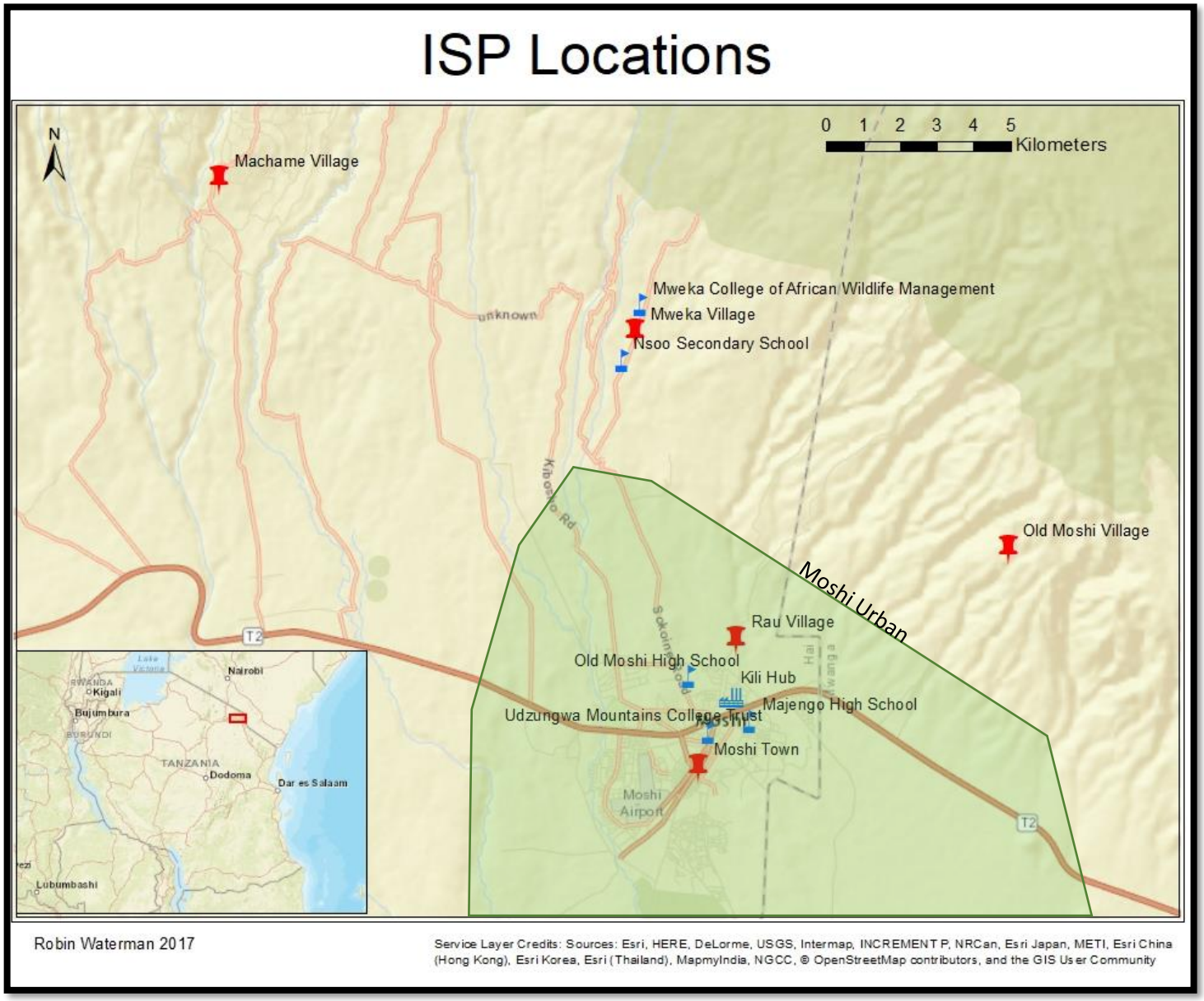
Appendix I: Study Site



Appendix II: Questionnaire

Introduction:
My name is Robin Waterman and I am an American college student studying abroad in Tanzania with the School for International Training (SIT)'s Wildlife Conservation and Political Ecology program. This questionnaire will be used as part of my Independent Study Project but all responses will remain completely anonymous. By completing this form you are consenting to participate in my study. If you are interested in learning more about my project or have any other questions please contact me at: rwaterman@wesleyan.edu.

Questionnaire ***(Please circle your answer and write in your age and occupation):***

1. **Age:** _____
2. **Gender:**
   a) Man
   b) Woman
   c) Other
3. **Education (highest level completed):**
   a) None
   b) Primary school
   c) Secondary school
   d) 1-2 years of college
   e) Bachelor's degree
   f) Master's degree
   g) Doctorate degree
4. **What kind of school did you attend?**
   a) Public
   b) Private
   c) Some public, some private
   d) None
5. **What is your occupation?** _____
6. **Which religion do you identify with?**
   a) Islam
   b) Christianity - Roman Catholic
   c) Christianity – Protestant (i.e. Lutheran, Pentecostal)
   d) Traditional/Indigenous
   e) Unaffiliated/Irreligious
   f) Other Religion:_____
7. **According to your beliefs, humans have**:
   a) always existed in their present form, as created by God or other divine power
   b) evolved over time, guided by God or other divine power
   c) evolved over time, due to natural processes
8. **According to your beliefs, plants and animals have:**
   a) always existed in their present form, as created by God or other divine power
   b) evolved over time, guided by God or other divine power
   c) evolved over time, due to natural processes
9. **According to your beliefs, humans have**:
   a) evolved from apes
   b) evolved from monkeys
   c) evolved from a common ancestor of apes, monkeys, and humans
   d) not evolved from any other living thing

Utangulizi:
Jina langu ni Robin Waterman na ni mwanafunzi Mmarekani. Ninasoma katika Tanzania na chuo ya SIT. Kinachohusika na uhifadhi viumbe hai, ekolojia, na siasa. Fomu hii ya maswali itumika kwa mradi wangu wa mwanafunzi lakini maelezo ya fomu hii yatabaki bila majina. Kwa kujaza fomu hii, umekubali kushirika katika somo hili Ikiwa unataka kujifunza zaidi kuhusu mradi wangu au una maswali mengine tafadhali wasiliana na rwaterman@wesleyan.edu.

Maswali ***(Tafadhali zungushia duara majibu yako na andika umri wako na kazi yako):***

1. **Umri:**_____
2. **Jinsia:**
   a) Mwanaume
   b) Mwanamke
   c) Mengineyo
3. **Elimu:**
   a) Hakuna yoyote
   b) Shule ya msingi
   c) Elimu ya sekondari
   d) Mwaka 1-2 ya chuo
   e) Shahada ya kwanza
   f) Shahada ya uzamili
   g) Shahada ya udaktari
4. **Umepata mafunzo shule za aina gani?**
   a) Serikali
   b) Binafsi
   c) Binafsi na serikali
   d) Hakuna
5. **Unafanya kazi gani?** _____
6. **Dini au dhehebu:**
   a) Uisilamu
   b) Kikristo - Katoliki
   c) Kikristo – Protestanti (kama Lutheran, Pentecostal)
   d) Tamaduni
   e) Uhusiano
   f) Zinginezo: _____
7. **Kutokana na Imani yako, binadamu:**
   a) amekuwepo kama alivyoumbwa na Mungu
   b) amebadilika kutoka kipindi hadi kipindi, aliongozwa na Mungu au nguvu zingine za kiroho
   c) amebadalika kutoka kipindi hadi kipindi, kwa sababu ya mabadiliko ya asili
8. **Kutokana na Imani yako, mimea na wanyama:**
   a) wamekuwepo kama walivyoumbwa
   b) wamebadilika kutoka kipindi hadi kipindi, waliongozwa na Mungu au nguvu zingine za kiroho
   c) wamebadalika kutoka kipindi hadi kipindi, kwa sababu ya mabadiliko ya asili
9. **Kutokana na Imani yako, binadamu:**
   a) walibadilika na sokwe
   b) walibadilika na kima
   c) walibadilika kutoka kwa kiumbe wa kale wa sokwe, kima, na binadamu
   d) hakutokana na kiumbe hai yeyote

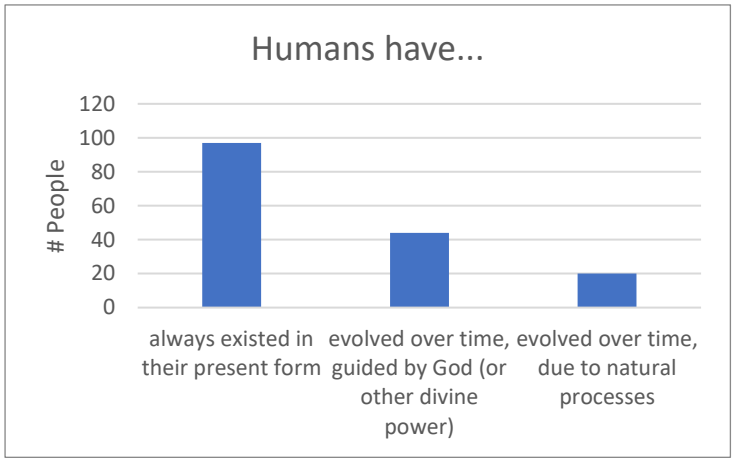
10. **How old do you think the Earth is?**
    a) More than 4 billion years old
    b) 1-100 million years old
    c) Less than 10,000 years old
11. **Olduvai Gorge is a famous:**
    a) conservation area that protects apes and monkeys
    b) conservation area that protects an important stream
    c) archeological site with fossils of hominids (species ancestral to humans like *Homo habilis*)
    d) archeological site with fossils of humans (*Homo sapiens*)
    e) archeological site with fossils of apes and monkeys
    f) I have not heard of Olduvai Gorge.

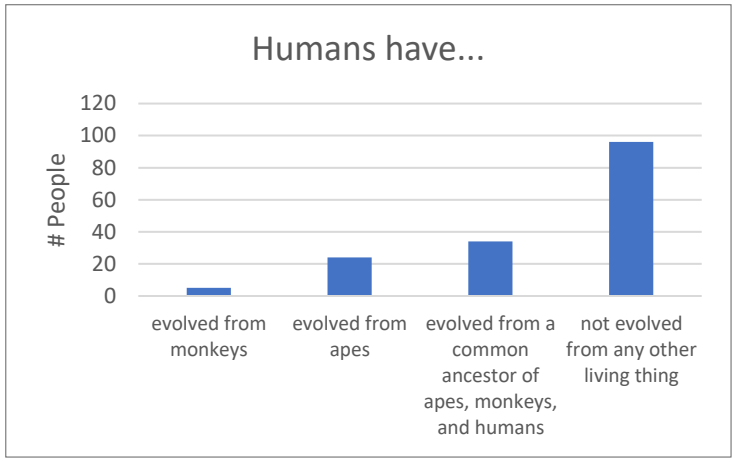
12. **What do you think "natural selection" means?**
    a) The strongest individuals survive and produce more offspring.
    b) The individuals best adapted to their environment survive and produce more offspring.
    c) I have never heard of natural selection.
13. **Species of living things are well-adapted to their environments because:**
    a) they were originally created that way
    b) they change over time for the preservation of the species
    c) they change over time as more successful individuals pass on their traits to the next generation
14. **All of the species of living things that have ever existed:**
    a) were created at one time
    b) have evolved slowly over time from a single cell
15. **Compared with their wild relatives, domesticated crops and livestock today:**
    a) produce a similar amount of food
    b) produce more food because humans have selectively bred individuals with desirable traits
    c) produce more food because nature has selected for the fittest individuals
    d) produce less food because they have been removed from their natural environments
16. **Populations of disease-causing viruses/bacteria may become resistant to drug treatments because:**
    a) the drugs become less potent over time
    b) the few individuals with resistance survive and produce offspring that are also resistant
    c) the viruses/bacteria change their behavior to avoid exposure
17. **When used over multiple seasons, pesticides are:**
    a) less effective because pest populations evolve genetic resistance
    b) more effective because pest populations go extinct
    c) equally effective

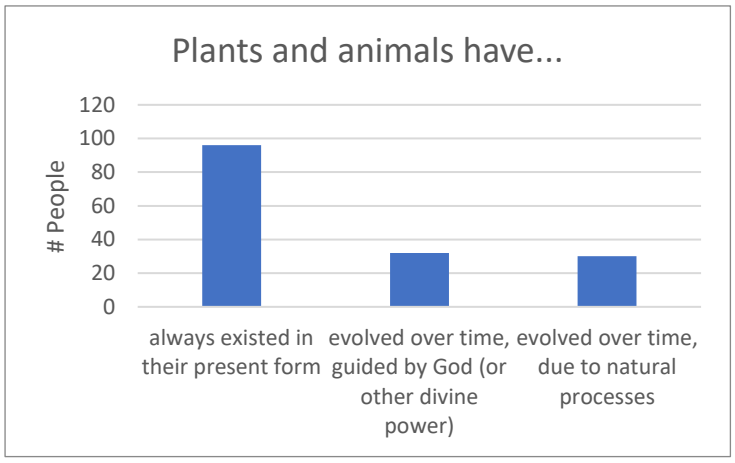
18. **Monocropping (growing only one crop every season) is generally:**
    a) beneficial because it is more efficient than growing different crops
    b) harmful because it increases the chance of pest and weed outbreaks

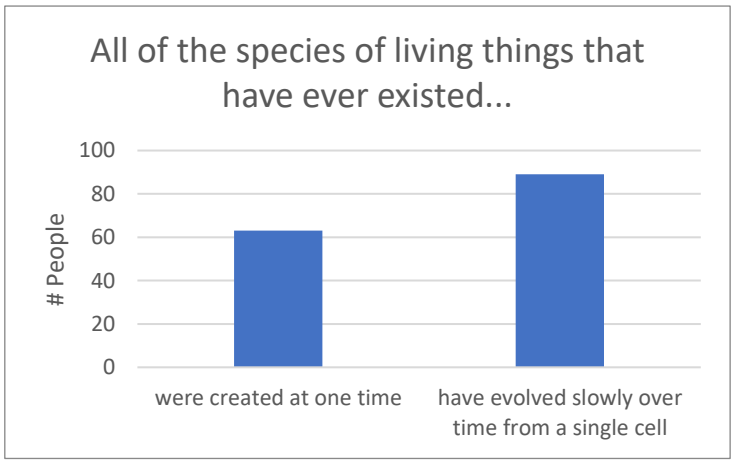
10. **Dunia ulimwengu ina umri gani?**
    a) Zaidi ya miaka bilioni 4
    b) Miaka milioni 1 – miaka milioni 100
    c) Chini ya miaka elfu 10,000
11. **Oldupai Gorge inajulikana sana kama:**
    a) sehemu ya uhifadhi na kulinda viumbe hai sokwe na kima
    b) sehemu ya uhifadhi na kulinda mto muhimu
    c) sehemu ya malikale yenye mifupa/kisukuku ya spishi wa kale na binadamu (kama *Homo habilis*)
    d) sehemu ya malikale ya mifupa/kisukuku ya binadamu wa sasa (*Homo sapiens*)
    e) sehemu ya malikale yenye mifupa/kisukuku ya sokwe na kima
    f) Sijawai kusikia sehemu hii.
12. **Unadhani nini "uteuzi wa asili"?**
    a) Viumbe vyenye nguvu vinavyoendelea na vinavyozalisha watoto zaidi.
    b) Viumbe vinavyoendana sana na mazingira husika vinavyoendelea na vinavyozalisha watoto zaidi.
    c) Sijawai kusikia.
13. **Spishi ya viumbe wanaoishi wanaendana sana na mazingira yao kwa sababu**:
    a) waliumbwa hivyo tangu mwanzo
    b) wamebadilika kwa muda kwa ajili ya uhifadhi wa kizazi au spishi
    c) wamebadilika kwa muda kwa sababu viumbe vyenye mafanikio hutoa sifa zao kwa kizazi kijacho
14. **Spishi zote za viumbe hai ambayo vilikuwepo:**
    a) viliumbwa wakati mmoja
    b) vimetokana na mabadiliko taratibu kutoka kwa seli moja au kiumbe moja
15. **Kulinganishwa kwa ndugu wao wa karibu wa wanyamapori, sasa mifugo na mimea ya mazao:**
    a) huzalisha sawa kiasi cha chakula
    b) huzalisha chakula kingi sababu wanadamu wamechaguliwa viumbe bora zaidi
    c) huzalisha chakula kingi sababu asili imechaguliwa viumbe bora zaidi
    d) huzalisha chakula kidogo sababu hawako tena katika mazingira yao ya asili
16. **Idadi ya magonjwa yanayosababisha virusi/bakteria yatakuwa sugu kwa madawa na tiba kwa sababu:**
    a) yanachoka/kupungua nguvu kutokana na muda
    b) viumbe wachache na upinzani vinaishi na kuzaa kizazi na upinzani pia
    c) virusi/bakteria hubadilisha tabia kujikinga na mazingira ya kutambuliwa
17. **Kwa kipindi kirefu, dawa za kuua wadudu:**
    a) zizizokuwa na madhara makubwa kwao kwa sababu idadi ya wadudu wanaendeleza upinzani wa maumbile
    b) zenye madhara sana kwa sababu idadi ya wadudu inazidi kutoweka
    c) ina madhara sawa
18. **Kilimo cha zao moja (kulima zao hilo hilo kila msimu) ni kwa kawaida:**
    a) chenye manufaa kwa sababu hupanda zao moja tu na hupata mavuno zaidi
    b) chenye madhara kwa sababu kinaongeza na kuchangia kwa kiasi wadudu na magugu kirahisi

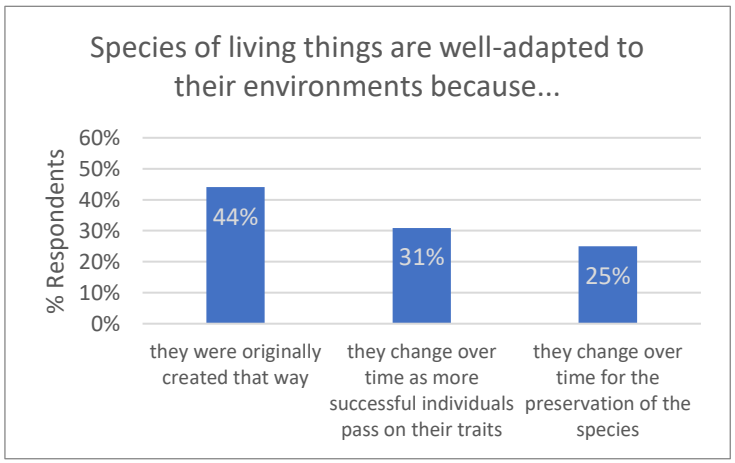
Appendix III: Individual Frequency Distributions for Questions used in SumEvo and SciKnow

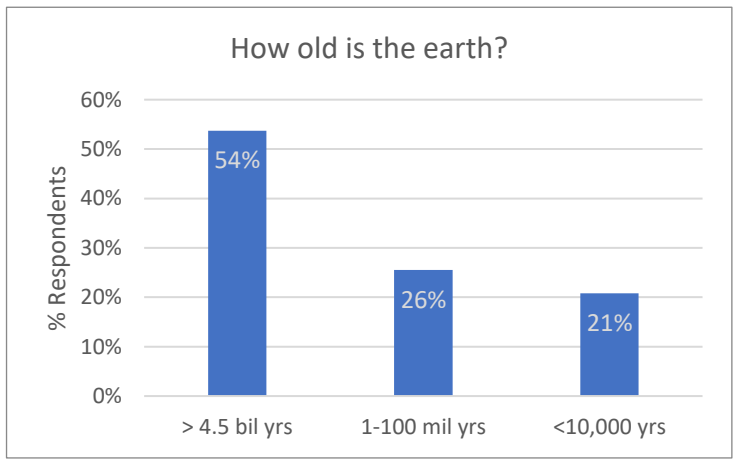


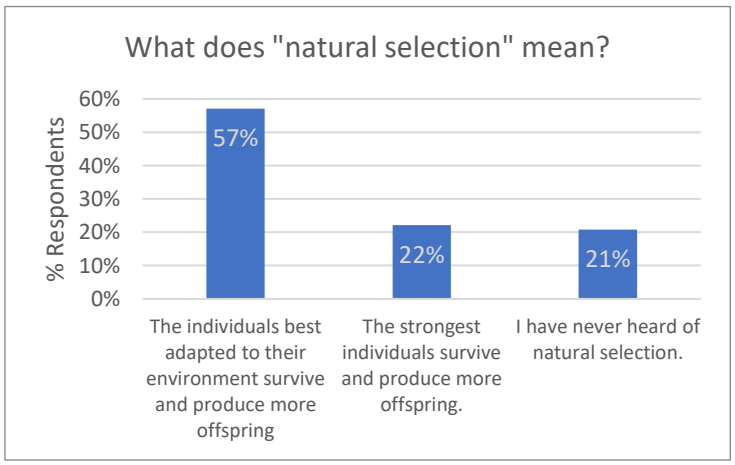


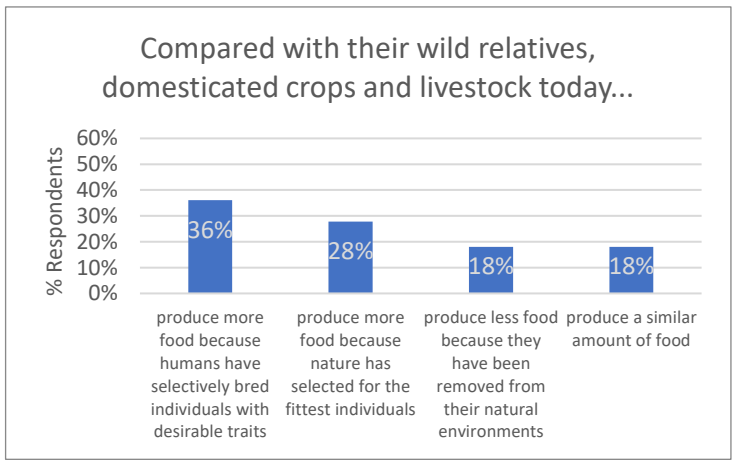








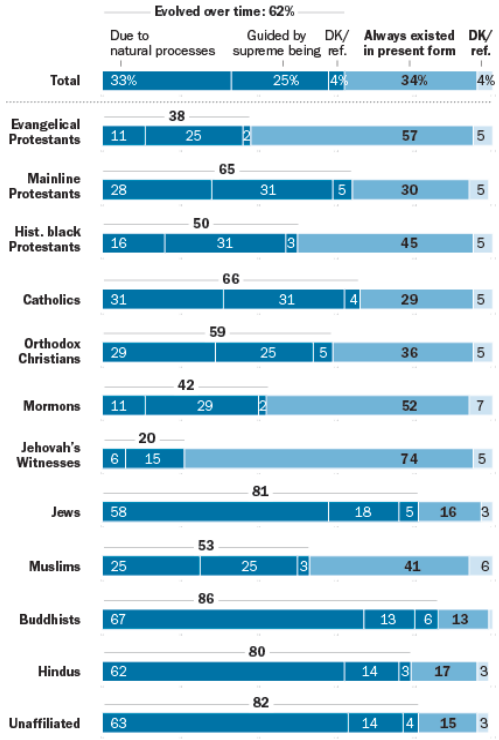




Appendix IV: Pew Research Comparative Data

Belief in evolution by religious tradition

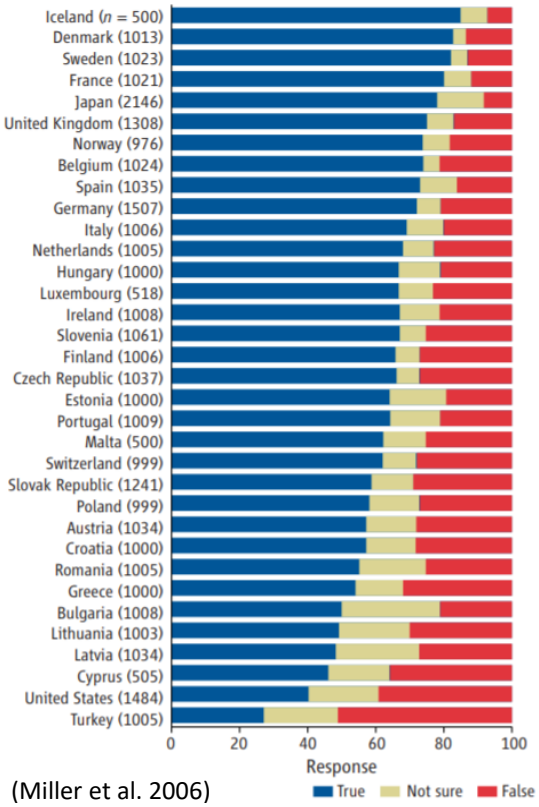
% who say humans ...



Source: 2014 U.S. Religious Landscape Study, conducted June 4-Sept. 30, 2014.
Note: DK/ref. responses included in "evolved over time" are those who believe humans evolved, but are unsure exactly how this evolution occurred. Nested figures may not add to subtotals due to rounding.

PEW RESEARCH CENTER

Human beings, as we know them, developed from earlier species of animals.

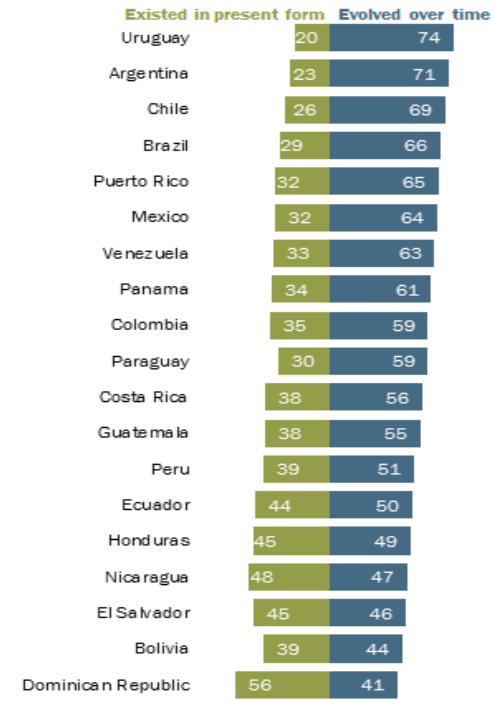


(Miller et al. 2006)

Public acceptance of evolution in 34 countries, 2005.

Views on Evolution

% who say that humans and other living things have...

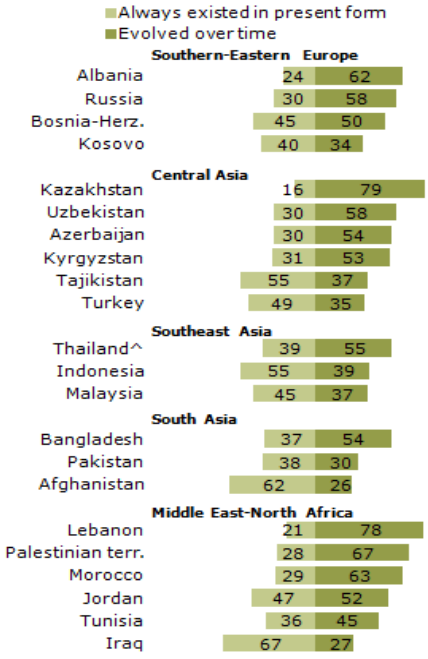


Q11

PEW RESEARCH CENTER (2014)

Belief in Evolution

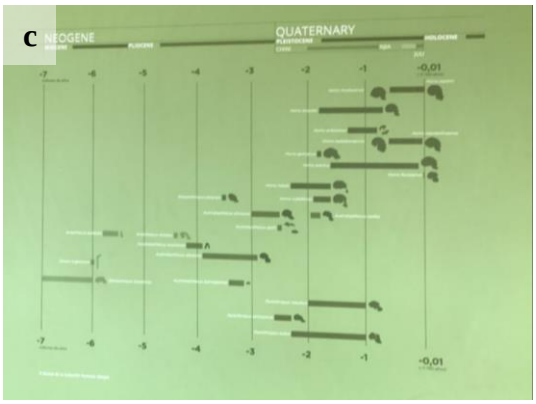
% of Muslims who believe humans and other living things have ...



This question was not asked in sub-Saharan Africa.
^Interviews conducted with Muslims in five southern provinces only.
Data from Egypt are not available due to an administrative error.

PEW RESEARCH CENTER Q20. (2013)

Appendix V: Museum Displays



OGM: Skeletal reconstruction of ancient hominid (a), painting and hominid footprints reconstruction (b), and overlapping line model display of human evolution (c)

NNHM: Diorama of Australopithecine hominids (d)

DSNM: Branching tree model display of human evolution with fossil skull reconstructions (e), display of "Zinj" fossil skull (f), images from (Baum and Baum 2011)